This study aimed to create a proto-type robotic pick and place system that utilized pneumatics components to drive an arm, an air compressor as a source of power, sensors technology as a feedback device, and a programmable logic controller (PLC). Robotic pick and place a system consists of a loading station, testing station, processing station, and sorting station. The process involved the sorting of plastic and metallic material into different slots.

INTRODUCTION

Industrial automation has offered higher levels of productivity, efficiency, and quality as well as reduction to cost on the industry. In most Industries, the path towards increased productivity is through increased automation process and control. Automating using robot systems will increase productivity, efficiency and quality control. During operation, robots can be controlled to accommodate more work, and even operate beyond working hours.

With the advent of robotics, laborious and time consuming work in industrial plant and factories have made ease for workers to complete the operation. These workers are assigned to manipulate or control these robots instead of requiring them to carry the task by themselves. This control is made easy with the use of Programmable Logic Controller (PLC). The PLC is now used in every modern production processes to automatically control every aspect of the operation without human intervention.

There is however an inevitability of worker exhaustion which can result to a decrease in the production line. This is the reason why robotics arises in industrial automation processes
today. In countries where robots are extensively employed, the quality of life and living standards have greatly improved.

Automation is achieved through automatic systems that are able to control processes without human intervention. This system must have the capability to start, regulate, and stop a process in accordance to the measured variables in order to obtain the desired output. This system is called Control System (Maloney 1986). Control systems are categories in two controlling types, namely the closed-loop system and the open-loop system.

A closed-loop system is a control system with an active feedback loop. In the closed-loop control system, a position sensor continuously monitors the position and the actuating movement of the robot which continuously alters the movement to conform to the desired paths of both direction and velocity. The open-loop system, on the other hand, is a control system that does not use feedback loop to determine whether the input has achieved the desired purpose. The open-loop control system has a position and rate-of-change sensors on every movement. Thus, the controller cannot correct any error and cannot compensate the disturbance in the system.

This study aims to develop a robotic arm utilizing an electro-pneumatic robotic pick and place system that mimics programmable logic controller or PLC. This type of robot falls under closed-loop control system. The electro-pneumatic robotic arm pick and place are powered by compressed air and controlled by a programmed or machine language.

The robotic arm is composed of pneumatic cylinders performing linear and rotational motion; control valves that allow compressed air flows; and sensor technology that is capable of detecting the picked object. The use of pneumatics for robotics arm is much cheaper than using servo motors.
OBJECTIVES OF THE STUDY

This project aims to attain the following objectives:

• to build a prototype robotic arm pick and place system;
• to verify the relationship between Electro-Pneumatic components and PLC; and
• to come up with a program with the system’s proper motion sequence using a Programmable Logic Controller (PLC).

SIGNIFICANCE OF THE STUDY

Developing the robotic arm with desired control system would answer the call to expose the researchers to industrial automation and hereby giving the researchers the opportunity to be at pace with the latest thrust of the industry.

This project can also provide Capitol University an opportunity to jump-start similar project concepts for potential instructional purposes and to enhance learning across academic disciplines in the field of engineering and technology.

This project can also provide new challenges to the university’s academic instructors to improve their instruction delivery; explore other methods of learning to alleviate the academic standard of the University in terms of technical reinforcement; thereby placing the university’s graduates on equal competitive footing with graduates of other universities.

METHODOLOGY

Operation

Figure 1 shows the basic flow of the robotic arm pick and place system. The loading station delivers the metal and plastic material. As it passes through the testing station, the material is detected by a sensor. The processing station is responsible for interpreting the data in a programmable logic controller PLC. The result of this output from the processing station will be fed the
sorting station. The sorting station will separate the metal and plastic material. The system will repeat its process.

Figure 1. Schematic diagram showing the conceptual framework of the robotic arm pick and place system.

**Design**

The design of the mechanical arm is based upon the availability of pneumatic cylinders considering the exact movement of the actuators. The robotic arm can be operated pneumatically with a desired motion sequence and can be manipulated via programmable logic controller by interfacing the robot into the microcontroller based PLC.

**Subject**
**Electro-Pneumatic Components**

Five (5) pneumatic cylinders were used in this project: one (1) compact cylinder for the upward and downward motion; one (1) rotary cylinder for the left and right motion, degrees of freedom 180 degrees; one (1) linear cylinder for the forward or backward motion; and two (2) spring return cylinder for the gripper.

Directional valves are used to control the movement of the pneumatic cylinder. There are three (3) 5/2 way directional valves and one (1) 3/2 way directional valve. The 5/2 way directional valve has 5 ports (2 ports for the exhaust, 1 port for the pressure source, and 2 ports for the pneumatic cylinder), and 2 directions, extend or retract.

An atmospheric air of 14.7 psi is compressed by the air compressor. The compressed air then enters the air filter to remove excess moisture before moving on to the air distribution switch for dispersal to the power directional valve, double acting cylinders, and spring return cylinders. Minimum input pressure (1 bar) and a maximum input pressure (4 bar) is applied to drive the pneumatic valve. Each directional valve is controlled by electricity generated by a 24Vdc solenoid coil.

**Sensors**

An inductive sensor and a capacitive sensor are the two sensors used in this project. The inductive sensor detects only metallic objects while the capacitive sensor detects any material.

An inductive sensor is the low-cost solution for non-contact detection of metal objects. This sensor is extremely reliable, heavy duty, and virtually indestructible. It can handle a wear-free operation and is resistant to temperature, noise, light, or water. It has a markedly long service life. An inductive sensor detects only conductive materials, an operation distance of up to 50 mm, a switching frequency of up to 5 kHz, a maximum ambient temperature of 200 °C, and high noise immunity.
A capacitive sensor is also a non-contact sensor for measuring conductive and non-conductive materials in solid, powder, or liquid state. The capacitive sensor detects every type of materials (conductive, non-conductive, solids, fluids), an operation distance of up to 50 mm, a switching frequency maximum of 100 Hz, and a maximum ambient temperature of 70 °C.

**Programmable Logic Controller (PLC)**

A programmable logic controller (PLC), also referred to as a programmable controller, is the name given to a type of computer commonly used in commercial and industrial control applications. PLC’s differ from office computers in the tasks that it performs and the hardware and software it requires performing these tasks. While the specific applications vary widely, all PLC’s monitor inputs and other variable values make decisions based on a stored program and control outputs to automate a process or machine. The CL150 Bosch German technology is a programmable logic controller (PLC) used in this project to control the robotic arm pick and place system.

**Project Instrumentation**

The study made use of the following instruments during its experimentation:

- Automation Studio v.3 was used during the designing stage. It simulated the pneumatic sequence of the robotic arm pick and place system without interfacing it to the PLC.
- WINSPS software was used to manipulate the actual movement of the robotic arm pick and place system. The code of the program was encoded in this WINSPS software.
- Programmable logic controller was also used to control the logic operation of the robotic arm pick and place system. The PLC served as the brain of the robotic arm pick and
place system. Input and output components were directly connected to the PLC.

- PC or laptop computer was used for programming processes.
- The air compressor as the primary source of compressed air supplies the robotic arm pick and place system.
- Other tools were also used during adjustments and alignment on the actual process. These tools include pliers, screwdriver, electric drill, adjustable wrench, soldering iron, and multi-tester.

Operational Diagram

The system is centrally controlled by a programmable logic controller, which every input and output data are fed in the PLC. The PLC processes information that happens in the input and output components of the robotic arm pick and place system. Input components are switches that include the start, stop, emergency stop button, and the inductive and capacitive sensors. The PLC is electrically generated by a voltage power supply of 24Vdc.
Robotic arm pick and place system movement is powered by a compressed air.

**Pneumatic Diagram of the Project**

![Pneumatic Diagram](image)

**Figure 3. Pneumatic Diagram**

**Input and Output interface Connection to the PLC**
Input:
I0.0 – Start Button
I0.1 – Stop Button
I0.5 – Capacitive Sensor
I0.6 – Inductive Sensor
I0.7 – Emergency Stop

Output:
Q0.0 – Compact Cylinder
Q0.1 – Rotary Actuator
Q0.2 – Linear Cylinder
Q0.3 – Gripper Actuator

Closed-Loop Control System

In a closed-loop controller or feedback controller, the output of the system is fed back through a sensor measurement to the reference value. The controller then takes the error between the reference and the output to change the inputs to the system under control. Since the input and the output components are directly connected to the controller or PLC, the feedback connection of the sensor from the output cannot be seen externally. It is usually
found in the internal connection of the PLC. This is shown in figure 5.

![Diagram](image)

**Figure 5. Closed-loop System**

**RESULT AND DISCUSSION**

**Proto-type Robotic arm pick and place system**

The robotic arm pick and place system consists of a loading station, testing station, processing station, and sorting station.

1. **Loading Station**

   In this station, metal and plastic materials are loaded manually. Loading the materials must be done one at a time. Once two materials are loaded simultaneously in the process, an emergency stop button should be pressed to ensure safety.
2. Testing Station

The testing station consists of an inductive sensor and capacitive sensor. The sensors are calibrated to attune its sensing range and switching sensitivity to ensure efficiency.
The moment metallic material is loaded, the inductive sensor will automatically detect the metallic material as it passes through the sensor. A small amount of signal is only needed to trigger the switching of the sensor. This switching pulse will then be fed to the programmable logic controller to process the data.

A capacitive sensor will detect the plastic material. Switching pulse will then be fed to signal the programmable logic controller (PLC) to process the data.
3. Processing Station

The processing station involves the logic function of the robotic arm pick and place system in response to the programmable logic controller (PLC). The programmable logic controller (PLC) is responsible for processing the information fed by the input data which is the sensor’s input value. Figure 4.1.3.1 and figure 4.1.3.2 shows the robotic arm pick and place system responded to the logic function of the programmable logic controller (PLC).

Figure 10: Plastic Object

Figure 11: Metallic Object
4. Sorting Station

Since the PLC controls the robotic arm pick and place system, it is much easier to separate the metallic and plastic material in a different slot. The slot occupies up to three objects each for demonstration purposes. After three consecutive loads for each slot, material must be removed from the sorting station.

Figure 12: Metal Sorting Station

Figure 13: Plastic Sorting Station

Figure 13 shows that the plastic material occupies the second slot. Each slot is therefore exclusive for different materials.
5. System Error from Foreign Object Detection

When the robot detects foreign matter due to a process error or the like, it is necessary to stop the operation for the safety of the operator and the protection of the robot. It is customary to make the critical decision to apply the emergency stop button when there is a system error. Therefore, the robot moves along a path different from a taught path, resulting in a safety failure. To avoid such a circumstance, the work space around the robotic arm must be secure from any foreign object detection.

Data Recording Presentation

Table 1: Pressure inlet

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum pressure</th>
<th>Maximum Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gripper Cylinder</td>
<td>0.15 MPa</td>
<td>0.7 MPa</td>
</tr>
<tr>
<td>Linear Cylinder</td>
<td>0.05 MPa</td>
<td>0.99 MPa</td>
</tr>
<tr>
<td>Rotary Cylinder</td>
<td>0.15 MPa</td>
<td>0.7 MPa</td>
</tr>
<tr>
<td>Compact cylinder</td>
<td>0.1 MPa</td>
<td>1.0 MPa</td>
</tr>
</tbody>
</table>

Table 2: Velocity of the Robotic Arm for Plastic Objects

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time (t)</th>
<th>Distance (d)</th>
<th>Velocity = d/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.0s</td>
<td>0.44m</td>
<td>0.0314m/s</td>
</tr>
<tr>
<td>2</td>
<td>14.2s</td>
<td>0.44m</td>
<td>0.0310m/s</td>
</tr>
<tr>
<td>3</td>
<td>14.1s</td>
<td>0.44m</td>
<td>0.0312m/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average Velocity 0.0312m/s</td>
</tr>
</tbody>
</table>

Table 3: Velocity of Robotic Arm for Metallic Object

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time (t)</th>
<th>Distance (d)</th>
<th>Velocity = d/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.3s</td>
<td>0.38m</td>
<td>0.0309m/s</td>
</tr>
<tr>
<td>2</td>
<td>12.2s</td>
<td>0.38m</td>
<td>0.0311m/s</td>
</tr>
<tr>
<td>3</td>
<td>12.1s</td>
<td>0.38m</td>
<td>0.0314m/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average Velocity 0.0311m/s</td>
</tr>
</tbody>
</table>
CONCLUSION AND RECOMMENDATION

Conclusion

The proto-type robotic arm pick and place system utilizes programmable logic controller, sensor technology, and pneumatic components such as compact cylinder, linear cylinder, rotary cylinder, gripper, and directional valves. The robotic arm pick and place system is composed of a loading station, testing station, processing station, and sorting station. It can be generalized that the robotic arm pick and place system has satisfied the motion sequence of the system intended to manipulate every process by ladder programming through the use of programmable logic controller (PLC). Ladder programming is the primary programming language used to execute the motion sequence of the robotic arm pick and place system.

The electro-pneumatics and programmable logic controller are found to be interdependent to each other. Each of the pneumatic components has its own purpose and function in the system. Programmable logic control (PLC) was used to control these pneumatic components. With PLC, the manipulations of the robotic arm pick and place system, work is made easy. It also requires minimal work area compared to hard-wiring system. The accuracy of the robotic arm pick, with the right program installed in the robotic arm pick and place system, also decreases the quantity of human failures.

Recommendations

The outcome of the project caused the proponents to strive for a deeper understanding of industrial automation, robotics, and sensor technology. Although the outcome has proven to be beneficial in many respects, problems were met on how to expedite the necessary hardware.

With all the project challenges and shortcomings in making the project, the researchers recommend the following:
• The mechanical and physical aspects and appearance of the robotic arm pick and place system must be further be improved.
• To maximize the potential of the robotic arm pick and place system other features may be added, such as servo motors to drive the robotic arm pick and place system into a different axis.
• For further improvement of the project, additional features for conveyor system with the use of motors, stopper for the loading station, color detection sensor for different types of material, further enhancement and adjustment in the loading station so that the robotic arm pick and place system may be able to pick other shapes of the material.
• If budget warrants, the University President may purchase a low cost PLC and portable air compressor for the robotic arm pick and place system.
• Enhanced laboratory facilities in the University.
• The University may also consider a budget allocation for an undergraduate project study or thesis in the form of loan especially to projects that are considered capital intensive—such as this robotic automation and variants of the same study.

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