AC 2008-705: ROBOT PALLETIZING WORK CELL SIMULATION

Akbar Eslami, Elizabeth City State University
Dr. Akbar Eslami is a professor and Engineering Technology coordinator in the Department of Technology at Elizabeth City State University. He received his Ph.D. in Mechanical Engineering from Old Dominion University. His research interests are in computer aided manufacturing, design,and automation.

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Abstract

The purpose of this project is to design a fully functional automated palletizing work cell that will simulate real-world palletizing of two different size bottles in a classroom environment. Successful completion of this project is based on the following components working together in a system: the bottle feeder with a pneumatic actuator, two photoelectric sensors, a conveyor, a programmable logic controller (PLC), and a robot. All the components are integrated to perform a unit task of palletizing. The process begins when a pneumatic actuator pushes a bottle from the tray of the bottle feeder onto the conveyor belt. The conveyor belt then transports the bottle to the inspection station, where two photoelectric sensors are mounted to detect the bottle and determine its size. One of the sensors sends the signal to stop the conveyor while the other sensor prompts the robot to start palletizing.

I. Introduction

The Senior Design Capstone Project has been identified as a valuable instrument of the assessment process. This instrument is now becoming more popular in undergraduate programs for the assessment of behavioral and cognitive achievement[1]. Consequently, technology students at Elizabeth City State University (ECSU) are required to complete a Capstone Design Project in their final semester. Simulating real-world robot palletizing is the goal for this Capstone Project. The students, working together as a team, utilize their knowledge, problem solving skills, communication and team work skills, to apply many of the technical competencies they acquired throughout their course of study.

The main objective of this Capstone Project is to design and simulate a fully automated palletizing system where the robot can identify different sizes of bottles and palletize them accordingly. This project can be implemented in other applications as well. For example, the automated palletizing process (APP) is capable of handling different size packages and cartons, and placing them into various machines for processing. The APP is capable of moving different sizes of bottles from one location to another, without the need for additional bottle handling equipment, and counting and arranging the bottles accordingly.

Today, it is not uncommon to see palletizing robots performing the work of humans in an industrial environment. One factor that greatly influences utilization of robots in a palletizing work cell is cost of operation. Robots can work faster and more consistently, can withstand harsher working environments, and are virtually immune to injury. A tight labor market and a need for greater process consistency is the driving interest for robot palletizing[2]. Labor is the highest operation cost for many companies. Over the past 10 years, the U.S. has seen a 34% increase in labor costs. These costs include healthcare coverage, pension costs, as well as other costs such as taxes, cost of regulation, etc[3]. With automated palletizing, labor costs are extremely reduced compared to manual labor. Robots, with all their flexibility, can be programmed to solve a wide variety of distribution and packaging problems. Flexibility, ease of operation, and speed are the recommending factors for the use of robots in the handling, moving, sorting, and palletizing of goods and materials[4]. Robot palletizing is widely accepted in the manufacturing and material handling industry. Many companies that have added robot palletizing work cell to their production line are pleased with the robot's capability to handle heavy load items.

II. Robot Palletizing Process

Figure 1 shows the different components of the robot palletizing work cell. It consists of: a robot with an I/O controller[5], a conveyor[6], a Programmable Logic Controller[7] (PLC) that controls the conveyor's motor, a bottle feeder equipped with a pneumatic actuator, and two photoelectric sensors[8] that send signals to the PLC and robot. The bottle feeder consists of a sloped tray and a pneumatic actuator. The sloped tray feeds bottles in front of the actuator. The robot has its own pneumatic solenoid valve that can open or close an air input by receiving signals from the output module of the robot. While the conveyor belt is stopped, the actuator that is connected to the solenoid valve of the robot extends and pushes a bottle onto the conveyor belt.

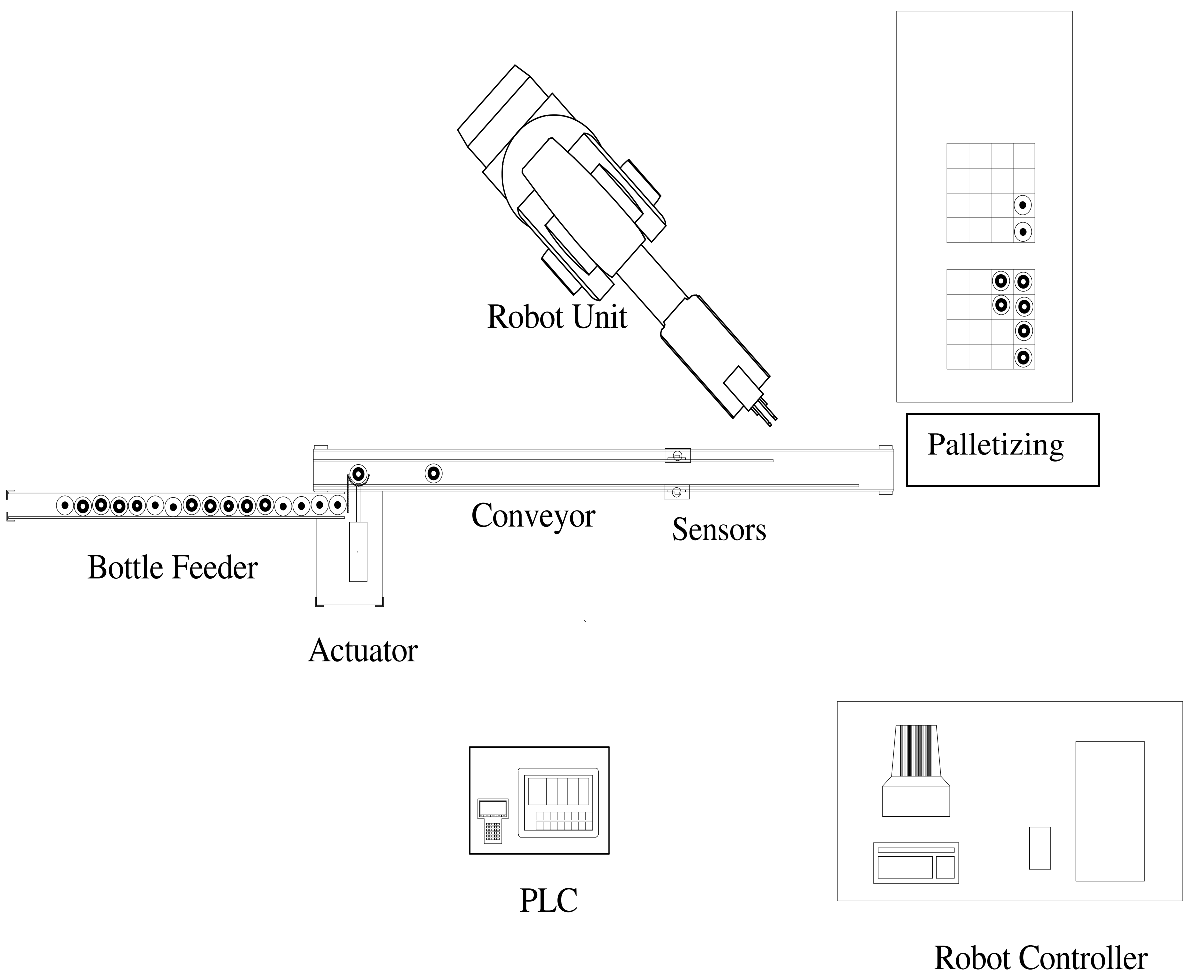

Figure 1: Robot Palletizing Work Cell

The flow chart in Figure 2 outlines the robot palletizing process from start to finish. As depicted in Figure 2, the process starts when the pneumatic actuator pushes the first bottle onto the conveyor belt, after the robot's pneumatic solenoid valve receives a signal from the robot controller. A pneumatic flow control valve is used to regulate the pressure to the actuator; this ensures an even, consistent, and smooth feeding of bottles onto the conveyor belt. After a few seconds, the PLC sends a signal to the conveyor's motor to start the movement of the belt, which transports the bottle to the inspection station, where the two photoelectric sensors, one upper and one lower, are mounted. Each sensor consists of a beam emitter and its receiver. Once the bottle reaches the inspection station, it cuts the beam of the lower sensor, sending a signal to PLC in order to stop the conveyor belt. If the bottle only cuts the beam of the lower sensor, this indicates it is a short bottle. If the bottle also breaks the beam of the upper sensor, this indicates it is a tall bottle. In either case, the robot will palletize the bottle in its proper place. While the conveyor belt is stopped and the first bottle is being scanned by the sensors in the inspection station, the robot's program reactivates the actuator to push the second bottle onto the conveyor belt. There is a 15 second time limit for palletizing of a bottle in an appropriate location. After the time has elapsed, the PLC will restart the conveyor belt to transport the second bottle to the inspection station. This process will continue until all the bottles are palletized.

III. Components Integration and Configuration

Students were faced with major challenges in the project including wiring and integrating the different components of the work cell. The wiring diagram is depicted in Figure 3. The robot controller has input (AX41C) and output (AY13C) modules equipped with 24V dc power terminal connections. Both emitters and receivers of photoelectric sensors are wired to receive 24V dc power from the input and output modules of the robot controller. The chassis of Allen Bradley PLC houses a 120V ac power supply, a CPU 5/2, 120V ac four and eight-terminal input modules with 120V ac com terminal connections, and a 120V ac eight-terminal output module with 120V ac terminal connection. The APP system works properly when each component receives and sends the proper signal. A relay with coil of 24V dc and contact of 120V ac is utilized to connect the photoelectric sensor 1 to input module of PLC. This allows the photoelectric sensor 1 to send the signal to the PLC to stop the conveyor when a bottle cuts the light beam of the sensor. The upper sensor, photoelectric sensor 2, which determines size of the bottle, is wired to general input one (GI1) terminal of the robot controller. This allows photo sensor 2 to send a signal to the robot controller to perform the required tasks.

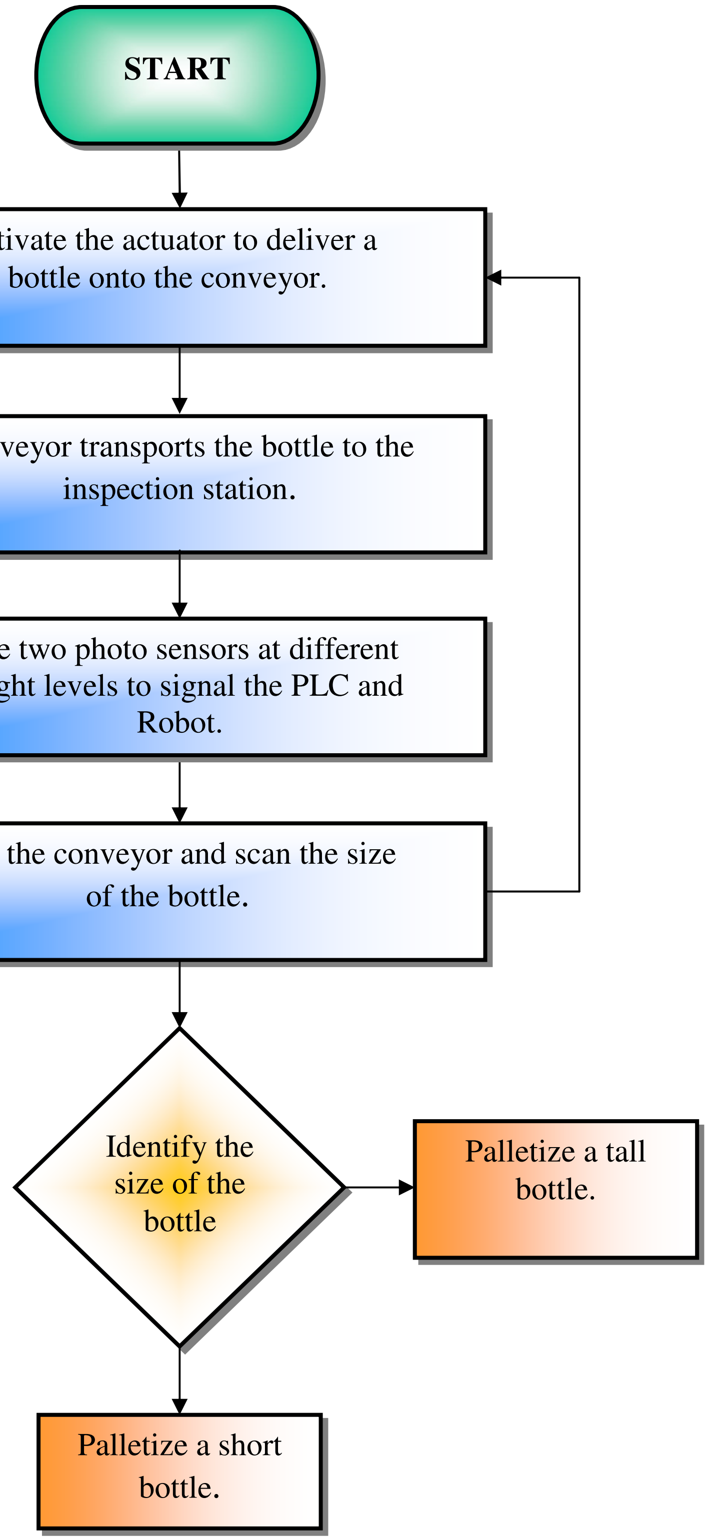

Figure 2: Flowchart Outlining the Palletizing Process

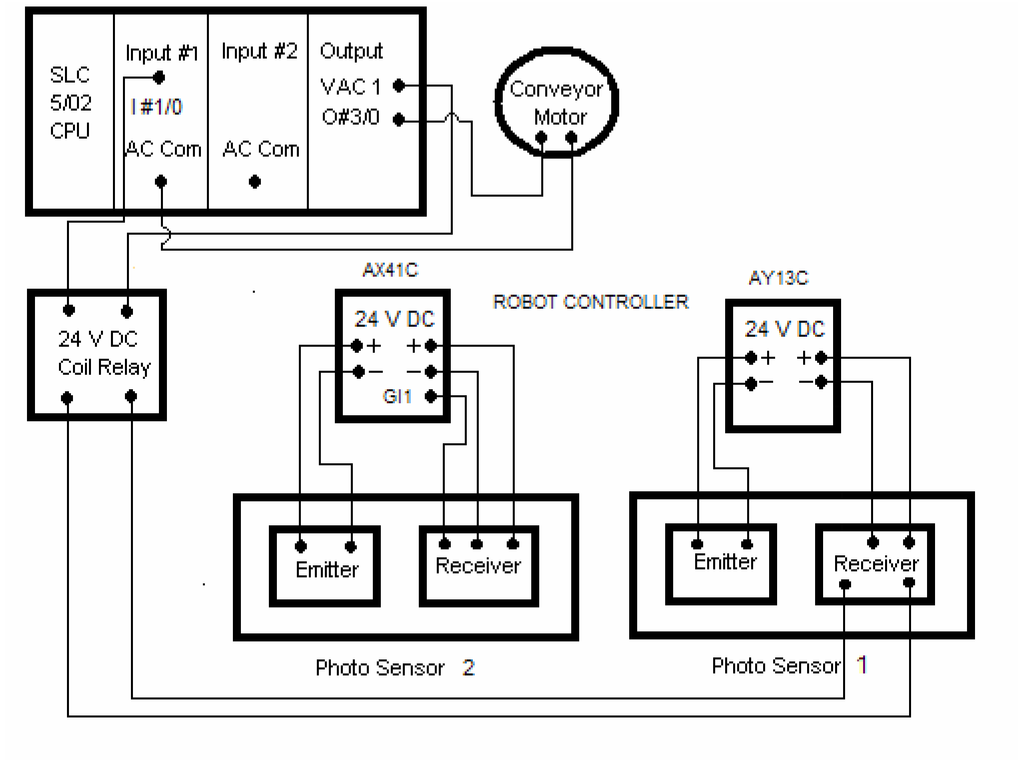

Figure 3: Wiring Diagram

Figure 4 shows the robot program. GI1 terminal which is denoted as input 1 in the robot program has two values, either 1 or 0. The robot program constantly scans this input for a value. If program detects a value of 0, it is an indication that a tall bottle has cut the beam of the sensor. If a value of 1 is detected, it is an indication that the beam has not been cut and bottle is short one. Based on those two values, robot program will execute appropriate program lines and robot starts to palletize the bottle accordingly. The solenoid valve, which is designated as HND 2 in the robot program, opens the air line and extends the actuator if it has a value of 1 and retracts the actuator if it has a value of 0.

5 MOV P6	*ROBOT MOVES TO POSITION POINT P6*
6 HND 1=0	*OPEN END EFFECTOR*
10 MCOUNT1=1	*INCREMENTING COUNT FOR PLT 1 BY 1*
15 MCOUNT2=1	*INCREMENTING COUNT FOR PLT 2 BY 1*
20 DEF PLT 1, P2,P3,P4, 4,4,1	*DECLARE 3 PT PALLET 1, 4x4, ZIG ZAG PATTERN*
25 DEF PLT 2, P10,P11,P12, 4,4,1	*DECLARE 3 PT PALLET 2, 4x4, ZIG ZAG PATTERN*
30 HND 2=0	*EXTENSION OF ACTUATOR* (*actuator pushes a Bottle onto conveyor*)
35 DLY 1	*DELAY FOR 1 SEC*
40 HND 2=1	*ACTUATOR RETRACTED*
42 DLY 10	*10 SEC DELAY TO SCAN GI1 INPUT*
45 IF IN 1=1 GOTO 50 ELSE GOTO 150	*CHECKING FOR SIGNALCOMING FROM GI1* *(Line 50: Palletizing a short bottle, line 150: palletizing a tall bottle)*
50 MOV P6, 60	*MOVE 60MM ABOVE P6*
55 DLY 1	*DELAY FOR 1 SEC*
60 OVRD 30	*SET OVERIDE TO 30%*
65 MVS P6, 60	*MOVE 60MM UPWARD. (SEPARATION)*
70 MOV P7	*MOVE TO POINT P7*
75 DLY 2	*DELAY FOR 2 SEC*
80 HND 1=1	*CLOSE END EFFECTOR*
82 DLY 1	*DELAY FOR 1SEC*
85 MVS P6, 60	*MOVE 60MM UPWARD. (SEPARATION)*
90 DLY 1	
94 MOV P15	*MOVE TOPOINT P15*
95 OVRD M_NOVRD	*RETURN TO DEFAULT VALUE*
100 MOV(PLT 1,MCOUNT), 60	*MOVE 60MM ABOVE PALLET 1 FIXING OPERATIONS POSITION*
105 DLY 1	
110 OVRD 30	
115 MVS(PLT 1,MCOUNT) 60	*MOVE 60MM ABOVE PALLET 1 FIXING OPERATIONS POSIT (SEPARATION)*
120 DLY 1	
125 HND 1=0	*OPEN END EFFECTOR*
126 DLY 1	
130 MVS(PLT 1,MCOUNT1), 60	
135 MCOUNT 1=MCOUNT1+1	*INCREMENT COUNTER BY 1*
140 OVRD M_NOVRD	
141 MOV P15	
145 IF MCOUNT1<17 THEN GOTO 30	*REPEAT OPERATION 16 TIMES*
150 MOV P6, 60	
155 DLY 1	
160 OVRD 30	
165 MVS P6, 60	
170 MOV P8	*MOVE TO P8*
175 DLY 1	
180 HND 1=1	
181 DLY 1	

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185 MVS P6, 60
190 DLY 1
191 MOV P16
195 OVRD M_NOVRD
200 MOV(PLT 2,MCOUNT2), 60
205 DLY 1
210 OVRD 30
215 MVS(PLT 2,MCOUNT2), 60
220 DLY 1
225 HND 1=0
230 DLY 1
235 MVS(PLT 2,MCOUNT2), 60
240 MCOUNT 2=MCOUNT2+1
245 OVRD M_NOVRD
246 MOV P16
250 IF MCOUNT2<17 THEN GOTO 30
255 MOV P6                        MOVE TO SAFE POSITION
260 END                           END PROGRAM
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Figure 4: Robot Program

Figure 5 shows ladder logic diagram using RSlogix 500[9] software. As depicted in Figure 5, in rung 0, the output (conveyor belt) O:3/0 is tied to a normally closed relay enable bit T4:0/EN and normally closed input I:1/0 (photoelectric sensor). The conveyor belt is latched, in order to stay energized until the photoelectric sensor detects the presence of a bottle. The bottle cuts the light beam and causes de-energizing of the normally closed input I:1/0, and the conveyor stops for the next step of the process. In rung 1, I:1/0, the normally open input, energizes the timer on delay T4:0 presets to 15 seconds. The normally open input enable bit T4:0/EN which uses for latching the timer on delay T4:0, allows the timer to keep timing for fifteen seconds before energizing the normally open input done bit T4:0/DN in rung two. The fifteen second time delay will give the robot enough time to palletize the bottle at this stage. In rung 2, the normally open input done bit T4:0/DN is connected to an output reset T4:0. The reset coil will restart the conveyor belt by re-energizing the T4:0/EN input in rung 0. In rung 3, the input of normally open I:1/0 is connected to a counter up C5:1 with a preset of 2000 bottles. Every time a bottle breaks the light beam of the photoelectric sensor, the counter counts up until the number reaches 2000, which indicate the storage area is full.

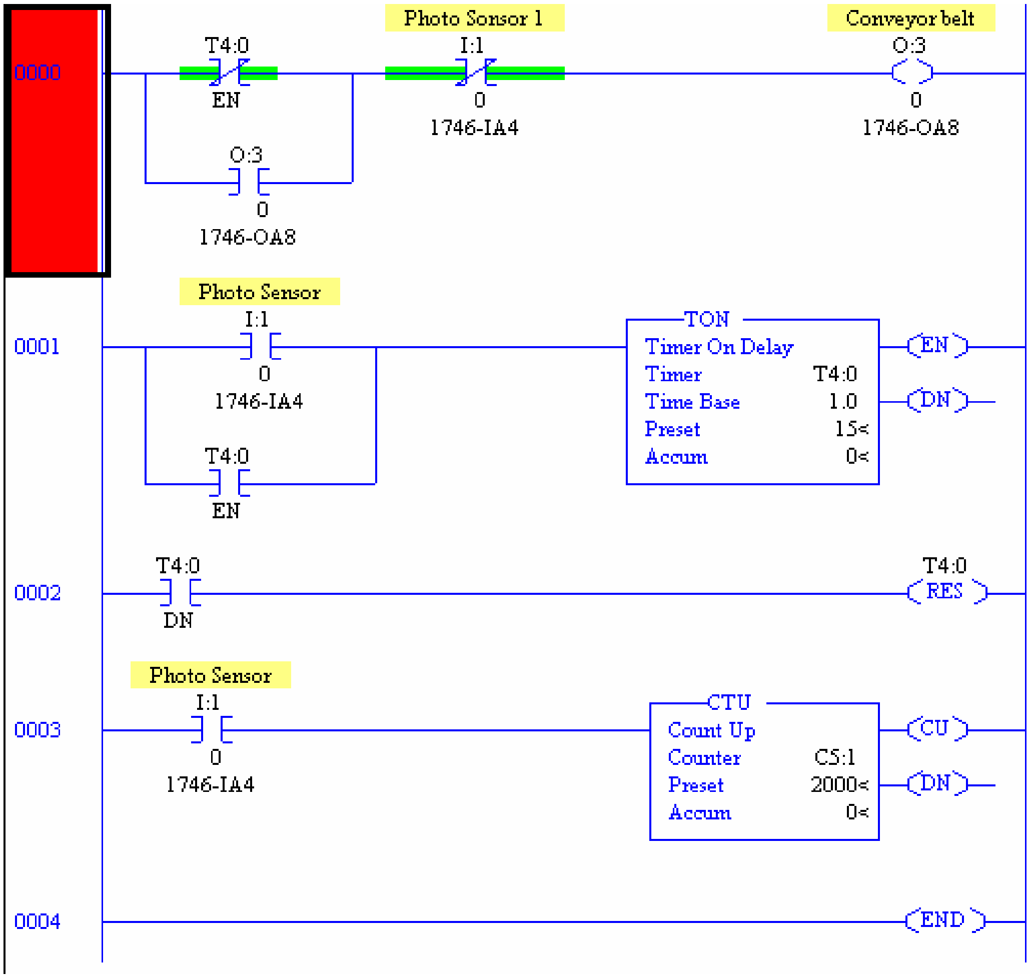

Figure 5: Ladder Logic Diagram

IV. Project Planning

The APP project was designed and simulated by a team of five students, with each student being assigned different tasks by the team leader as part of their involvement in the project. Each team member played a vital role in designing, building, testing, troubleshooting, and running the APP project. As depicted in Figure 6, the project planning process started with developing a work breakdown structure (WBS) method, in which the project was broken down into its five major components. These components were then subdivided into various subcomponents with associated activities. The WBS method was used to ensure that all activities were identified and included and that these activities could be completed in the proper sequence.

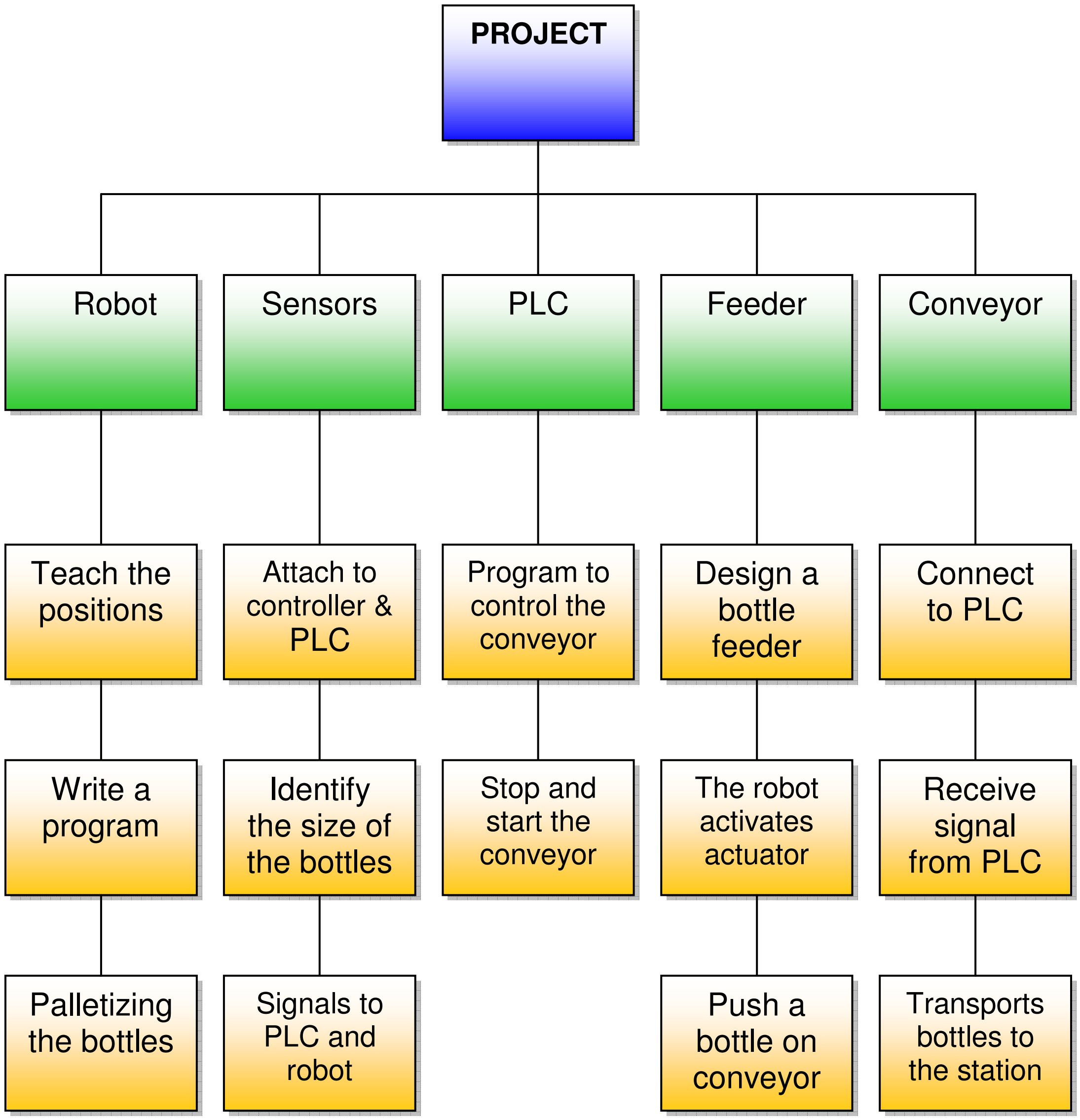

Figure 6: Project Break Down

Once the project planning process was completed, Gantt chart techniques for planning and scheduling were developed. Figure 7 shows a Gantt chart with bars representing the time allocated to accomplish each activity in the project. The Gantt chart outlines the project's activities over a 12-week period. In this case, it depicts the time spent in the designing, purchasing of material, and installing of the bottle feeder assembly; the ordering, installing, and connecting of the two beam emitters and receivers; programming and running of the robot; programming the PLC; and writing a final report of the Capstone Project.

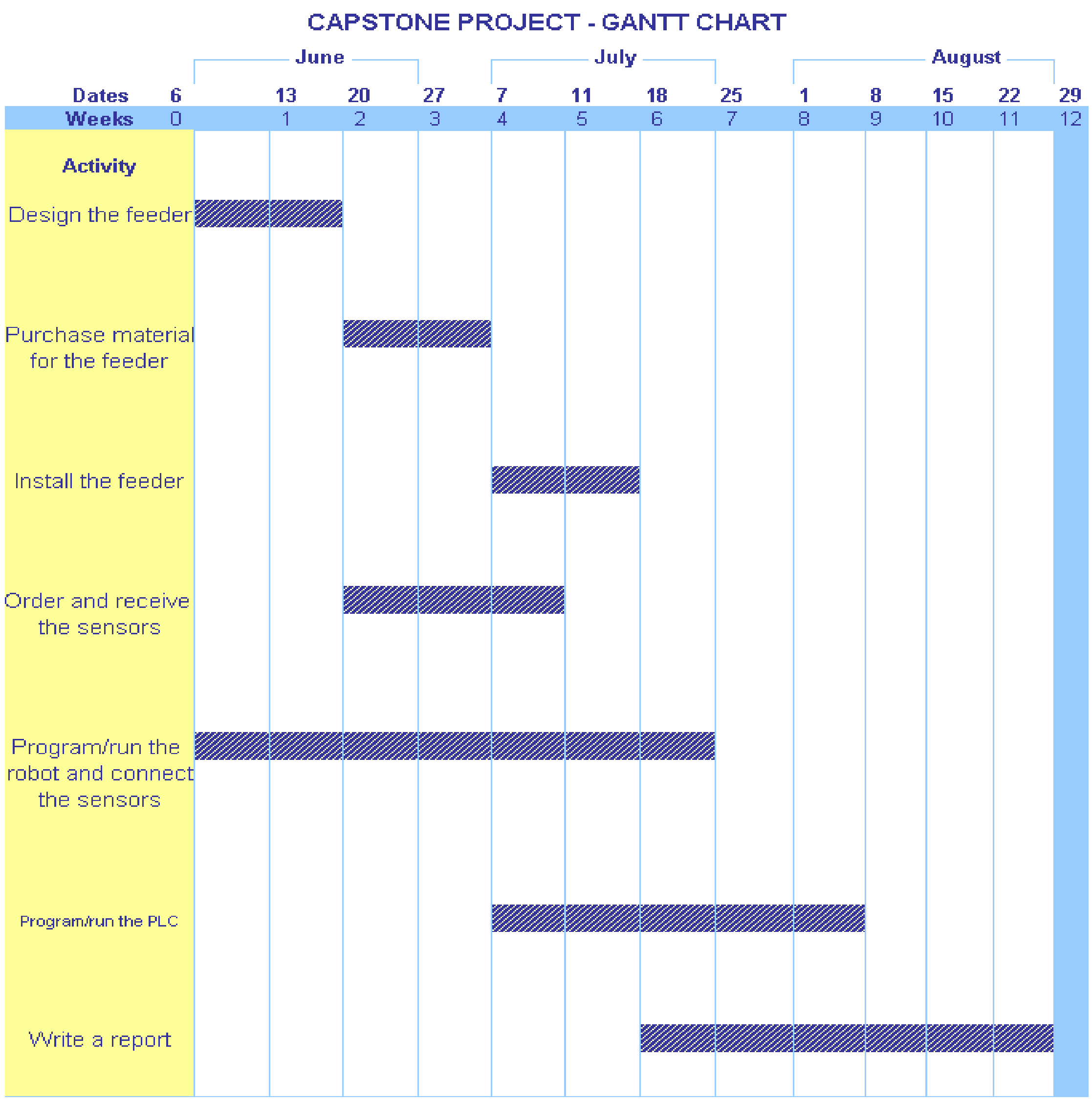

Figure 7: Gantt chart

Two of the students acted as the design engineers. They designed and constructed the bottle feeder system, which consists of a tray and a pneumatic actuator (with an airflow control valve) for placing a bottle on the conveyor belt. The tray has a moderate slope, which allows the bottles to slide into place for the actuator to push them onto the conveyor belt. One of the students was responsible for teaching the positions and writing the robot's program to palletize bottles according to the zigzag method, as well as wiring the I/O modules to the other components.

Meanwhile, the other student was involved in writing the PLC program, setting the sensors, and wiring them to the PLC and robot controller. The team leader, acting as Project Manager, was responsible for overseeing the various stages of the capstone project. He, along with another student, gathered research documentation and data for the report, helped to resolve problems and issues quickly, and ensured that parts and supplies were available and collected.

During the construction of the work cell project, the students were faced with different challenges that caused the palletizing process to malfunction at times. For instance, the air pressure to the pneumatic feeder was too high, thus causing the actuator to apply excess force on a bottle while being pushed onto the conveyor belt. To correct this problem, an airflow control valve was added to the actuator assembly that allowed the pressure to be adjusted accordingly. Also, a relay was used to isolate powers in the PLC and photoelectric sensor, since the PLC and photoelectric sensors operate with 120V ac and 24V dc, respectively.

V. Student Assessment and Outcomes

Faculty members of the Department of Technology at ECSU use Capstone Design Project as an assessment tool to validate outcomes of the program and students' competencies. The Capstone Design Project afforded students an opportunity to implement many of the competencies learned in their field of study including design, software simulation, wiring, system construction and how to present the project in written and verbal form to their instructors and classmates. Students are required to put into practice many of the competencies learned in their program and apply them in a practical real world project. A team of faculty members utilized a capstone design project matrix instrument to validate students' competencies in the areas of technical knowledge, problem solving skills, writing, oral presentation, and team work.

VI. Conclusion

This project provided an opportunity to students to design and simulate a practical project. They practiced how to program, build, install, operate, diagnose and troubleshoot components of the system. Teamwork and communication were two key factors in completing the project. Dr. Eslami mentored students in order to resolve problems and issues that arose during the project. The students were faced with many challenges including programming; integrating and wiring the various components, as well as putting them in the proper location in order to perform the required task. Successful completion of the palletizing process was a definite indication that all components were interacting and receiving the proper signals. Although the palletizing process was simulated in a classroom environment, it can be widely used in industry to palletize not only bottles, but also other items of various types and sizes, such as boxes, metals, etc.

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