AN-NAJAH NATIONAL UNIVERSITY

FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

COMPUTER ENGINEERING DEPARTMENT

Hardware Graduation Project:

Automated Assembly Line

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Presented in partial fulfillment of the requirements for the Bachelor’s degree in Computer Engineering.

Second Semester, 2023

Acknowledgment

We extend our heartfelt gratitude to all those who played a vital role in bringing this project to fruition. We express our sincere appreciation to An-Najah National University for their unwavering support, enabling us as students to contribute towards the betterment of our country and community. We would like to extend a special thanks to our supervisor, Dr. Anas Toma, whose guidance, dedication, and unwavering belief in our capabilities were instrumental in our success. We are also immensely grateful to all the individuals who provided support and encouragement throughout the journey, through both the ups and downs. It is with deep gratitude that we present this report and project as a token of our appreciation and recognition for their invaluable contributions.

Dedication

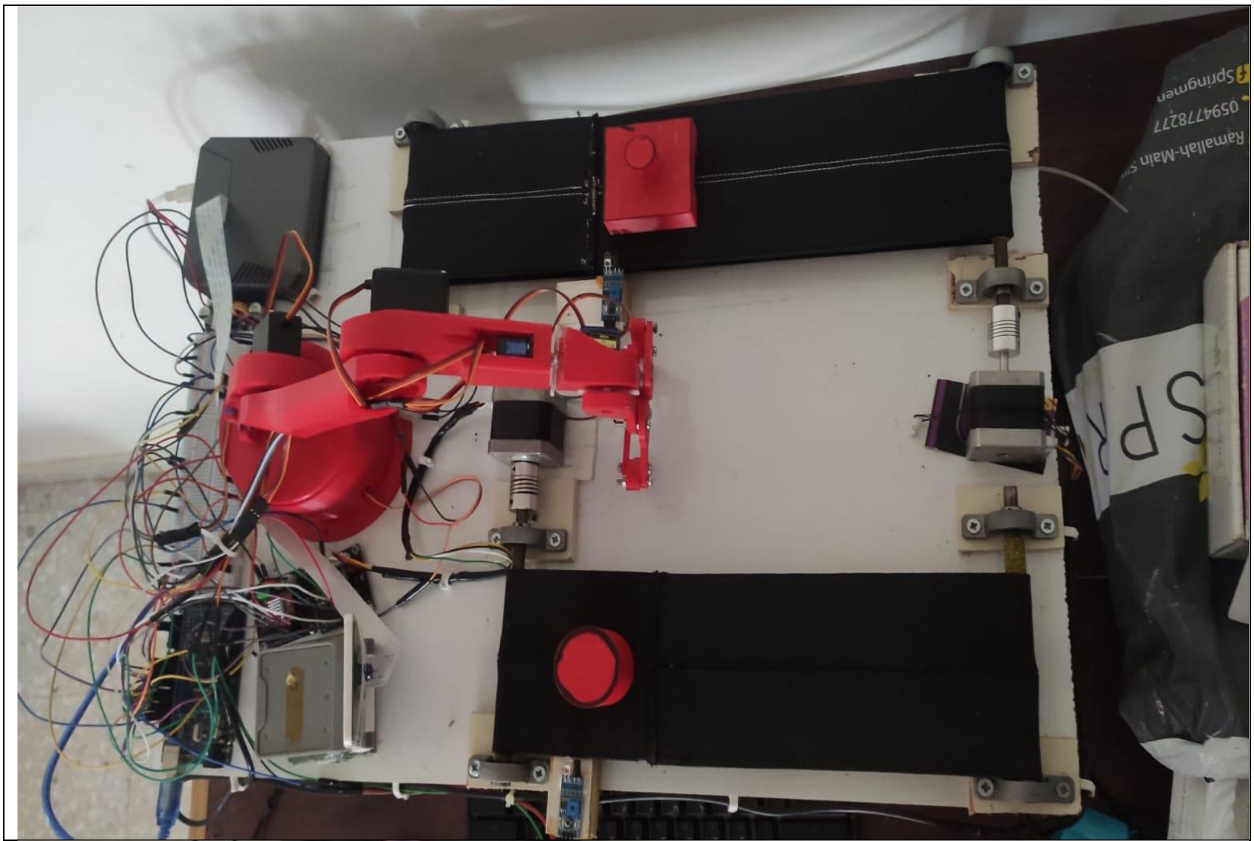
We would like to thank everyone who supported us those who this work won't be done without from friends, family, and those people who made it their life's journey to write articles that help those who are thirsty for knowledge.

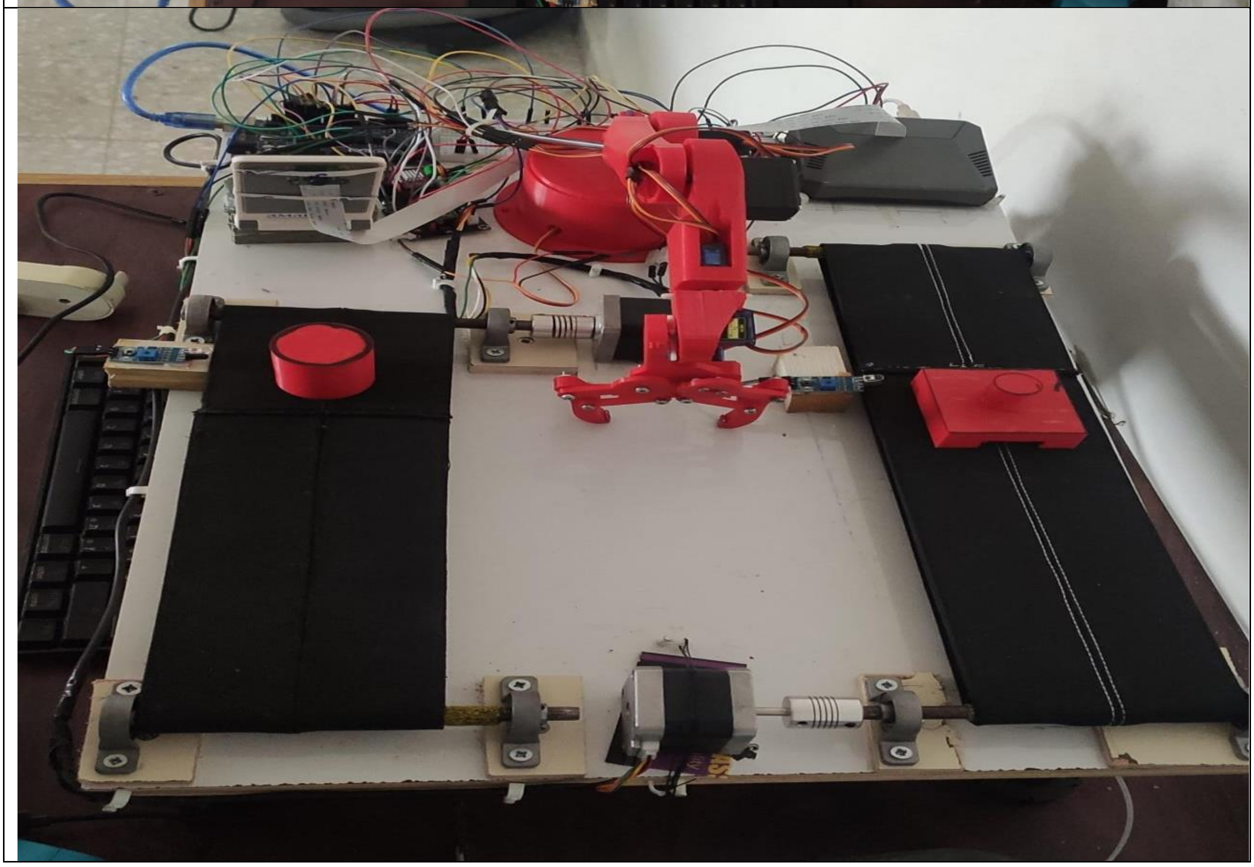
DISCLAIMER

This report was written by students (Baraa Khalaf and Yasser Saife) at the Computer Engineering Department, Faculty of Engineering, An-Najah National University. It has not been altered or corrected, other than editorial corrections, as a result of the assessment, and it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of the student(s). An-Najah National University accepts no responsibility or liability for theconsequences of this report being used for a purpose other than the purpose for which it was commissioned.

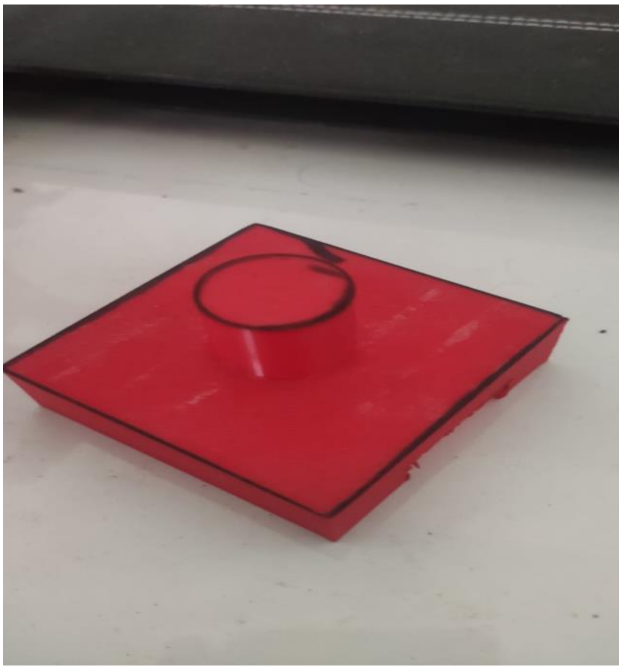
Content

Images of Module:





Images of the two component to be assemble:



Abstract

Automation in manufacturing is very important nowadays, almost all factories use robots because robots can perform the work three to five people, depending on the task, in addition it saving the cost and increase the accuracy which mean minimal waste, and it can remove workers from dangerous tasks, and it leads to increasing in productivity.

Hence the idea, to design an Automated assembly line. The system can assemble two parts to make one object, the two parts will be already manufactured and ready to enter the system using production line for each one, then the system will detect that each part arrive in the lines and this will be synchronies with a five axis robotic arm that will take the two parts after checked it and assemble it together and the final object will leave the system as one-part final result object.

We will start our development process by printing the robotic arm using 3d printer, then we will connect the arm parts with servo motors and test the arm, then we will design the production lines using stepper motors to control the speed of the lines, then we will find a mechanism to check the parts and put them together to make the final product.

1. Introduction

1.1 Problem Statement

The aim of this project is to design and develop an automated assembly line utilizing a five-axis robotic arm for the efficient assembly of two parts into a final product. The project is motivated by the need to enhance manufacturing processes by leveraging automation technologies to increase productivity, reduce costs, improve accuracy, and ensure worker safety.

1.2 Significance

- Enhanced Efficiency: Implementing an automated assembly line using robotics improves productivity by performing tasks faster and more accurately than manual labor.
- Cost Reduction: Automation reduces labor costs by minimizing the need for hiring and training workers, resulting in long-term cost savings.
- Improved Quality: Robotic assembly ensures consistent and precise part assembly, leading to higher product quality and fewer defects.
- Worker Safety: Automating hazardous and repetitive tasks reduces the risk of injuries and promotes a safer work environment.
- Technological Advancement: Developing an automated assembly line using robotics represents a leap forward in technology, providing valuable hands-on experience and promoting innovation.
- Future Applications: Insights gained from this project can be applied to other manufacturing sectors, facilitating the broader adoption of automation technologies.

1.3 Objectives and Scope

Objectives:

- Design and Development: The primary objective of this project is to design and develop an automated assembly line system using a five-axis robotic arm for the efficient assembly of two parts into a final product. This includes the design and construction of the robotic arm, integration of servo motors, and implementation of control mechanisms for the production lines.
- Testing and Optimization: Another objective is to conduct thorough testing and optimization of the automated assembly system. This involves verifying the functionality and reliability of the robotic arm, ensuring accurate part detection and transportation in the production lines, and optimizing the overall system performance.
- Parts Verification and Assembly: The project aims to implement a mechanism to accurately verify the arrival of each part in the production line and ensure the correct assembly of the final product. This includes the use of sensing technologies, image processing algorithms, or other suitable methods for part verification and quality control.

Scope:

- Hardware Development: The project focuses on the development of the physical components required for the automated assembly system, specifically the design and construction of the robotic arm using 3D printing and the integration of servo motors for arm control.
- Production Line Control: The scope includes the design and implementation of control mechanisms for the production lines, using stepper motors to control speed and synchronization. The emphasis is on achieving optimal line performance and part transportation.
- Part Verification and Assembly Mechanism: The project includes the implementation of a mechanism to verify the arrival of each part in the production line and ensure correct assembly. However, the specific sensing technologies or image processing algorithms to be used will be determined during the project development phase.
- Software Development: While not the primary focus, limited software development may be required for

programming the robotic arm's movements and coordination with the production line control.

- Limited Integration: The project scope encompasses the integration of the robotic arm with the production lines and the coordination of their operations. However, integration with higher-level systems, such as a central control system or data analytics, may be considered as future enhancements but falls outside the current scope.

1.4 Report Organization

1.4.1 Second chapter: In this chapter, we covered the important subjects we learned previously, as well as the external courses and the primary constraints and obstacles we encounter while working on the project.

1.4.2 Third chapter: we talked about literal review and similar projects.

1.4.3 Fourth chapter (Methodology): We talked about the mentality through which we built the application, in addition to the features that we offer and the technology's used.

1.4.4 Fifth and final chapter: we talked about the results, as well as the lessons we learned from working on the project and future developments.

2. Constraints and Earlier Coursework

2.1 Constraints

2.1.1 Budgetary Limitations

The development of the hardware model for the automated assembly line system must be carried out within the confines of a specific budget. The financial constraints may impact the selection of materials, components, and technologies used in the model. Cost-effective alternatives may need to be considered without compromising the overall functionality and purpose of the hardware model.

2.1.2 Time Constraints

In every operation, time is of the utmost importance. Researching, communicating, testing, designing, analyzing the needs, planning, and wasting time due to inexperience all cost time, which, no matter how trivial, rapidly adds up.

2.1.3 Lack of Mechanical knowledge

The project involves many mechanical aspects that we only partially understood. Considerable 3D printed pieces required some balance and mechanical understanding and production lines.

2.1.4 Hardware Availability

The availability of necessary hardware components may pose constraints during the development process. Limited access to specific parts, sensors, or robotic components may require alternative solutions or substitutions. We designed the hardware model considering the availability and compatibility of the required hardware components.

2.2 Earlier coursework

2.2.1 Microcontrollers and PIC

These classes covered the fundamentals of the Arduino, including as basic serial communication and controlling steppers and servo motors.

2.2.2 Networks and Communication and Wireless

We used the ESP8266 module to connect the Arduino with the mobile wirelessly.

2.2.3 Critical Thinking and Research Skills

This course has provided me how to conduct research and write a report, and it's one of the few non-technical courses that is also lifetime.

3. Literature Review

During the development of our automated assembly line project, our primary objective was to address the challenges associated with speed, time, and accuracy in the assembly process. To identify the most effective solution, we conducted extensive observations of work processes in local and general factories. By closely examining these real-world scenarios, we gained valuable insights into the intricacies and requirements of assembly tasks. This informed our approach to designing an automated assembly line system that would optimize productivity, minimize time consumption, and ensure precise and efficient assembly of components. By drawing inspiration from these observations, we aimed to create a solution that would streamline the assembly process and improve overall efficiency in various industries. This can be explained as follows:

3.1 The Regular work in Factory

In traditional factory settings, the regular work often involves a series of manual tasks and assembly processes that can be labor-intensive, time-consuming, and prone to various challenges. Workers are typically required to repetitively perform the same actions, such as picking up parts, aligning them, and connecting them together. This repetitive nature of the work can lead to physical strain, fatigue, and decreased productivity over time. Moreover, the reliance on manual labor introduces the risk of human error, resulting in inconsistencies in product quality and potential rework or waste.

Another common challenge in regular factory work is the need for precision and accuracy. Manual assembly processes are susceptible to variations, such as misalignments, incorrect placements, or improper fastening. These inaccuracies can lead to defective products, increased reject rates, and the need for additional quality control measures. Ensuring consistent quality and meeting production targets becomes a considerable challenge in such scenarios.

Time inefficiencies are another issue. Manual assembly processes are slower, resulting in longer production cycles and difficulties in meeting customer demand. Inefficient workflows and coordination further contribute to delays and production bottlenecks.

Worker safety is a concern as well. Manual work exposes workers to hazards and repetitive motions, which can lead to injuries or health issues.

3.2 Assembly-Automation System

Our automated assembly line system effectively addresses the challenges encountered in traditional factory work, providing solutions that enhance productivity, accuracy, and safety. By automating the assembly process, we significantly reduce manual labor, minimizing physical strain, fatigue, and associated productivity declines. The system's precise and consistent movements eliminate the risk of human error, ensuring uniform product quality and reducing waste.

With its streamlined workflows and optimized time utilization, our automated assembly line improves efficiency, reducing production cycles and meeting customer demand more effectively. By minimizing delays and production bottlenecks, the system enhances overall productivity, allowing factories to achieve higher output levels and improved profitability.

Worker safety is a top priority in our automated assembly line. By relieving workers of repetitive or hazardous tasks, the system reduces the risk of injuries and health issues. It creates a safer work environment by eliminating exposure to potentially harmful substances, heavy lifting, and other physical risks associated with manual labor. By enhancing worker safety, our automated assembly line system contributes to a more positive and fulfilling work atmosphere, fostering employee well-being and satisfaction.
Overall, our automated assembly line system provides a comprehensive solution to the challenges encountered in traditional factory work. It enables factories to achieve higher productivity, consistent product quality, improved efficiency, and enhanced worker safety. By harnessing automation technology, we empower businesses to optimize their operations, stay competitive, and create a more efficient and harmonious work environment.

3.3 Similar Projects

Several projects worldwide have focused on developing automated assembly line systems to address the challenges faced in various industries. These projects aim to streamline production processes, enhance efficiency, and improve product quality. Through the utilization of robotics, advanced sensors, and automation technologies, these initiatives seek to automate repetitive tasks, reduce human error, and increase productivity. By examining these similar projects, we gained valuable insights into successful approaches, technological advancements, and potential areas for improvement in our own automated assembly line system.

4. Methodology

This section contains detailed information about the techniques and methods we used to develop the project, from designing and assembling the mechanical structure to controlling the arm and positioning, as well as how they are linked together to produce the final product.

4.1 Choosing the idea

At the onset of our graduation project, we found ourselves amidst a sea of ideas and existing projects in the field of computer engineering. We were determined to avoid replicating previous endeavors and sought to create a project that would stand out as unique and unprecedented. Consequently, significant time was dedicated to brainstorming and researching until we finally conceived the idea for our project: the automated assembly system. This distinctive concept, previously unexplored by our peers, motivated us to pursue an innovative path and develop a solution that would revolutionize assembly processes in various industries.

In the beginning, the idea was not clear either, so we went to the doctors of the Department of Mechanics and Mechatronics and presented the idea to them and studied it with them, and in the end we reached the final idea and the basic features that our system will have.

After we agreed on the idea of the project, we began to think about the primitive form of the project, so we decided to build a robot arm to do the process of assembling the pieces together because the arm is accurate in the process of capturing the parts that are genie assembled, and the arm allows us the freedom to move, unlike devices that move on XY axes. Then we made production lines.

4.2 Mechanical Part

The mechanical component of the project is responsible for moving the arm and moving the production lines, this entails the presence of motors, belts, etc. to generate the motion in cooperation with a controller to guide it. This requires the following steps:

4.2.1 Mechanical Design

In the first step, we worked on designing the components of our model like production lines and 3D printed robotic arm.

So we printed the arm as shown in figure 4.1 below, then we assembled it using screws and servo motors, we use 6 servo motors for this arm.

Then we made the scraping of the production lines and we assembled them.

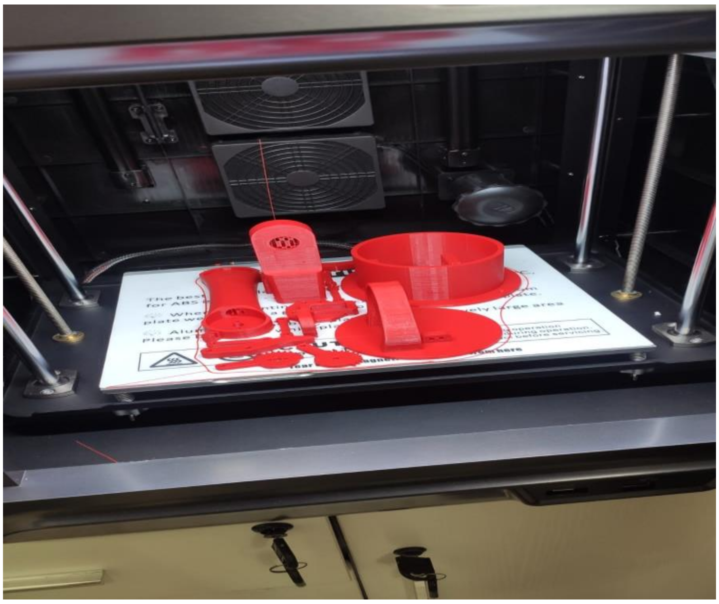


Figure 4.1: 3D printed arm parts

4.2.2 Assembling

It is the part that demands the use of bolts and drill bits to put the components together, and it must be done correctly for the project to function properly.

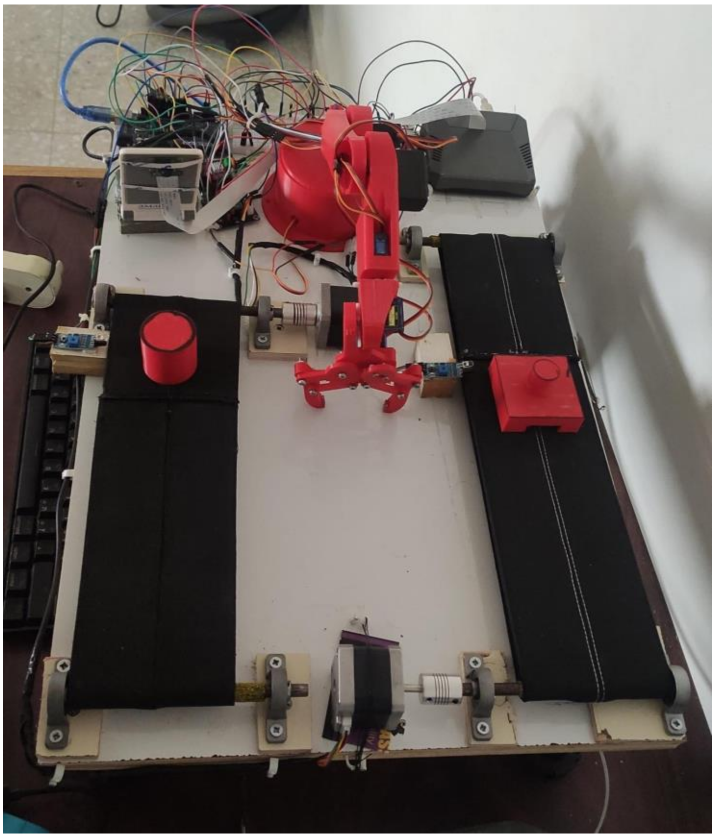


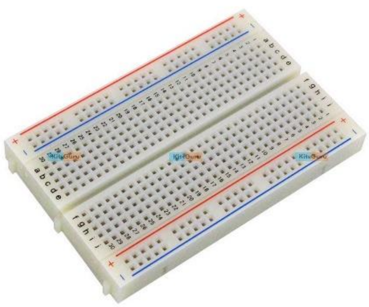
Figure 4.2: Mechanical Body

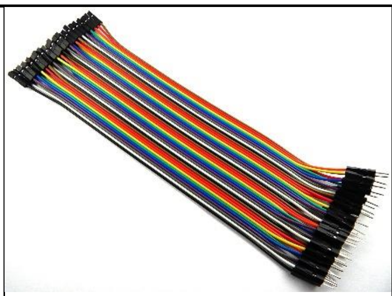
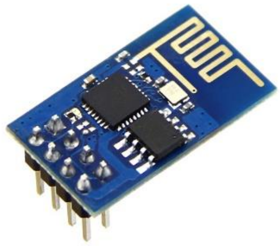
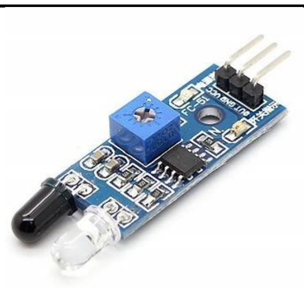
Once we had all the components in place, as illustrated in the preceding figure, we initiated our work on the motors to ensure smooth and reliable movement, aiming to eliminate any potential mechanical issues that could hinder our progress. Our focus encompassed achieving optimal balance and evenly distributing weight to prevent vibrations that might compromise the integrity of the project. Additionally, we conducted thorough tests to verify the proper functioning of the robotic arm, ensuring its seamless integration within the system. By prioritizing these mechanical aspects, we aimed to establish a solid foundation for the project's success and longevity.

4.2.3 Parts

Item Name	Item Image	Quantity
Stepper Motor		2
MG996R HIGH TORQUE SERVO MOTOR 180 DEGREE 9KG		2
MG995 High Speed Servo Motor (180 Degree)		1
TowerPro SG 90 Micro Servo Motor		3

steel rod 8mm		length 60cm
5mm x 8mm Flexible Shaft Coupling Rigid		2
Vertical Self Alignment Block Bearing Flange		8
power supply 10A		1
3D prints arm parts		1

Arduino mega 2560		1
shield stepper driver 42ch		2
module cl4015 (12v-5v)		1
Bread board		1

Wires (female-male)		
Wires (male-male)		
ESP8266 WIFI module		1
IR sensor		2
Raspberry pi 4 model b 8G		1

Raspberry pi camera		1
50CM Raspberry Pi Camera Cable		1

Table 4.1: Project Parts

4.3 Controller Part

The controller part is in charge of directing the mechanical part and powering it, and it is made up of Arduino mega:

4.3.1 Arduino

To streamline the operation of the motors and facilitate the management of electrical signals, we employed the Arduino platform. This versatile microcontroller allowed us to consolidate and differentiate the various electrical signals associated with the motors. Additionally, we utilized the Arduino to develop the necessary code required for the successful implementation of our project. By leveraging this combination of hardware and software, we effectively controlled and synchronized the electronic components involved in our project, ensuring smooth and efficient functionality:

4.3.1.2 Driving Stepper Motors

In order to effectively control the motor and ensure its protection, we incorporated a 4988 driver into our system. This driver proved to be instrumental in facilitating precise motor control and safeguarding its operation. To simplify the connectivity process and ensure accurate voltage supply, we utilized a specialized shield designed specifically for the 4988 driver. This shield streamlined the connection between the driver and the motor, providing the necessary voltage and enhancing overall control accuracy.

To establish the connection between the motor and the shield driver, we utilized the four available inputs on the shield, specifically designed for the motor's coil configuration. These inputs, labeled as

(1A, 1B, 2B, 2A), correspond to the two coils of the motor. By grouping and pairing the wires emerging from the motor, we identified the individual coils. Manual rotation of the motor allowed us to determine the coil pairs based on the resistance experienced. This identification process enabled precise coil-to-input mapping, ensuring proper functioning of the motor.

Furthermore, the shield featured additional inputs, including power supply inputs (12V), a step input, a direction input, an enable input, and inputs for Vcc, Gnd, and 5V connections. These inputs were crucial for powering and controlling the motor, as well as providing necessary signals for step-wise movement, direction control, and overall system enablement.

The following image illustrates the connection process:

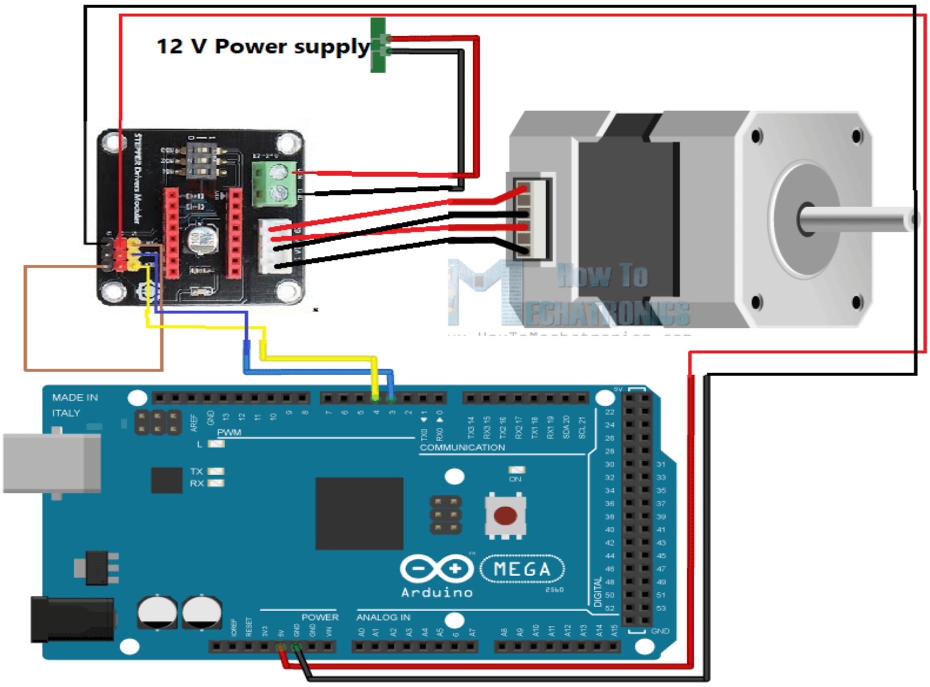


Figure 4.3: Driver Circuit

Moving Stepper motor:

For seamless integration and control of the motors, we leveraged the functionality provided by the "Stepper.h" library in our code. This library proved to be a valuable resource as it allowed us to create dedicated objects for each motor within our system. By utilizing this library, we gained access to a wide range of functions and methods specifically designed for stepper motor control.

Where this object takes the speed of the motor and keep running until the object on the production line reach the IR sensor area then the IR detect the object and then we set the speed of the motor to 0 to stop it.

When the arm takes the object from the production line we set the speed for motor to make it run and get the next object.

4.3.1.3 Controlling The Servo motor

Based on the information provided in the servo motor's datasheet, we proceeded with its connection in our project. The servo motor featured three wires, each serving a specific purpose. The red wire indicated the power supply connection, represented by (Vcc), and was connected to the power source, providing a voltage

of 5V. The brown wire denoted the ground connection, labeled as (Gnd), ensuring the completion of the circuit and enabling proper functioning of the motor. Lastly, the orange wire represented the PWM (Pulse Width Modulation) signal input. This wire was connected to one of the Arduino outputs, allowing us to control the servo motor's movement by providing it with angle instructions during operation. By establishing these connections and supplying the appropriate voltage, we ensured seamless communication and precise control over the servo motor's angular positioning.
The 5v of the servo motor taken from power supply after convert it from 12 v to 5v to take enough power for servo in order to work efficiently with the arm weight.
Below is a picture of the linking process:

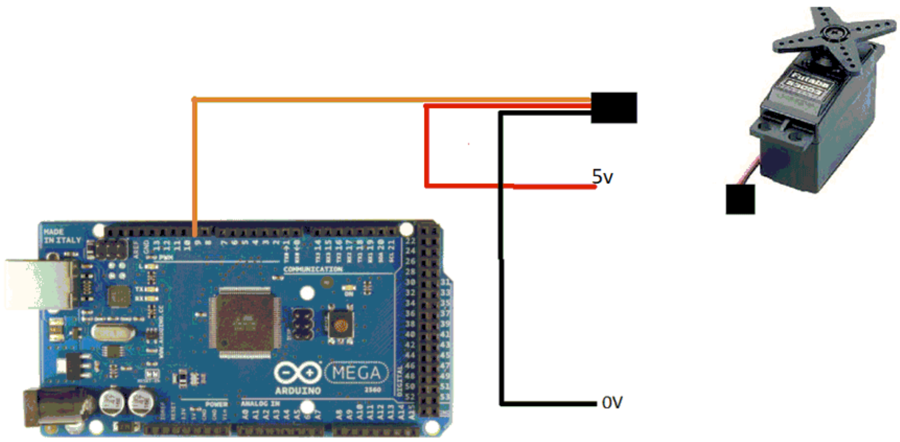


Figure 4.4: servo motor

Moving Servo motor:

We can access the Servo Motor. directly using (Servo.h) library
➔#include <Servo.h>
we used some function the help us to read and write on Servo Motor :
Servo.attach(pin#): to attach servo motor with Arduino pin.
Servo.Write(angle): to give the angle value to the Servo Motor.

4.3.1.4 Controlling The Arm

the arm consists of 6 servo motors, we connect each one of them with Arduino and power supply as mentioned above.

Moving Robotic Arm:

we defined an array of angels for each servo motor in the arm, for each move we start from the first servo which is the one in the base and then to the next one until we finish all, we give each servo an angle from its array using write function, for each servo when the angle arrive from we check if the angle greater or smaller than the current angle of the servo, if the new angle is larger then we increase the current angle by one until we reach the new angle value in order to make the move smooth, on the other hand if the new angle is smaller than the current we decrease the current angle by one until we reach the new angle value.

To make a specific move we store the angels for each motor in its array, the value in the same index for each motor represent the move for the whole arm.

4.3.1.5 Controlling IR Sensor

Based on the information provided by IR Sensor datasheet, the sensor has three pins, the first one is VCC which we connected it with 5v from power supply, the second pin is GND which we connected it with GND from the system, the third pin is the output pin which indicated that there is object arrive and return 0, we connected this pin with Arduino.

4.3.1.6 Controlling WIFI Module

In our project, we incorporated the ESP8266 module to enable wireless communication and connectivity. To establish a seamless connection between the ESP8266 and Arduino, we followed a specific process. First, we connected the ESP8266 to the Arduino using jumper wires. The ESP8266 module has several pins, including Vcc (power supply), Gnd (ground), Rx (receive), and Tx (transmit). We connected the VCC and GND pins to the corresponding power and ground pins on the Arduino, ensuring a stable power supply. Next, we connected the Rx and Tx pins of the ESP8266 to the Tx and Rx pins on the Arduino, respectively as shown in the figure below, to establish a serial communication link. By using a serial communication protocol, we enabled data transmission between the two modules. Additionally, we set the appropriate baud rate to ensure proper communication synchronization. This connection between the ESP8266 and Arduino allowed us to leverage the wireless capabilities of the ESP8266 module, enabling remote control, data transfer, and interaction with other devices or networks.

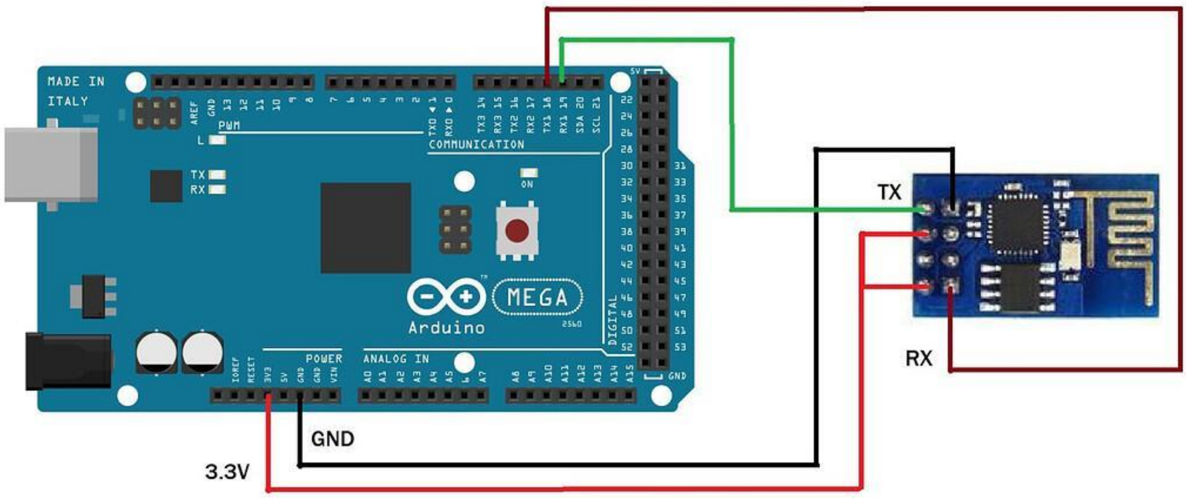


Figure 4.5: WIFI Module

So we use this module to connect our project system with mobile application.

4.3.1.7 Mobile Application control

We used RemoteXY website to design our mobile application, and we used RemoteXY library in our Arduino project to transfer data between mobile application and our Arduino system, we used WIFI Module to enable wireless connection.

In our mobile application we have two pages, the first page for the whole system which shown in the figure below, it enable us to start and stop the system, controlling Arm speed through a slider which change the delay value between each steps in servo motors, controlling production lines speed through two sliders for each one, display how many final product we generates, display the status of the production lines through a LED for each line, if the LED green that’s mean the line is running, if the LED yellow that’s mean there is object received at IR, finally is LED red that’s mean the line is OFF and finally display any errors occurs in the system.

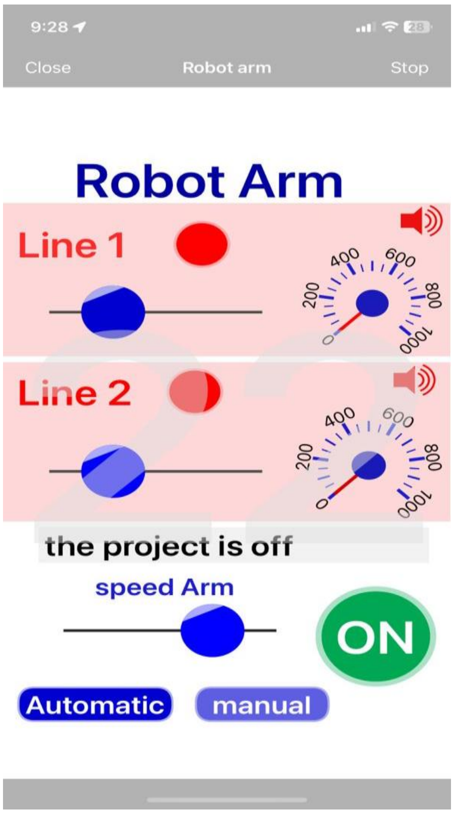


Figure 4.6: Mobile App: First page

The second page of the mobile application as shown in the figure below, in contains 6 sliders for controlling each servo angels manually from 1 to 180, and it contains two buttons to choose from automatic arm and manual arm control, finally it contains a Reset button to move the arm to initial position.

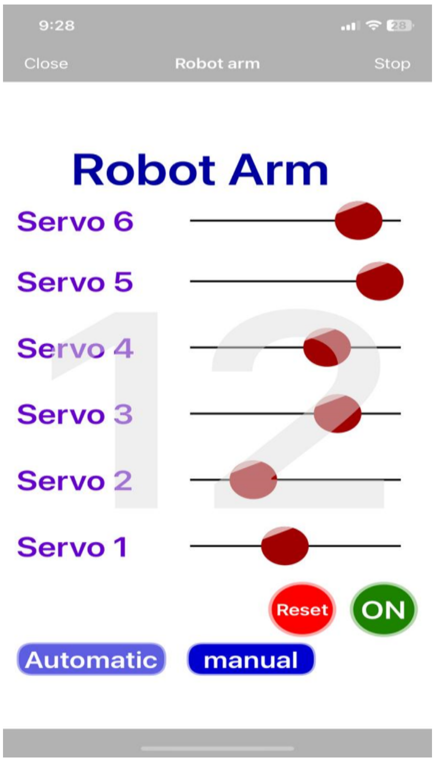


Figure 4.7: Mobile App: Second page

4.3.1.8 Raspberry pi and image processing

For image processing we used Raspberry pi 4 model b with Raspberry camera, we want to check the object in the first line, we check two things the color of the object and the shape, for the color we want the object to be red and the shape to be cylinder, any other colors and shapes the system consider it as defect and the arm throw it out.

We used machine learning model and trained it with images, and we wrote a python script to capture frames from camera and send it to the model, and send the output of the model to Arduino to take the corresponding action.

This is an examples of the output shown in the two figures below:

Figure 4.8: Class0 redCylinder

Figure 4.9: Class1 defect

5. Results And Problems Discussion

5.1 Drivers

Throughout the project development, we encountered various challenges, one of which revolved around the drivers. A significant issue we faced was the sensitivity of the drivers to static electricity. If the drivers came into contact with even the slightest touch while connected to a power source, they would immediately burn out. This problem persisted during the initial stages and consumed a considerable amount of time before we identified its root cause. We had to exercise caution and implement strict anti-static measures to mitigate the risk of damaging the drivers. This experience highlighted the importance of handling sensitive electronic components with care and reinforced the significance of incorporating proper grounding and static discharge precautions in our project workflow.

5.2 Servo Motor Malfunction

The servo motors used in your automated assembly line experience issues such as erratic movements, motor jitter, or complete failure. These problems could be caused by power supply issues, or incompatible control signals, so we use a power supply to provide motors with enough power.

5.3 Mechanical Alignment

Achieving precise mechanical alignment in your assembly line can be challenging. Misaligned parts or components can lead to inaccuracies during the assembly process, resulting in faulty or incomplete final products, so we test the system many times and store the most accurate positions for each servo motor to achieve the best results.

5.4 Communication Interference

One of the significant challenges we encountered in our project was related to wireless communication using Wi-Fi. We relied on this technology for data transmission and control between our system and mobile application. However, we experienced interference issues that disrupted the smooth operation of our system and caused intermittent connection problems. This interference posed a significant hurdle in maintaining consistent and reliable wireless communication. We had to invest additional time and effort in identifying and mitigating the sources of interference to ensure uninterrupted communication between the system components. Overcoming this problem required careful optimization of signal strength, channel selection, and implementation of error handling mechanisms to address intermittent connection issues effectively.

5.5 Image Processing Accuracy

During the implementation of our image processing system using machine learning algorithms, we encountered a significant challenge related to achieving accurate and reliable image recognition or object detection. Several factors, including varying lighting conditions, occlusions, and object appearance variations, directly impacted the accuracy of our image processing algorithms. These factors introduced uncertainty and inaccuracies in the recognition and detection process, leading to potential misclassifications or missed detections. Overcoming this challenge required extensive experimentation, fine-tuning of the algorithms, and implementing robust techniques to handle various environmental conditions. We invested significant time and effort in collecting diverse training datasets and augmenting them to cover a wide range of scenarios to improve the system's accuracy and robustness. Additionally, we explored different pre-processing techniques and algorithm adjustments to mitigate the impact of lighting variations and occlusions. Despite these challenges, we persevered in enhancing the image processing accuracy by continuously refining our algorithms and addressing the limitations posed by real-world imaging conditions.

5.6 Final results

After extensive development and testing, we are proud to present our final result: a remarkable project that performs exceptionally well across the majority of the scenarios we evaluated, effectively meeting all our predefined objectives. Our automated assembly line demonstrates remarkable efficiency, accuracy, and productivity, showcasing its ability to assemble two parts into a final object seamlessly. Throughout the development process, we overcame numerous challenges, including hardware limitations, software complexities, and unforeseen obstacles. However, our dedication and perseverance ultimately yielded a remarkable solution that far exceeded our initial expectations. We are confident that our project represents a significant advancement in the field of automation and serves as a testament to the capabilities of computer engineering. With this final result, we have achieved our goal of creating an innovative and impactful system that revolutionizes the manufacturing process and paves the way for future advancements in the industry.

6. Conclusion

6.1 Summery

Through our dedicated efforts, we successfully built a highly capable mechanical device that has transformed complex tasks into effortless ones. While there remains scope for further enhancements, certain factors such as time constraints, limited resources, and knowledge limitations prevented us from implementing them at this stage. Nonetheless, the most significant achievement is the completion of a functional project that showcases tremendous potential for improvement. This marks a significant milestone and serves as the foundation for future advancements. Looking ahead, our vision is to build upon this project, continually refining and expanding its capabilities. Our long-term goal is to establish a series of projects that build upon and enhance the existing system. This project represents a crucial step in the right direction, setting the stage for future innovation and development in the field.

6.2 Improvements

In terms of improvements, there are several areas where our project could benefit from further enhancements. Firstly, we could focus on optimizing the speed and efficiency of the automated assembly line by fine-tuning the movement algorithms and exploring advanced control techniques. Additionally, incorporating more advanced image processing algorithms could enhance the accuracy of object recognition and detection, particularly in challenging lighting conditions or when dealing with occlusions. Furthermore, integrating real-time monitoring and feedback mechanisms would allow for proactive identification and resolution of any issues or errors during the assembly process. Finally, investing in additional research and development could lead to the incorporation of advanced machine learning techniques, enabling the system to adapt and learn from new manufacturing scenarios. By pursuing these improvements, we aim to continually enhance the performance, flexibility, and productivity of our automated assembly line.

6.3 Future works

Looking ahead, there is a multitude of potential avenues for future work in our project. One exciting direction involves exploring the integration of artificial intelligence and machine learning algorithms to enable the automated assembly line to adapt and optimize its operations based on real-time data and feedback. This could involve developing predictive maintenance algorithms to identify and address potential issues before they impact production. Additionally, incorporating advanced robotic manipulators and grippers could expand the range of objects that can be handled and assembled by the system. Moreover, exploring the integration of IoT (Internet of Things) technologies could enable seamless communication and coordination between multiple assembly line modules. Lastly, there is immense potential in scaling up the system for industrial applications by developing modular and customizable designs that can be easily integrated into existing manufacturing environments. By focusing on these future endeavours, we aim to continuously push the boundaries of automation, efficiency, and productivity in the manufacturing industry.

6.4 Outcome

The outcome of our project is highly promising and impactful. We have successfully developed an automated assembly line that demonstrates remarkable capabilities in terms of efficiency, accuracy, and productivity. The system's ability to seamlessly assemble two parts into a final object has the potential to revolutionize manufacturing processes. Through our diligent efforts, we have achieved a functional and working prototype that serves as a stepping stone for further improvements and future advancements. Our project showcases the power of computer engineering in creating innovative solutions that address real-world challenges. With this outcome, we have set the stage for continued progress and have laid the foundation for future breakthroughs in automation and manufacturing technology.

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