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Design of Remotely Accessible Automated Systems to Enhance Industrial Automation Education

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Abstract

Industrial scale automated systems can be used to provide authentic learning experiences for students. Skillsets needed to design and build automated systems are essential to our national economy. However, students often have limited access to equipment due to limitations in available lab time and available equipment. This paper describes the design of three web-based automated systems (material sorting system, pick-and-place automated system, and remote-control of robot system) and preliminary evaluation of the systems. Preliminary findings include 1) students seemed interested and intrigued by the set up; 2) there is a time-delay between the control action and the image being presented over the webcam; and 3) students want more time to use the system. Future directions include evaluating instructional effectiveness, identifying which aspects of the experience help students learn, and determining optimal time frames for completing assignments.

Motivation

Automation has a profound effect on the way we do work. According to U.S. Census Bureau reports, in 2015, the U.S. exported $16.04 billion in advanced technology products in the flexible manufacturing category —up 3.3% from $15.5 billion in 2014 and $14.5 billion in 2013 [1-2]. This trend is likely to continue to increase as the manufacturing sector continues to transform into a high tech, less labor-intensive and more value added industry using advanced automated systems. Hsieh [3] surveyed 150 industry partners on the skill sets needed for industrial automation career. Of these, 78 responded that their companies employ technicians or engineers who maintain automated manufacturing systems as part of their job. Of these 78 participants, the majority (about 88%) indicated that their primary market segment/industry includes one of the following: oil & gas, automotive, semiconductor & electronics, energy storage and distribution, metals, or machine builder. Almost half (47%) indicated that their job level was manager or above; the rest were primarily either engineers or technicians. Survey results indicate the most common pressing challenges by far—noted by over half of the respondents—was the difficulty of recruiting and retaining skilled technicians and engineers. Difficult-to-find skills included programmable logic control programming, system integration, and automation.

Current methods for internet controlled automated system include, but not limited to, the use of Supervisory Control and Data Acquisition (SCADA), Decentralize Software Services (DSS), PCs connecting to PLCs through hubs, user interface using Microsoft Internet Explorer and LAN line control, computer network services, and Visual Studio with ASP NET [2, 4, 6, 7]. These methods can provide industrial companies easy access to their automated systems where they can be controlled at any time and any location. Using one of these methods could cut down maintenance and other costs for an industrial company. The use of the World Wide Web to control systems has increased dramatically over the years. This is evident by observing large industrial companies' manufacturing processes such as General Motors and the Oil and Gas industry [8]. Hsieh and Scott [9] used similar technology, web pages, PHP script, and web server to remotely control an Adept 1 SCARA robot and a Mitsbishi ERV Articulated Robot.

The system allowed students to conduct the experiment thru the web pages at their time of conveniences. Later, Pal and Hsieh [9] developed a remotely controlled Gantry mechanism system in which a webcam is mounted on the gantry mechanism; students can pan, title and manipulate the webcam to observe an Adept 1 SCARA Robot over the Internet. These examples demonstrate that the technology is mature and can be used for educational purpose. The greatest benefit is that users can use the system anytime and anywhere. This can potentially alleviate the constraints of limited availability of industrial scale equipment and large class size. This paper focuses on (1) the recent design of three web-based automated systems—a material sorting system, pick-and-place automated system, remote-control of robot system; and (2) preliminary evaluation of the systems.

Remote Control System Architecture (RCSA)

A generic RCSA consists of following components, namely, (1) web server, (2) user interface, (3) equipment to web server interface, and (4) web browser to web server interface. Figure 1 shows a RCSA. The robot is the system to be controlled; Apache is the web server; Logitech joystick is the remote control unit and a JavaScript communication application serves as the interface between client and web pages; Visual Basic and MySQL applications are interfaces between the web server and robot controller; and the interface between the web browser and web server is the PHP script language used to develop the web pages (HTML and AJAX).

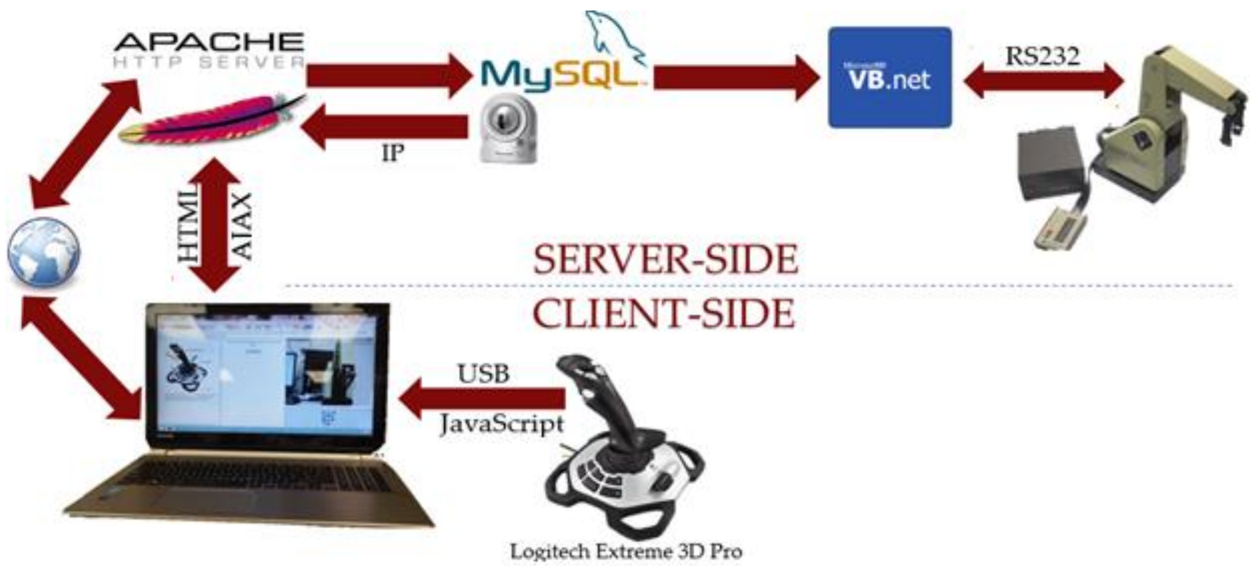

Figure 1. Generic Remote Control System Architecture.

Remote Control of Material Sorting System

Material sorting is a very common manufacturing process. The intents of this system are to (1) develop a miniaturized automated color sorting system to be controlled by a PLC and (2) allow students to remotely control the system and observing the sorting process. To make the sorting process continuous, the system (1) randomizes the color marbles through a mixing machine, (2) sorts and feeds the marbles based on color into appropriate conveyors, and (3) feeds all the marbles into the mixing tank again. System components are (1) programmable logic controller, (2) color sorting sensor, (3) color marbles mixing mechanism, and (4) main and sub conveyors for marble transferring. Figure 2 shows a sketch of the overall system design and marble mixing mechanism.

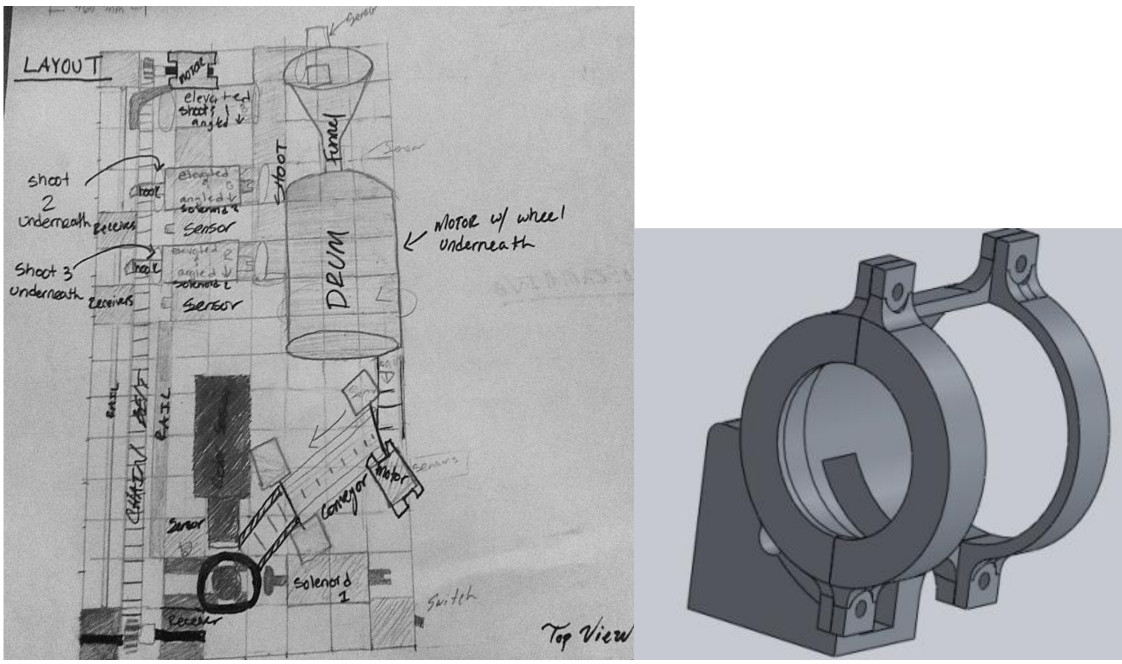

Figure 2. Sketch of Overall Marble Sorting System Design and CAD Drawing of Mixing Mechanism Design

Figure 3 show the final constructed marble sorting system and programmable logic controller module. The system includes FisherTechnik parts, color sorting sensor, conveyors, mixing dram, and conveyor gates.

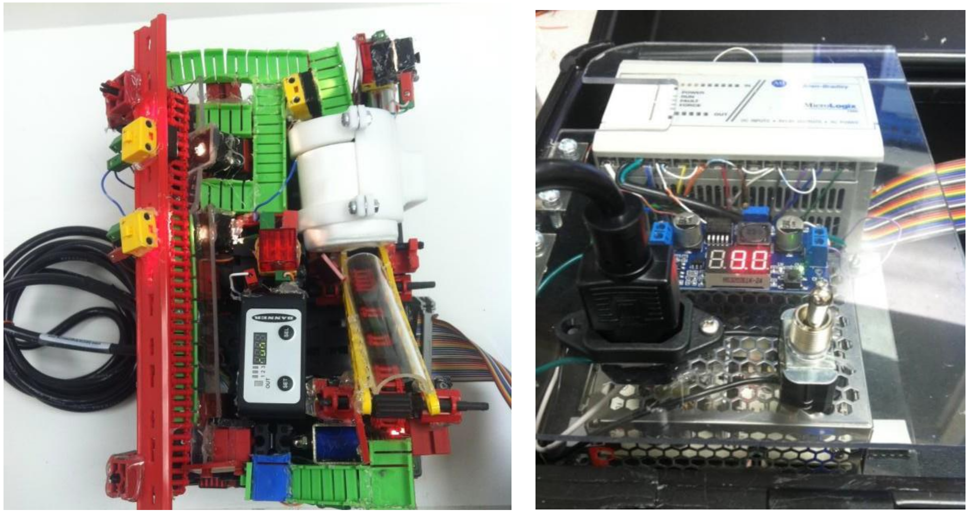

Figure 3. Marble Sorting System and Mixing Mechanism

Figure 4 shows a web user interface for remotely controlling the system. A user can see the operation of the entire system using a webcam and turn the system on/off from a web page.

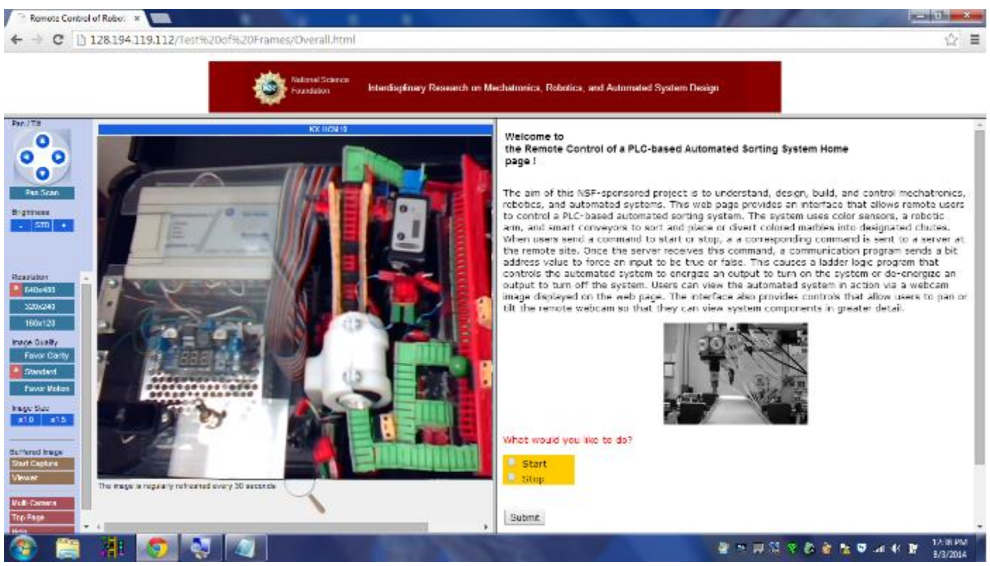

Figure 4. Web interface for remote control of Marble Sorting System.

Remote Control of Pick-and-Place Automated System

Pick-and-place operation is another common manufacturing process. The intents of this system are to (1) develop an up-to-scale color sorting and pick-and-place color automated assembly system controlled by a programmable logic controller and (2) allow students to remotely control the system and observe the entire sorting and assembly process. The automated sorting and assembly system consists of two conveyors, two feeders and one pick-and-place pneumatic robot station (Figure 5). All components are controlled and synchronized by three Allen Bradley MicroLogix 1000 programmable logic controllers, as shown in Figure 6. The PLCs are connected to the stations through ribbon cables via Festo Easy Ports and then to field devices as shown in Figure 7.

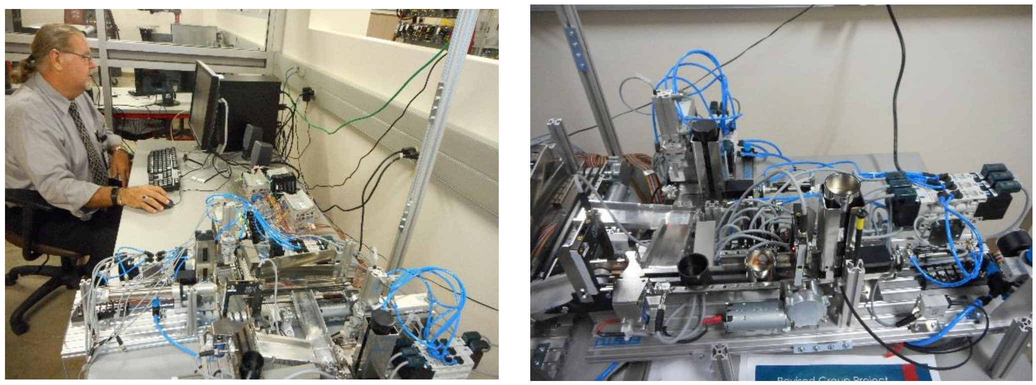

Figure 5. Side and top views of Automated Sorting and Pick-and-Place System

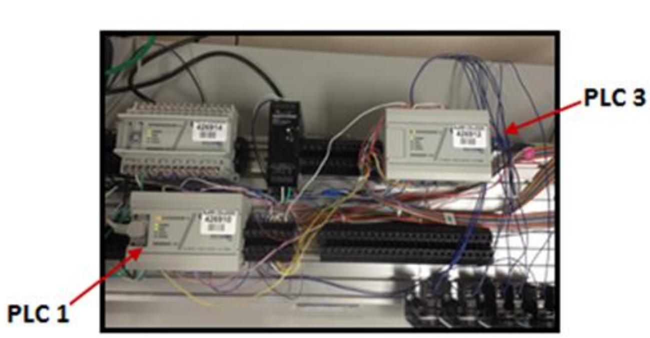

Figure 6. Three Allen-Bradley PLCs used in system

Figure 7. Ribbon cable connections between Easy Port and field devices

PLC1 controls the base feeder, sorting conveyor and the diverter gate solenoid for the feeder/sorting station. When the PLC receives a "Start" signal from a remote user, the feeder fiber optic sensor (FOPT) detects the presence of parts in the feeder, the feeder cylinder extends and pushes a part into the path of the infeed Optic Photo Eye (OPT). When the OPT detects the part, it energizes the sorting station conveyor motor (K2). The sorting conveyor moves the part and passes it in front of an Inductive Proximity Switch (IND). If the part is plastic, it is passed on through to the plastic base assembly station; however, if it is metal, the IND detects this and causes the diverter gate solenoid (SOL) to energize and diverts the metal base to the metal base assembly station. The PLC then retracts the base feeder cylinder, which completes the cycle of this station.

PLC2 is used for sensor inputs, to control the cap feeder, and to control the transfer cylinder for the metal assembly station. When a metal base enters the assembly station, another FOPT detects that it is present and PLC2 extends the cap feeder and provides a cap to the robot of the metal assembly station. At the end of the robot arm cycle, PLC2 retracts the cap feeder cylinder and the PLC causes the metal part transfer cylinder to extend, which transfers the part across a chute and onto the outfeed conveyor. This is the end of the metal assembly station cycle.

PLC3 controls the pick-and-place robot assembly process in the metal assembly station. When a metal base is present and a cap has been fed from the cap feeder, the pick-and-place robot arm: moves down to pick up the cap, closes the jaws to grasp the cap, moves to the top/home position, moves to the extended/top position, moves to the extended/down position to place the cap on the base, opens the jaws to release the cap, moves to the extended/top position, and returns to top/home position. To provide control for the operation, the PLC utilizes inputs from various sensors to monitor the operation while sending outputs to various devices to control the operation.

Remote control of the automated system is accomplished through a dedicated web server that hosts the web pages and allows guests to log into a web page to “Start” and “Stop” the system while viewing the operations in real time through a camera that is mounted above the system, as shown in Figure 8.

Figure 8. Remote control of automated sorting and pick-and-place system.

Remote Control of Robotic System

An industrial robot is another major component used within many manufacturing processes. However, an industrial robot is an expensive piece of equipment and each institution may have only a few. Figuring out how to alleviate the high student to equipment ratio and maintain quality of lab exercises is a constant battle. The intent of this system is to increase equipment usage through the development of a remotely controllable robotic system. The system can be remotely controlled using a joy stick and users can observe the robot performing pick-and-place operations. The system components include (1) robot and controller, (2) joy-stick, and (3) web server. Figure 9 shows the overall system design and a user remotely controlling the robot via joy stick.

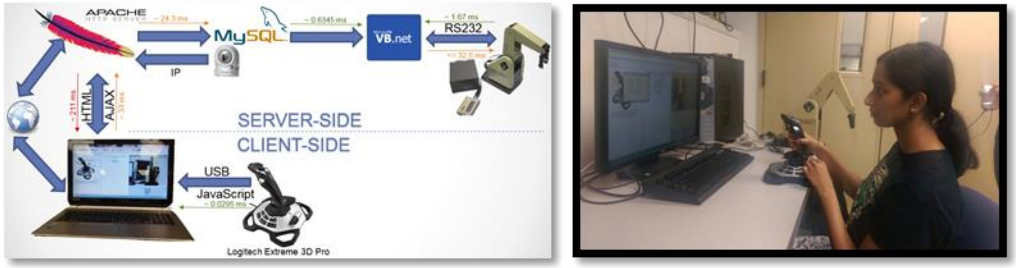

Figure 9. Architecture for remote control of robot and
user using joy-stick to manipulate a remote robot system.

Figure 10 shows the web page interface that allows users to observe the movement of the robot and coordinates of the robot while it is moving.

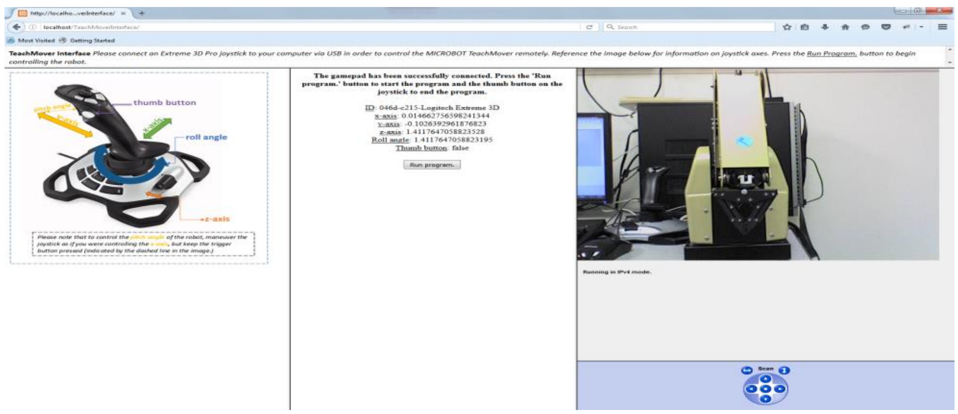

Figure 10. User interface design and real-time observation of robot system.

Survey and Student Activities

The **Pick-and-place Automated System** was used during the spring 2016 semester at Alamo College in San Antonio. There were 38 students in the course. The majority of the students participating in the course were dual-credit high school students. A survey was conducted to gauge student response to the teaching methods used. The survey indicated that the hands-on portion of the training greatly helped them understand and visualize programming using the robot teach pendant. Students least preferred the end-of-chapter questions, which resulted in homework. However, these were an important part of helping students prepare for quizzes and exams. Figure 8 shows the class activities that students were involved in.

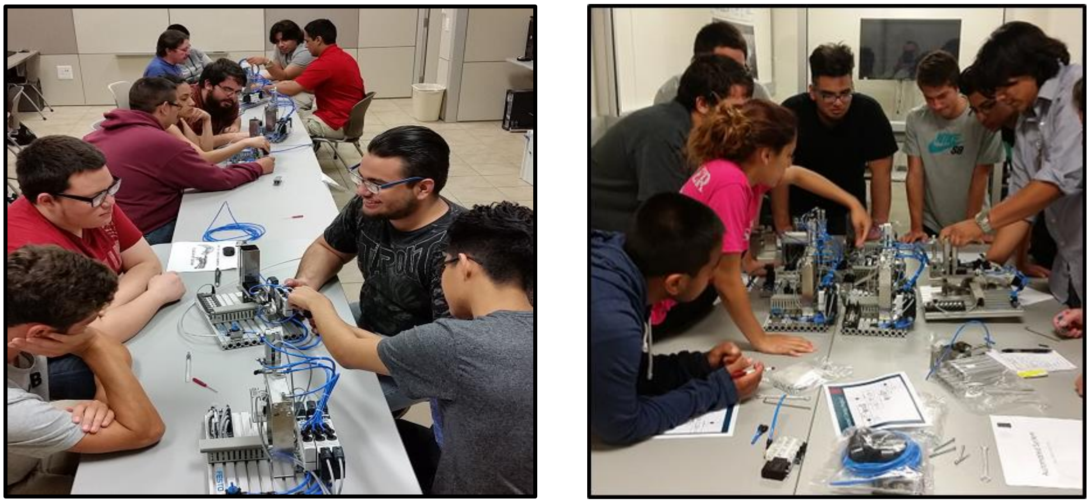

Figure 8. Student class activities

Preliminary findings from the survey include 1) students seemed interested and intrigued by the set up; 2) there is a time-delay between the control action and the image being presented over the webcam; and (3) students want more time to use the system.

Conclusion and Future Directions

In this paper, we present three different case studies with the same theme of remote control and monitoring of an automated system. It is our belief that remote labs can be used to alleviate the problem of high student to equipment ratio and provide students the opportunity to work with industrial scale equipment. This experience will potentially help students to develop skill sets needed for the automation field. Future directions include evaluating instructional effectiveness, identifying which aspects of the experience help students learn, and determining optimal time frames for completing assignments.

Acknowledgements

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