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Development of a Low Cost Laboratory System for Teaching Automation System Integration in the Manufacturing Engineering Technology Curriculum

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Abstract - In many automated manufacturing assembly systems today, several components that are manufactured by different companies have to be integrated together into a functional automated cell. In order to achieve full functionality, most companies require services of system integrators to put together different proprietary hardware and software into a single work cell. The demand for such skilled workers especially in the Northern Illinois manufacturing base of Rockford and Chicagoland still remains very high. In many colleges, it is difficult to provide this important area of skill due to the expensive equipment required, or the highly diversified skills needed. In its continuing efforts to restructure and improve the curriculum, Northern Illinois University's (NIU) Department of Technology has recognized such needs of industry and has developed several new areas in its Manufacturing Engineering Technology (MET) program. These new areas include vision applications in manufacturing, robotics, programmable controllers, automated data capture and management, and networking applications in manufacturing. So far these areas have been existing as "islands of technology" and are well incorporated in the Automation and Programmable Controllers courses. However one key component that has not been fully developed is integration. To solve the needs of our diverse student population, and to produce graduates who posses the skill sets that our industry base needs, the NIU Department of Technology has developed a new laboratory that incorporates integration of these "islands" of technology to provide an automated assembly system. The scheme consists of an automated bottle capping and sorting system that is accomplished on a refurbished conveyor. Bottles are loaded automatically by robot, and a vision system is used to inspect the bottle to determine its type. A second robot installs either a white cap or black cap at the next pallet stop depending on the bottle type. A third robot places the finished bottle in the appropriate bin. A PLC is used to control the "hand-shaking" of signals, the pallet stops and the whole process cycle. This paper describes its implementation and how it is used in the automation curriculum to teach integration.

Keywords: - Robotics, Machine vision, Programmable Controllers, Digital I/Os

Introduction.

Although manufacturing accounts for a larger share of total employment in Illinois than in the nation, Illinois' labor productivity for manufacturing, as measured by the value added per production hour worked, trails the national average by less than 1 percent, according to the most recent statistics[1]. This has been attributed in part, to the diversified nature of the state's manufacturing base and the lack of specialization in higher-value-added manufacturing industries. There is evidence that in the past 10 years the level of manufacturing in the US has declined slightly, partly due to lower labor costs in international markets and the shift in the early 90's to the information technology sector. One way of addressing these shortfalls is to provide manufacturing engineering education aggressively at all levels of education and to as many schools as possible. However many states cannot achieve this because of limited resources and lack of access to expensive facilities required to provide such curriculums.

The demand for qualified engineers and technologists continues to increase in the U.S. despite the fact that the rate of graduation of students in these areas has been declining since 1990[1 - 3]. According to the Bureau of Labor Statistics, the projected demand for skilled technicians is expected to increase by 12% by the year 2010[1], yet the trend of graduation of students in these fields are not likely to cope with this demand. The United States, for almost 20 years until 1999, continued to see a decline in enrollment in science, engineering and technology programs[2,3]. Between 1990 and 1999, the number of students graduating with engineering and technology fell by 8.9% and 21% respectively. Although this trend is projected to change within the next 10 years, with indicators already showing a slight improvement between 1999 and 2000 (up by 0.8% and 1.0% respectively), there will still be an insufficient number of skilled workers to fill the jobs. All these are coupled with the fact that manufacturing in the US has been on the decline due to lower manufacturing costs and competition from other countries calls for a re-examination of the way courses are offered in engineering and technology. It is very important, especially in this era of economic hardship, that academic institutions of higher learning address these problems and seek ways by which there can be a cost effective ways of offering programs that would otherwise be very expensive to offer.

While the number of jobs at the entry level is increasing, the skilled entry level employees are not entering the training programs as fast. The lack of skilled employees is a function of several variables. The first constraint to the individuals entering the manufacturing technician profession is the lack of instruction and training equipment available at the various levels of the educational ladder. This paper examines a method by which a cost effective solution can be provided. The Technology Department at Northern Illinois University has been devoting time to improving the technology that is being used in the automation labs. In this paper a low cost integrated assembly cell is presented. The cell integrates various facets of automation to present a curriculum that is broad and fairly modern. The components include robotics, machine vision, input/output (I/O) interfacing, sensory devices, pneumatics and programmable logic control (PLC). Most important is the fact that the student is able to integrate all these islands of automation through simple techniques and control the cell through PLC.

Integrated Automated Assembly Cell

The current project is developing an automated bottle capping assembly cell. The assembly cell will automatically pick and place an empty bottle on a circular track where the bottles are identified, capped, and dropped into the appropriate bin according to the color of the caps. The color of the caps depends on what is labeled on the bottle. This assembly cell will give students a chance to work with programming robots combined with a vision system to run the bottle capping assembly through PLC control for repeated cycles. This assembly cell is comprised of many different components. The cell uses an oval shaped carousel type continuous motion conveyor that moves the bottle from the first to last station. At the first station, the pallet triggers a photo cell that is connected to a PLC to activate a pneumatically actuated pallet stop that will keep the pallet in a stationary position as an empty bottle is loaded to the pallet. During the pallet stop, a Denso™ six axis robot (figure 1) is used to pick a bottle from a holding rack (figure 2), and places the bottle into the fixture. The fixture is secured to the pallet which fits on the conveyor. With the bottle placed inside of the fixture, it is ready to move on to the next station. In order to move on, the “end of cycle” portion of the 6-axis loading robot incorporates an I/O that signifies completion of cycle which is sent to the PLC through a relay controlled interface. It is noted here that the robot I/O has a different current capacity from the GE FANUC VersaMax™ PLC used in this application and hence the need for relays.

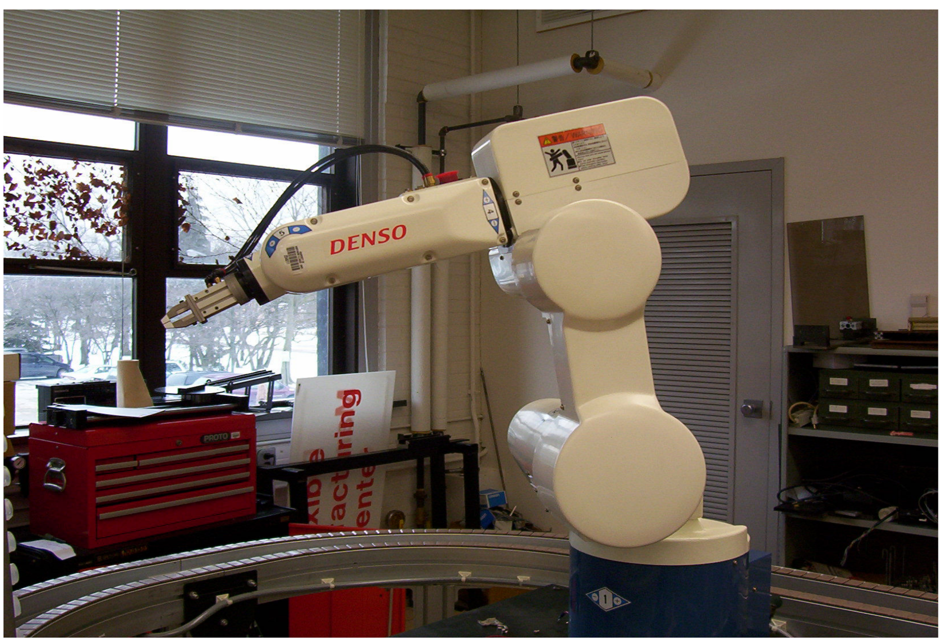

Figure 1. 6-Axis Robot and Empty Bottle Loading Rack

The next stage of the assembly involves the output from the machine vision. The purpose is to detect whether the bottle will need a black cap, or a white cap. In order to accomplish this task the Legend Series 500 SmartImage™ Sensor (figure 3) that is used sends a signal to the robot controller. The SmartImage Sensor is a machine vision hardware tool used for assuring quality in manufacturing, data gathering, and providing information related to quality control. The smart vision system comprises of an intelligent camera with an inbuilt CCD and processor. The system

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also comprises of an I/O board. The board allows the camera processor to interact with other external I/O devices. From this board, the results of the vision inspection can be electronically send to another I/O system or used for other control purposes. Details of how this has been incorporated in NIU's Technology program have been presented elsewhere[4].

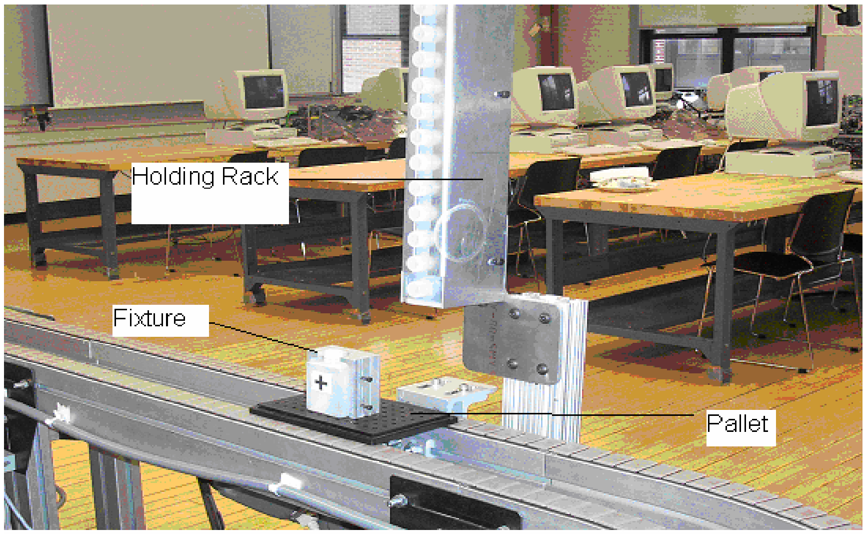

Figure 2. Close-up of the Empty Bottle Holding Rack.

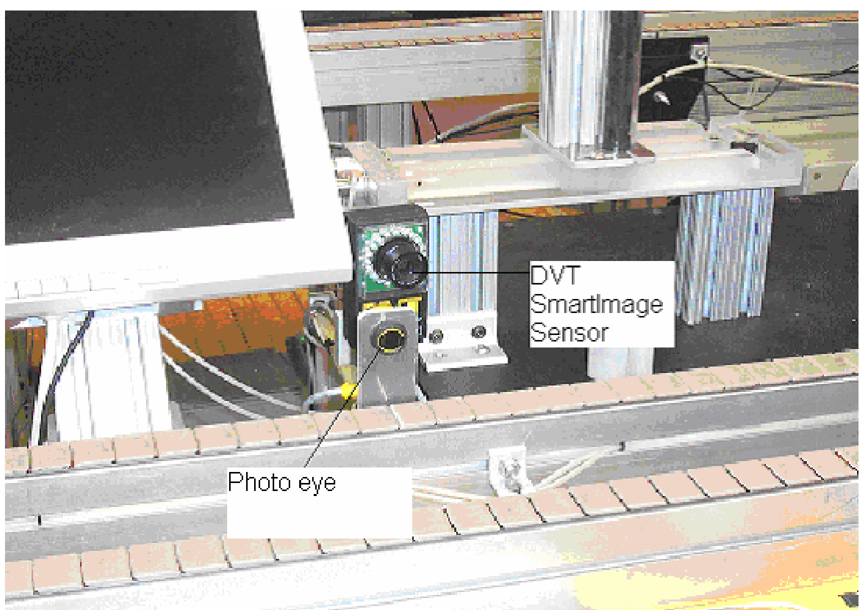

Figure 3. Details of Camera Positioning.

As the bottle travels down the line it passes a photo cell that is timed with a vision system to take a picture of the bottle. The individual bottles are labeled with either a cross or a ring (figure 4); the bottle with a cross will require a white cap while the ring requires a black cap. The vision system is set up to recognize the number of edges on the label. This feature is known as EdgeCount, and it is a tool that counts the total number of times the Soft Sensor path crosses edges in an image. An edge is defined as a transition point between dark and bright pixels. The ring has four edges while the cross only has two edges, if the EdgeCount is drawn horizontally across the image. When the vision system finds four edges (ring), a “pass” result is sent to the PLC via an I/O breakout board and this signal activates a cylinder to eject a white cap. If the two edges are found, a “fail” result is sent to a different PLC input via the same I/O board to activate the cylinder that ejects a black cap (figure 5).

With one of the bottle caps ejected by the cylinder, the next component is a four axis robot shown in figure 6 that will pick up the cap and screw it onto the bottle. To enable a pallet stop for this procedure, the same signal that is used to initiate an image capture is used to trigger a pallet stop via PLC. Once the bottle is in the stationary position, the four axis robot will be activated to pick up the corresponding bottle cap. Since there are two different caps, there has to be a subroutine within the program so the robot has the ability to pick a bottle cap in either of the two positions. The program for the four axis robot is activated by either a "pass" or "fail" in the vision system. If the bottle passes, the robot will automatically pick up the white cap. If the bottle fails, the program in the robot will jump to a subroutine that is programmed to pick up the black cap. With the proper bottle cap picked, the robot moves the cap to the bottle and screws it on tightly. After the bottle cap is on, the bottle continues to the final station of the assembly cell. Upon completion of the capping process, the PLC I/O system sends a signal to the PLC via a relay to de-activate the pallet stop. The bottle details from the vision system (black or white) are retained in the system and passed on to the second 6 axis robot that does the final storage. The programs are written in such a way that each bottle’s details are kept in memory until finally stored.

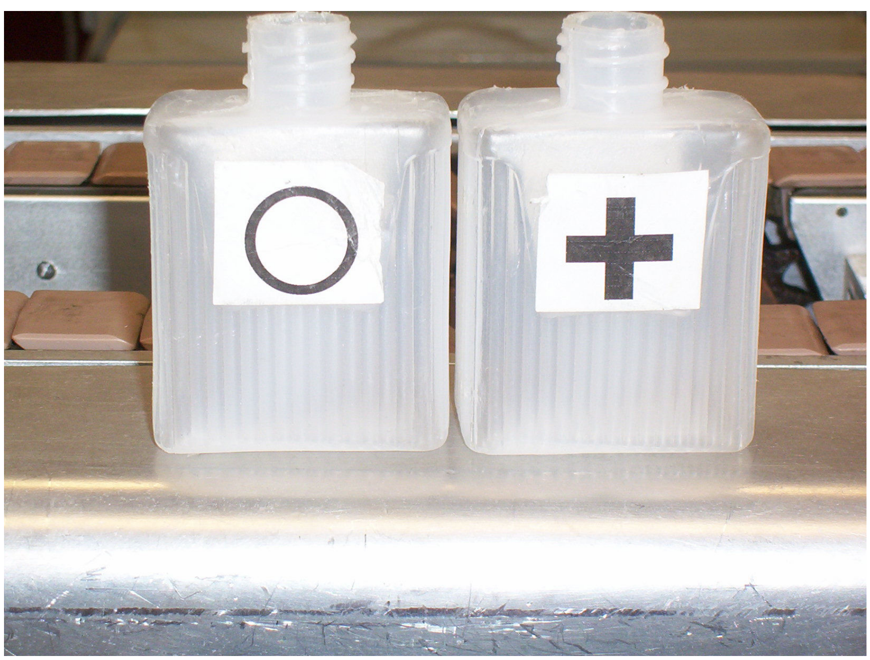

Figure 4. Empty Bottles for the Capping Process.

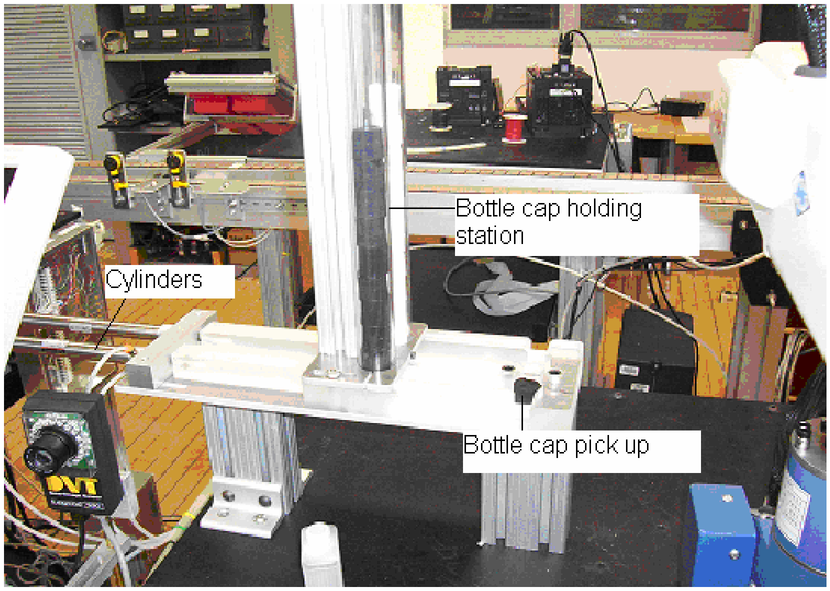

Figure 5. Details of the Cap-pick-up Station.

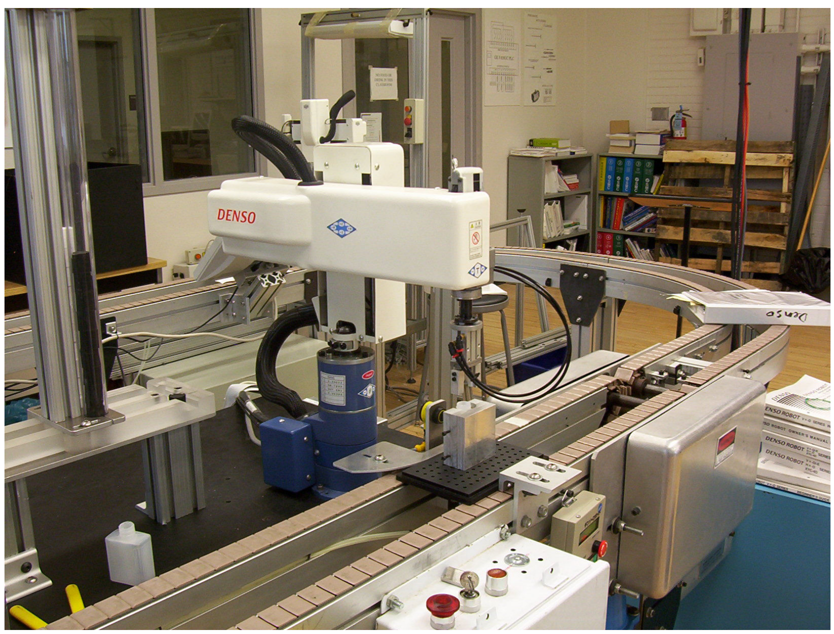

Figure 6. 4-Axis Capping Robot

As the capped bottle continues down the line, it will pass the final photo cell that will activate another stopper to hold the fixture in place. At the last station a six axis robot is used to remove the assembled bottles from the fixture, and places them into designated bins, one for bottles with a cross and the other for bottles with a ring. This robot must also be programmed using subroutines because the white and the black capped bottles are separated into different bins, each bin requiring a subroutine to define positioning movement for the correct placement. Placing the bottles into there corresponding bins is accomplished by receiving a signal from the four axis robot depending on the color of the bottle cap pick up by the robot. This is an "end-of-cycle" output designated for each of the cap installing subroutines.

Learning Outcomes

The main purpose of this project is to introduce concepts of automation integration in a Manufacturing Engineering Technology program. The integrated cell is an integral part of the automation class in the Department. Through this cell the students are instructed on several areas of automation. A number of cameras already installed independently in the lab[4] are used for experiments on machine vision. The students acquire skills on usage of vision and the integration of vision with other components. The automation curriculum has an extensive portion focusing on sensors and integration of sensors with actuators, mainly pneumatic. There is also a substantial section on using PLCs to control automation components. In addition to this, the three robots attached to this cell and a fourth stand-alone one are used in the instruction of robotics, including applications, programming and interfacing. This cell finally provides the students with an opportunity to integrate together what they have learned in the course into a functional automation cell. In many automation courses students tend to the different skills independently and rarely have a chance to integrate the components of automation. This cell therefore provides a low cost solution to an integrated automation curriculum. The only major cost to the Department has been the purchase of the robots, totaling some $40,000. Similar integrated systems with the robots and the controllers installed would cost well over $100,000.

Although this capping project is repeated each time the course is taught (every spring), the students have to start from scratch by developing the programs. Only the wiring of the different sensors and solenoid valves to the I/O board and PLC remain unchanged. The students work in teams typically of four to five. To assess what the students have learned in this project, the students develop a report outlining the details of how they implemented the programs, and how they integrated each component in the cell. In the report the students also include a listing of the robot program and PLC ladder program. Schematics of the wiring and pneumatics must also be included. In addition to the report the students fill out a confidential participation sheet showing how much effort each one put into the project since they work in groups. A timetable is prepared to allow each group to carry out their project within a two week period (eight hours of lab time). The project carries 40% of the lab score. At the end of the semester the students also fill out an evaluation of the course where they have the chance to express their views about their learning experiences in the class as whole.

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Biographical Information.

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