An-Najah National University

Faculty Of Engineering And Information Technology

Computer Engineering Department

ShopAssistant Robot

PREPARED BY:

Ahmad Ashayer

Mahmoud Arafat

SUPERVISED BY:

Dr. Luai Malhis

❖Acknowledgement

We would like to thank Dr. Luai Malhis, our supervisor, for all the time and assistant he spent with us and his amazing support during our project journey and always showed his trust in us along the way. We are also thankful to all the members of the Department of Computer Engineering for their assistance.

Also, we want to thank our friends and family who have been with us from the beginning to the end of our project, giving us all the support we needed for this stage Whether it is financial support or psychological support.

❖Disclaimer

This report was written by Ahmad Ashayer and Mahmoud Arafat 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 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 authors. An-Najah National University accepts no responsibility or liability for the consequences of this report being used for a purpose other than the purpose for which it was commissioned.

❖Contents

❖List of Figures

❖Abstract

This project aims to build a full automated system that helps the store or warehouse owner to prepare and search for the target packages shelves and store it as orders.

The goal of this is to make the time of preparing orders as slow as we can and to make the operation of preparing it faster and better, the owner can choose the components which are the packages on the shelves through a simple application and the robot car goes linearly and takes the needed component and store it inside a production line.
The processing of this operation depends on a special camera that help the robot to reach each location for each package and also a crane (Y and Z Axes) that helps it to carry them, the movement of this process depends of many types of motors like stepper motors and also DC motors.

Also though this operation the packages will pass through the production line and the owner has the ability to cancel any package that added to this production line and also he has the ability to pass whatever he want.

This fully automated system enhances the ability and increasing the speed of processing orders.

❖Introduction

- ## General background

With the development of technology, it has become necessary to introduce and develop it even in the field of trade. Therefore, we need to speed up the processes of processing orders, whether in large or small stores or warehouses.

Therefore, we need a complete automatic system that handles the speed of performing these orders and reduces the human effort and time required for the process of preparing these orders. This system is capable of performing all these functions at a satisfactory speed from the beginning of the order's exit until its packaging.

- ## Objectives

The main goal of the ShopAssistant Robot is to speed up the process of processing orders from warehouses with a complete smart system based on several things, the most prominent of these functions are:

1- Go to the location of the requested order: - This process is done intelligently by distributing a code tag that distinguishes each shelf.

2- Bringing the required package via crane: - One of the foundations of this system is a crane that moves in two directions and is responsible for carrying and bringing each package.

3- Passing and canceling packages on the production line: - This is one of the features in the project that gives the owner the ability to cancel and pass packages however he wants.

4- Packaging the final order: - This is one of the final features in this system to prepare the order for transportation.

• Significance

The importance of this work stems from facilitating and accelerating the process of preparing orders and submitting them to customers.
These benefits and features benefit both the owner and the customer in terms of accelerating the order and its packaging, and in terms of reducing human effort in terms of the number of workers in the warehouse and their effort in packaging and searching for packages and orders.

• Organization of the report

This report is organized showing a global overview of our project. It is divided into several chapters, each focusing on different subjects of the project:

 Chapter One provides an in-depth background on the research topic, laying the foundation for the study.

 Chapter Two reviews previous studies and challenges encountered, offering solutions based on insights gained from earlier research.

 Chapter Three examines project reviews, current trends, and past projects to identify problems and explore potential improvements.

 Chapter Four details the action plan, including the process for building the project, and the tools and programs used.

 Chapter Five presents and analyzes the results, providing a summary and comparison to deepen understanding.

 Chapter Six concludes with final thoughts, recommendations, and a summary of lessons learned, including suggestions for future enhancements and new features for further development.

❖ Earlier work

❖ **Micro-controllers Course:** This course provided a comprehensive understanding of microcontroller systems, essential for controlling robotic arms and other hardware in inventory systems. We learned to apply micro-controllers for automation and precise control, enhancing our ability to implement accurate and efficient systems.

❖ **Micro-processor Course**: This course equipped us with the skills to handle integrated circuits (ICs) and modules, focusing on their behavior with current and voltage. Understanding these components was crucial for designing reliable electronic circuits to control robotic arm movements and other system functions.

❖ **CPU Lab:** The hands-on experience gained from this lab was invaluable for developing practical skills such as wiring, soldering, and hardware debugging. This experience was particularly useful for troubleshooting issues in the inventory system and ensuring effective adjustments and finalizations.

❖Literature review

This project is considered a solution to problems faced by both the store owner and the warehouse owners, which are the time and costs during the process of preparing the goods, especially with the difference in the capabilities of the labor force in this matter.

Therefore, our project solves this problem because it contains an automated crane, and the system as a whole also contains a complete production line supported by all the features, and also a system for packaging orders. Thus, we have shortened the labor effort on this basis and gained a faster time for this process.

❖Gaps and Contributions

There are many challenges, such as the lack of all the components that the project needs to be more advanced and smoother.

- There is a gap, which is the admin's inability to know the robot's location. To do this, you will need an imu (Inertial measurement unit). This sensor is not available in the country and it isn't easy to provide it. It makes it easy to know the location of the robot and draw it on the web page in three dimensions.

- Improving the packaging line to include the components in the box and packaging from all directions, not just one direction.

One Shop Assistant Robot contains all the features that any store owner needs, and the order is prepared from scratch until it is delivered to the user without human intervention. The Shop Assistant Robot contains all the modern features that are applied on the ground.

❖Methodology

- ## Overview

The project will begin with the design and construction of the mechanical components, focusing particularly on the crane mechanism. This crane will operate along the Y and Z axes, relying on robust hardware elements such as stainless-steel structures and precise stepper motors to facilitate its movement. The integration of these mechanical parts with the hardware components is crucial for the crane's functionality. The specific details of the crane's design, the selection of materials, and the choice of motors will be discussed in detail later. Following the construction and assembly of these mechanical parts, we will proceed with the installation and testing of the complete system to ensure optimal performance and reliability.

- ## Hardware Components

  - **Raspberry Pi 4 Model B**

The Raspberry is the main controller in the entire project (the brain of the project) and works as a central hub through which all other components are connected and coordinated. It controls the process of capturing the Aruco code through the Raspberry Camera Model 2, which controls the car's movement through the two steppers. When the item is finished being taken from the shelves, an HTTP request is sent to the esp. 7 commands are sent (1, 2, 3, cancel 1, cancel 2. cancel 3, finish). The reason to chose the Raspberry is that it makes it easier for us to control all the components and to make the image processing process aruco code easier for us. In short, the Raspberry is an example of a maestro, which makes it an ideal choice for the control unit in our project.

Figure 1:Raspberry Pi Model B

- **ESP8266EX**

The ESP is responsible for the production and packaging line. It receives a command from Raspberry and according to the command it receives, it translates it and sends it to the Arduino via the serial to operate the parts in the production line and the packaging line. The main reason for choosing the ESP is because it includes fast wireless communication, wide-coverage, ease of use, and compatibility with many devices and systems, in addition to saving energy in some versions such as Wi-Fi 6 and Wi-Fi HaLow.

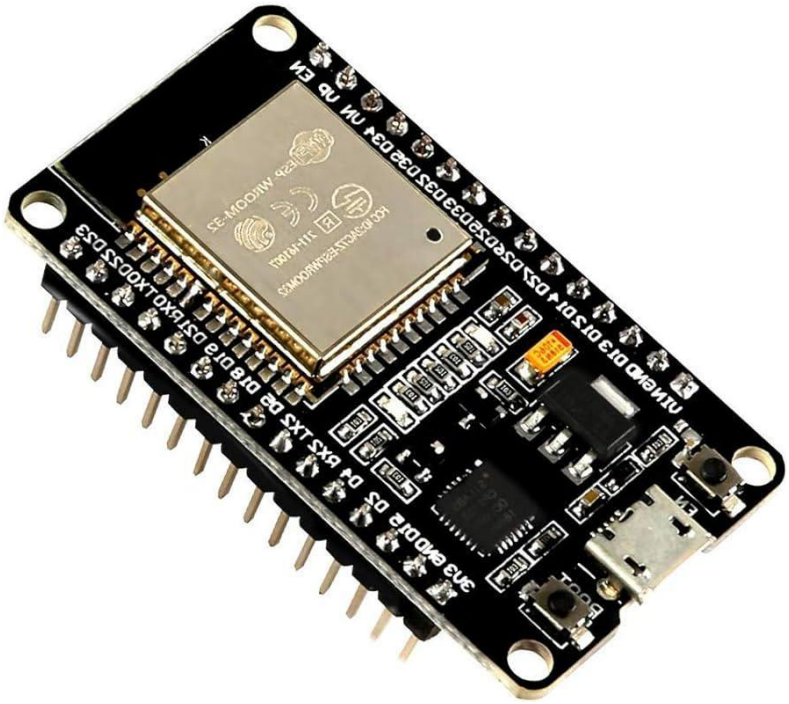

Figure 2:ESP8266EX

- **Arduino Uno**

Arduino Uno is an open-source electronics platform. Arduino Uno is based on an ATmega328P microcontroller. Arduino Uno has 14 digital pins. Two Arduino Unos are used, one to control the crane components complex and the other to receive commands from the esp. Based on the commands it receives, it controls the production and packaging line.

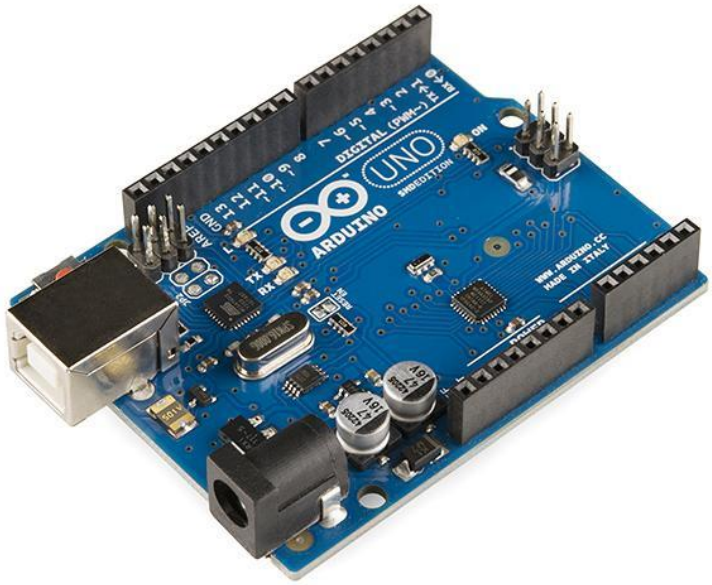

Figure 3:Arduino Uno

- **Raspberry Pi camera module v2**

Raspberry Pi camera is one of the main components of this system as it is needed for the car movement to stop in the correct target location, it is used with the Raspberry Pi and detects the Aurco code, Reliance on this is through OpenCV, which mainly helps in processing images in this process.

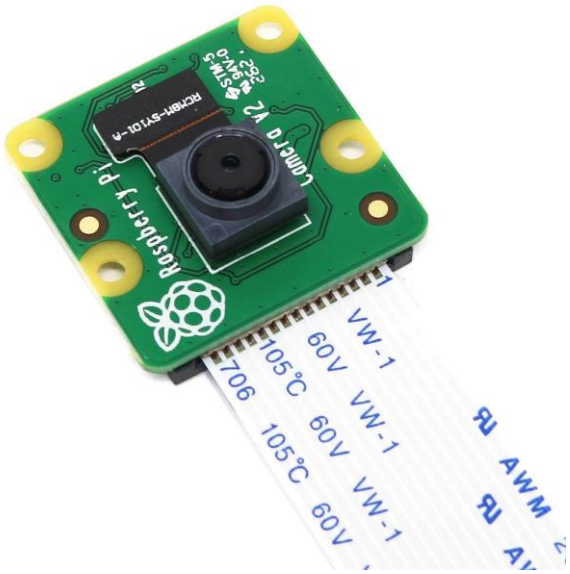

Figure 4:Raspberry Pi camera module V2

- **Stepper motor NEMA23 23HS5628**

One of the most important parts that were needed to build this system, is the one that relies on it mainly, because there are two basic purposes for it, one of which is to move the wheels of the robot car in a linear manner along the rail, and the other purpose is to move the crane, one on the z and one on the y, and so on in all, there are 4 stepper motors for this project.

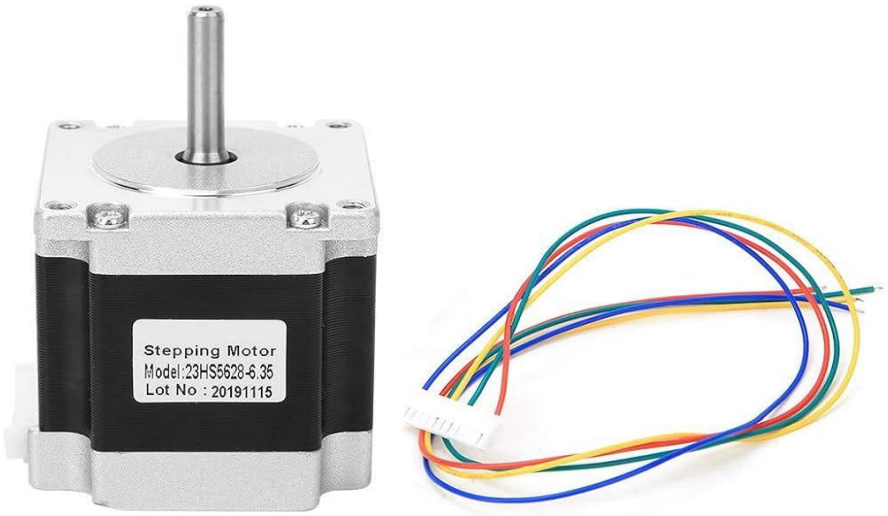

Figure 5:Stepper Motor Nema23 23HS5628

- **Stepper Motor J-5718hb3401**

This stepper was used for the Y-axis of the crane, the reason that this stepper is different from the others and the reason of choosing it is that this part of crane will carry all its weight of it and one of the good features of this stepper is the high torque of it.

Figure 6:Stepper Motor J-5718hp3401

- **Limit Switch**

It is used as a part of the process of moving the crane, it helps the crane to stop in several locations towards the shelves, and it's the best way to get high efficiency of stopping the crane axes.

Figure 7:Limit Switch

- **Power Adapter 12V**

It is used as the main power for feeding the motors like the stepper motors and also DC motors, the feeding of the motors via drivers so the power will pass through it.

Figure 8:Power Adapter 12V

- **Power bank 20000mah**

The use of this power bank is to feed the Raspberry Pi microcontroller, that's because the car is a closed box so the need of this type of power is to make it that easiest way to feed the raspberry of power.

Figure 9: Power bank 20000mah

- **Stepper Driver TB6600**

The use of this driver is feeding the steppers with power and control the steppers with its speed.

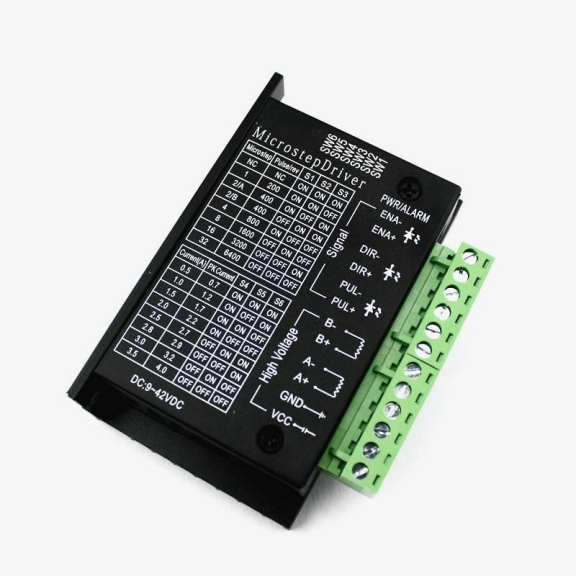

Figure 10:TB6600

- **DC motor**

This motor with its high torque has many uses in this system, there are two of them, one is for moving the production line and the reason for selecting this motor is the high torque because the production line carries all the items, the other motor is used for wrapping the orders.

Figure 11:DC motor

- **H-Bridge**

The use of this driver is to drive the DC motor that is on the production line, it takes the power from the power supply and drives and controls the direction of the DC motor on the production line.

Figure 12:H-Bridge

- **IR Sensor**

This is the main part of the production line, it used to stop the items on this line in locations that allow the crane to put the next items on this line, so it keeps a linear ordering for all the items on the line and makes it easy to control the state of all of them.

Figure 13:IR Sensor

- **MG996R Degree Servo**

The use of this motor is an important feature of this system, that is if the owner needs to cancel some of the items from this production line the servo motor is the best component for this feature, it pushes the item outside the production line in some place to keep it outside the order.

Figure 14:MG996R Degree Servo

- **Relay Two Chanel**

This is a subpart of passing the power through some components, the main use of it is to control some components and use it for some part of the time, like the DC motor for wrapping the items and also controlling RGB lights that are around the part of the wrapping order.

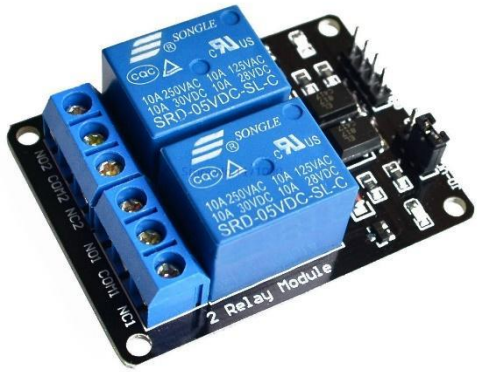

Figure 15:Relay Two Chanel

- **Jumper Wires**

This is the wires that used for all of the parts for this project for make a fully connected circuits and connect the components to each other.

Figure 16:Jumper Wires

- **RGB Wire**

The use of RGB is for making signal that the order is ready or not.

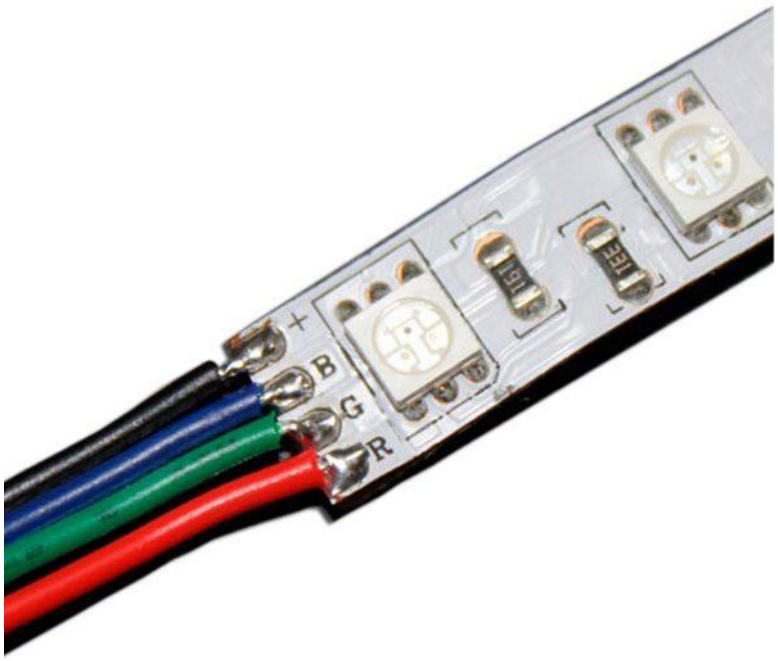

Figure 17:RGB Wire

- **Mechanical Components**

  - **Stainless steel shaft rods**

The use of the stainless shaft rods is to create a flexible and easy movement of the crane from a kinetic and mechanical standpoint, it helped a lot in reducing friction during the rise and fall of the crane's beam and played an important role in its passage at a constant speed.

Figure 18:Stainless steel shaft rods

- **Coupler 8mm**

In this project it is considered as an important part especially for the wheels of the car, it is used as a connector between the wheels and the motors, also it used for the stepper motor as a connector between the motor and the screw that moves the crane.

Figure 19:Coupler 8mm

- **Stainless lead screw with nut**

It is used as a main part of the crane for making a mechanical moving depending on the movement of the stepper motor inside the crane, it is the best way to make a full mechanical crane using simple components like this.

Figure 20:Stainless lead screw with nut

- **3D printed gears**

It used in a special way in the part of wrapping the order, it connected to the dc motor and when move it moves the other one like it that carries the box of order, so it make an innovative way to move.

Figure 21:3D printed gears

- **Car Wheels**

The selection of these wheels to make a flexible move of the car along the railway.

Figure 22:Car Wheels

- **Wood stand**

This stand is used for the wrapping part to make the roller of wrapping move without any friction so it makes the movement of the roll very flexible.

Figure 23:Wood Stand

- **Flange Bearing**

This part is used as a component to make the easiest way to move the production line with the DC motor and make this move a flexible movement.

Figure 24:Flange Bearing

● Working Procedure

▪ Process of Work

The raspberry pi waits until receiving the requests from the application so that the raspberry pi start operating, the request from the application will be a command which means where the robot car should move and stop, the camera on the raspberry pi will help it do detect the required aurco code.

After that when reaching the required location, the raspberry pi will send commands to the connected Arduino uno and the Arduino will operate the crane to reach the item and get it, the connection between them is via serial communication.

The stepper motors will raise the crane until it reaches the required high and so then the wood on the crane will press on limit switch that is inside the stainless steel to make the crane stop on the required location.

After that the car will reverse until it reaches the aurco code with id zero that means this is the id of the production line, after that the raspberry sends the required commands for the Arduino to put the item inside the production line and that's the full description of the robot work.

After making the item inside the production line, the raspberry pi sends http request to the ESP inside the production line to tell it that there is a new item inside the production line, from now on the ESP sends serial command to another Arduino uno inside the production line, this command is likely a number that tells the Arduino what is the number of items that reached the production line.

The Arduino start operating, it moves the DC motor that moves the item inside the production line until it reaches or pass an IR sensors inside the production line, that's because the item can't be in the same location that the car put it because there will be more items will come inside the production line, also the user can cancel any item that he doesn't want by sending a command from the Application to the ESP and then to the Arduino.

After finishing the order, the application will send command for finish to the ESP and then the ESP will pass it to the Arduino, the Arduino start moving the DC, and there is a servo motor inside the production line with IR that waits for the canceled items, when the canceled items pass this IR, it stops the DC and then the servo motor will push it outside the production line, the IR sensor here works inside a loop and dealing with counter, every item passes this IR will increment the counter by 1 and so on.

Finally, the ordered items will be inside a box in the end of the production line, this box is connected with DC motor and also connected with Wrapping paper, and while the order will be ready to send there will be RGB light that indicates the order situation, when its ready it shows green light, when it's not it shows red light.

- **Circuit Desings**

There are two circuits, one is inside the car and between the Arduino uno and the raspberry pi, this is the full connection for them and with the other components as the figure below:

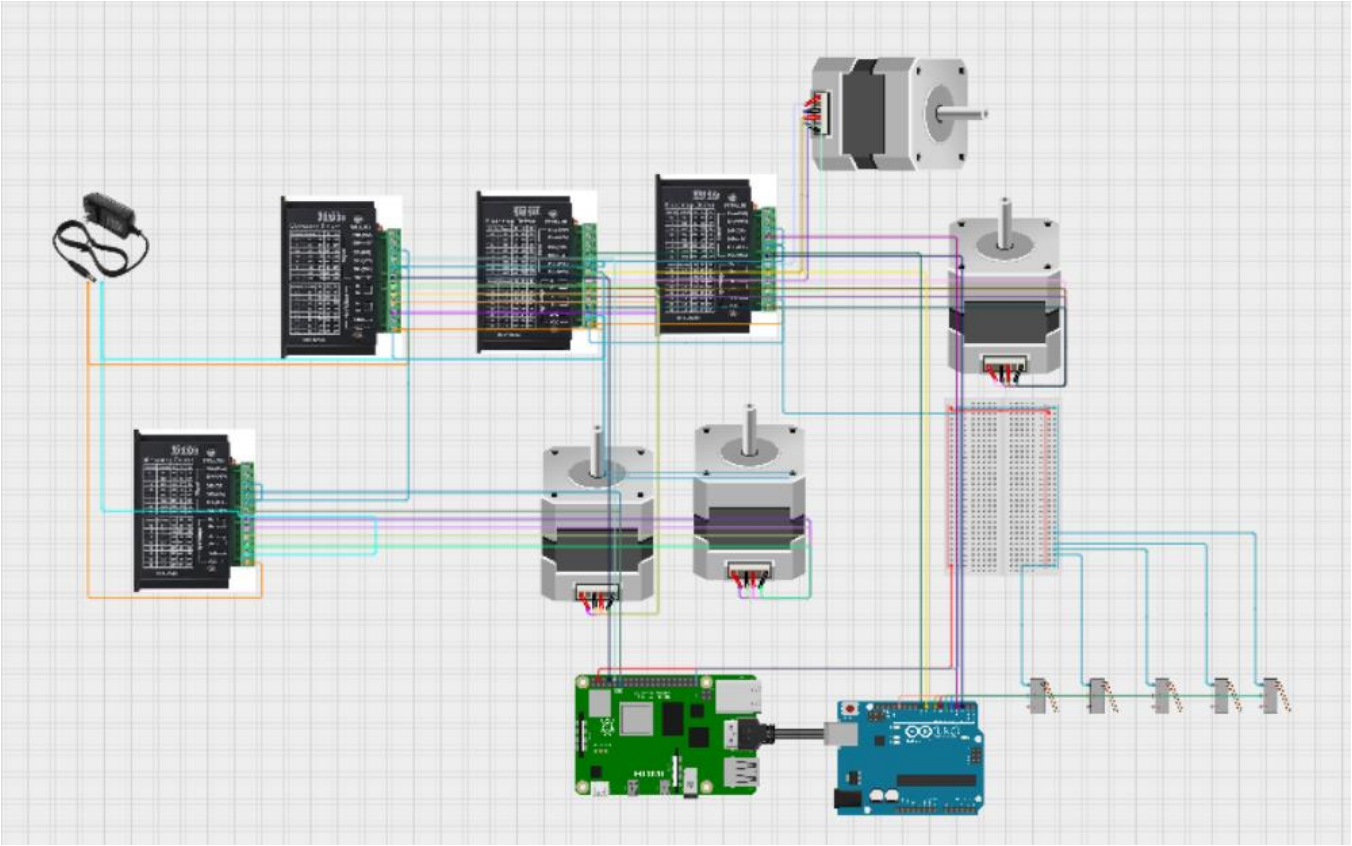

Figure 25:Raspberry Pi &Arduino Connection

Also, this is the connection between the production line circuit that is between Arduino, ESP, and the other components as the figure below:

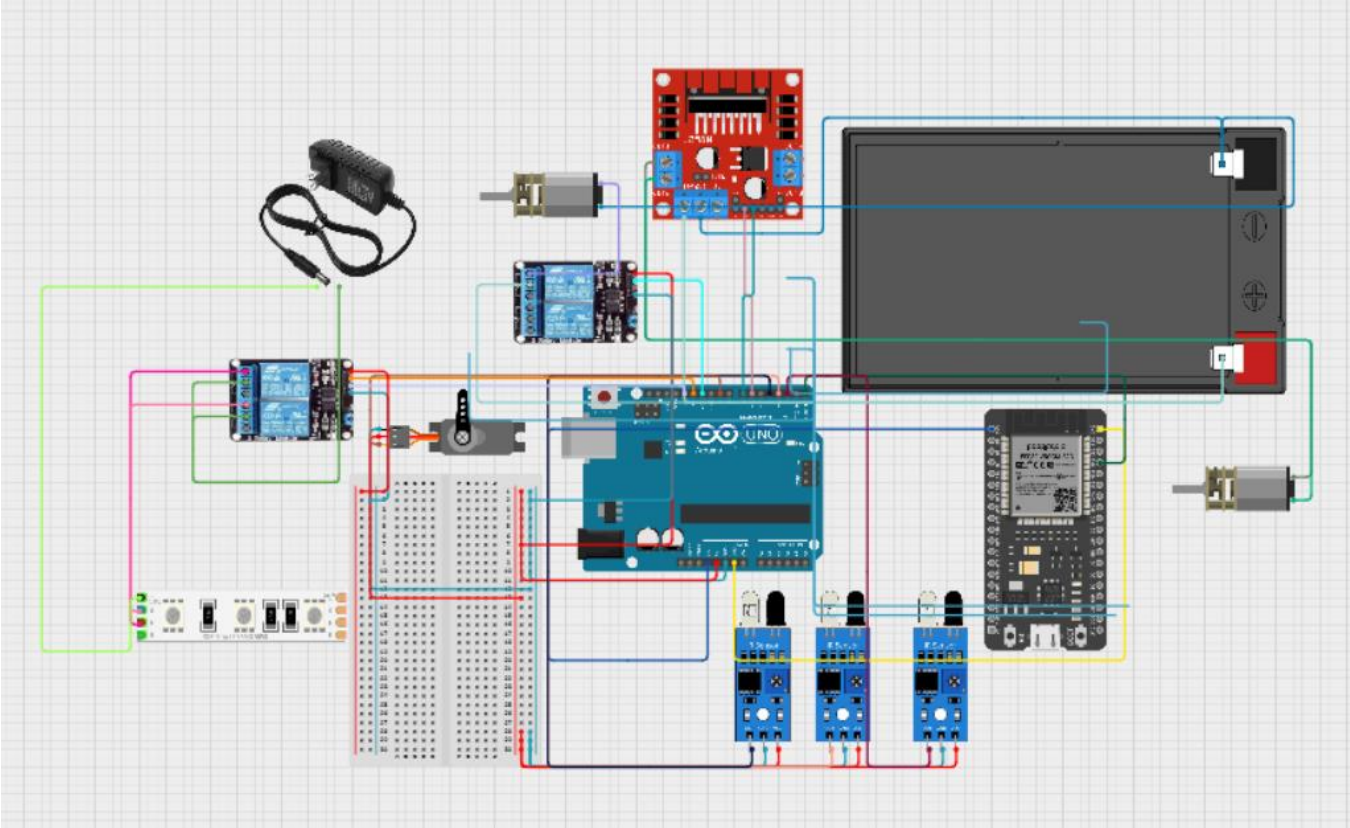

Figure 26:ESP & Arduino Connections

- **Project's Application**

It's a simple project application with each item button and multiple pages, one page is for getting the items from the Shelves and the other page for filling them, the ability of getting of filling the items depends on simple database that stored each item with its quantity.

Here are the two pages for the application as shown below:

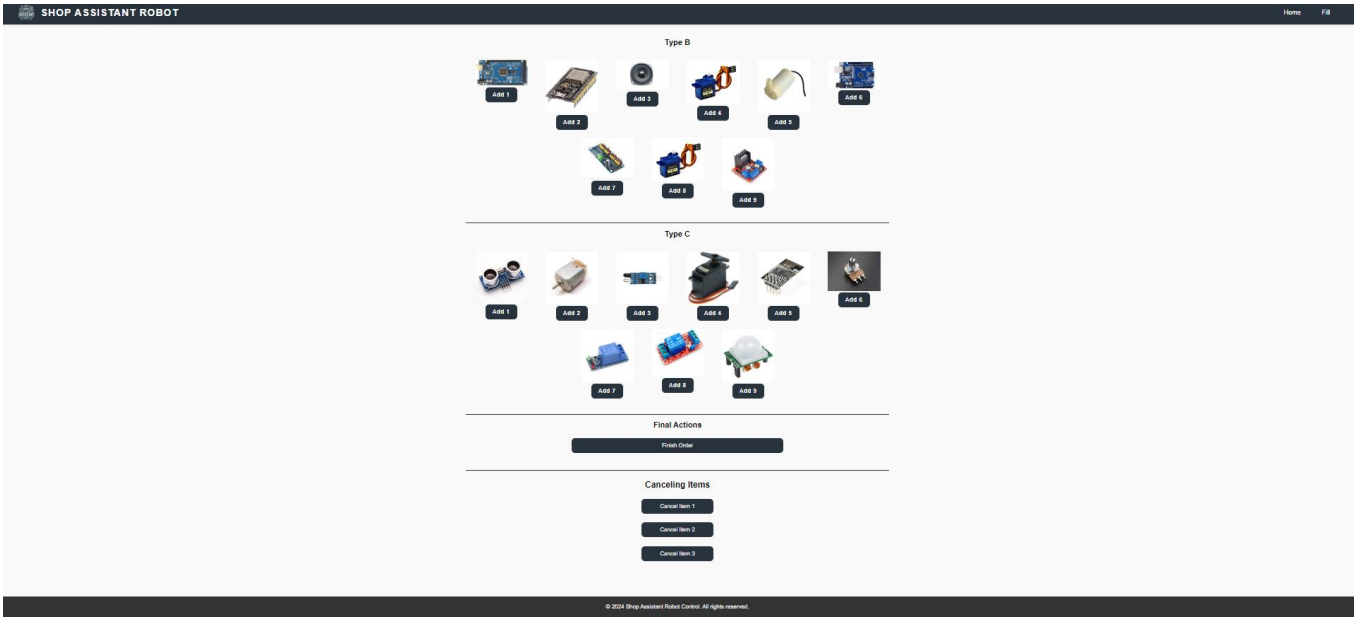

Figure 27:Getting Items Page

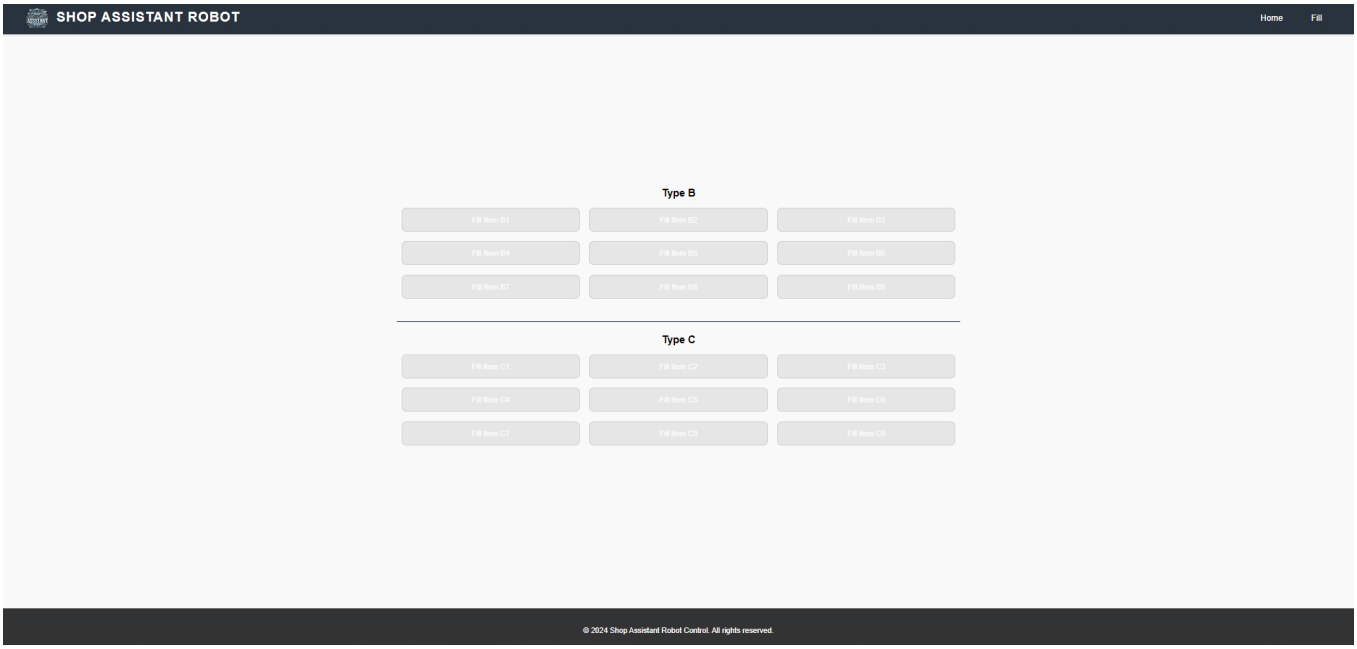

Figure 28:Filling Items Page

- **Project images**

Here are some of project images like the robot car, shelves, and also the production line:

Figure 29: Shelves

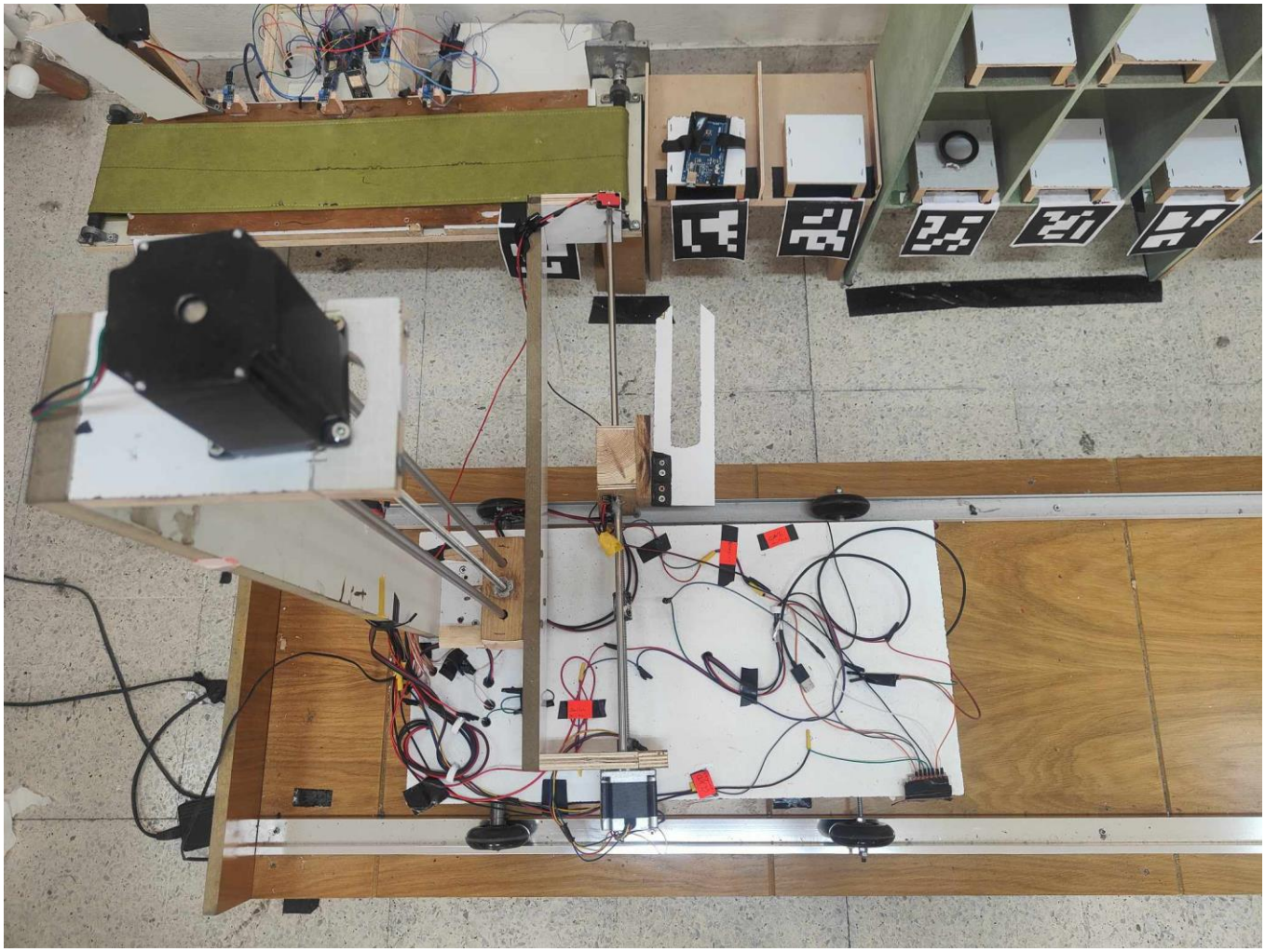

Figure 30: Robot Car

Figure 31: Production Line

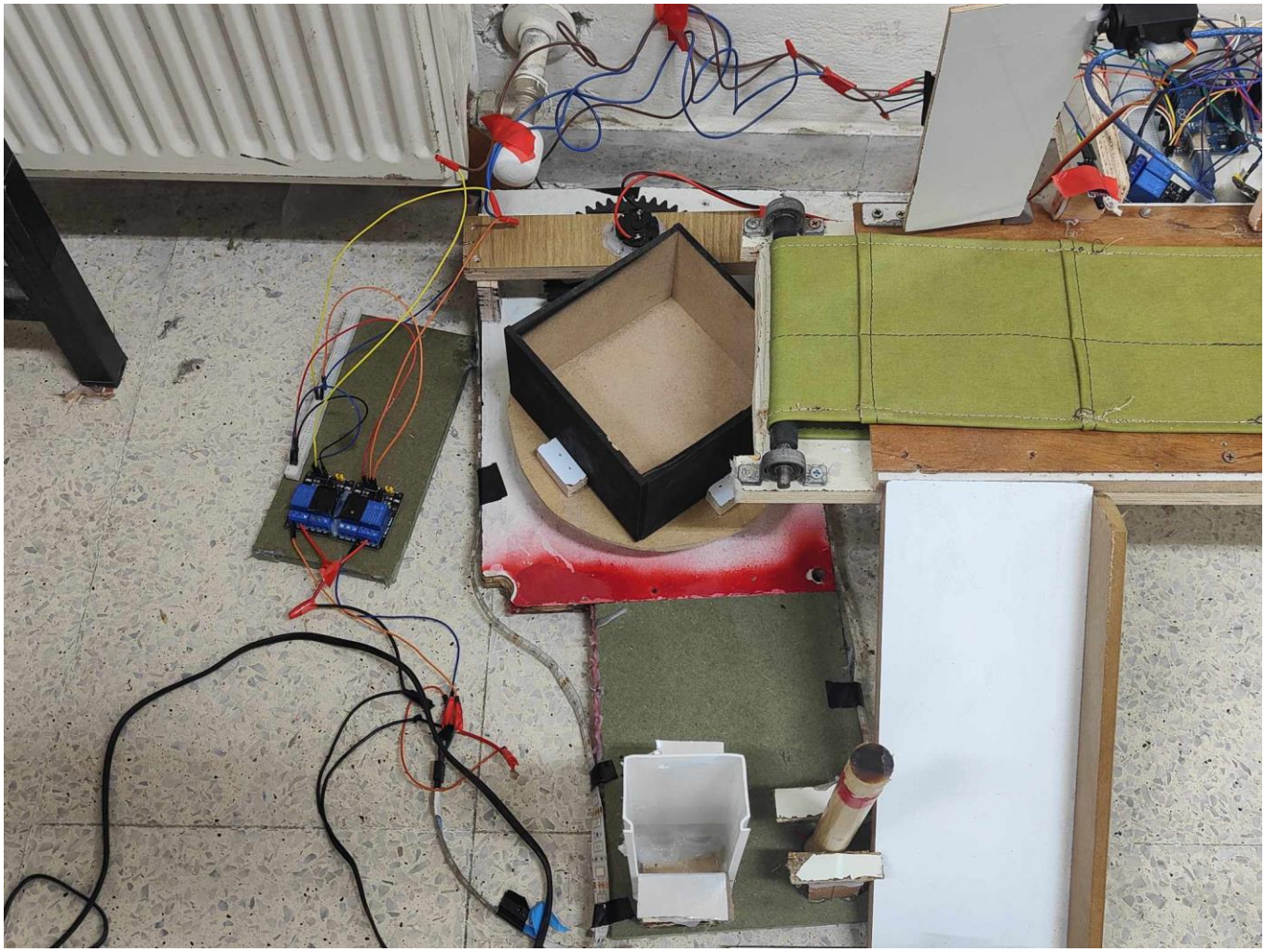

Figure 32: Box of items

❖Results & Discussion

The main goal of the project is to help stores improve production quality and reduce labor. By integrating different technology components and mobile application interfaces, we aimed to provide effective and convenient solutions for store owners. Our contribution lies in developing an advanced system that can execute orders through the web interface and allow them from the beginning of taking the trays from the shelves to reach the packaging point and presenting them to the customer as quickly as possible without human intervention. We used different technologies from Raspberry Camera to know where the item is located on any shelf and then move the lifter to the index where the item is located and take it and put it on the production line and filter it if the admin wants to remove it or put it in the packaging line

- **Results**

Robot movement method: The movement was controlled by Raspberry, which controls the robot's movement by two NEMA23 stepper motors (23HS 5628) to ensure the ability of the two motors to bear heavy weights and the accuracy of their movement. We faced problems in terms of finding suitable wheels for the project. The wheels must bear heavy weights. Several wheels were tested and office chair wheels were chosen because they can bear weights of more than 70 kg. The stepper motor stops immediately when the camera captures the required aruco code. We noticed that the Mira captures the aruco code directly and to ensure its capture, several speeds were tested to choose the appropriate speed for the camera to accurately capture the aruco code. When experimenting on a track, it was found that if there is a strike on the track, it gives an error rate in stopping the robot, and this constitutes a major problem in the project. The track must be flat and free of any issues for the car to move smoothly.

The camera captures the aruco code: The camera was programmed via opencv for its speed in capturing the robot standing opposite the required column to avoid errors such as moving the crane to the wrong place or the conflict of the z-axis in the crane at the ends of the shelf. The aruco code must be in a suitable position to avoid collision, so using the camera to capture the aruco code is the most appropriate. The other reason for not colliding the lift with the ends of the shelf is the location of the aruco code. Three locations were tested for the aruco code (right, left, middle). All positions were tested and it was found that the best location for the aruco code is the right for the ability of the crane to take the item correctly and not collide the lift with the shelves.

Moving the crane with the y-axis and the z-axis: The crane is designed to move with two axes, the y-axis and the z-axis. The y-axis raises the z-axis to become opposite the item that the robot wants to pick up. Then the z-axis is moved to launch the element, the element is designed to be supported on wooden bases and the z-axis and a wooden base holder are fixed on it, the reason for choosing the crane is its ability to reach high places and its ability to carry heavy items to the opposite side and a limit switch was used like elevators for the crane's ability to stop in the appropriate place where the z-axis is opposite the limit switch and we conducted several tests to find out the appropriate place and the ultrasonic sensor was tried and it turned out that it is not suitable due to the difference in its readings and the environment must be suitable around it for its readings to be correct and accurate numbers and from other experiments to find out the number of steps to raise the y-axis but because of the stainless lead screw which is difficult to provide with a length of one meter it was necessary to use a similar element but the gears are close to each other and this causes the problem of calculating the steps and for this reason we stayed away from this option.

The method of sending data to the production and packaging line and controlling it: ESP was used in this part and the main reason is that the robot is moving and the production line is fixed and they need to communicate with each other and as we explained before, Raspberry was used in the robot to communicate between the robot and the production line. It needs to use a microcontroller that contains Wi-Fi and for this reason, the most suitable option is ESP to move the production line. We used a DC motor because it has high torque and endurance and we used an MG995 servo to hit the item that the supervisor will stop for those who do not want it by hitting the item and descending it to a slope and because the MG995 servo has very high power and can drop the item from the production line, and an IR sensor was used to be able to control the safety of the item and the process of canceling it and arranging its entry into the box without conflict. As for the packaging line, gears were used to move the packaging axis instead of the Belt because the Belt does not match the speed of DC after some time it starts to break and not hold together. To carry out this process, a high-torque DC motor was used to pack a box containing the items and it was a suitable choice because its cost is very simple the number of turns is not important and its rotational strength can be controlled by a relay and the last thing is RGB to know the order process whether it is finished or not, the red light means that the order is in progress while the green light means that the order is finished.

How to fill the shelves when one of the shelves runs out: When some of the shelves are empty the user notice that in the application, and sends the requests to the car to fill the missing items, the process is likely to get but here is the reversed operation, and get the reserved item and put it where the missed items are.

Full integration: All parts of the project were manufactured separately and were all integrated in the end and the process was successful and smooth which led to the integration of the entire project system and their connection successfully.

Discussion

Problem Resolution

The project succeeded in solving problems and replacing them with simpler and inexpensive solutions. One of the most common problems we faced was the inability of the step ID to lift the crane to the y-axis. It was replaced with a limit switch, similar to the way elevators work.

Contributions

Using a track: A track was used instead of letting the robot move without a fixed line because the lack of a track may cause some problems such as the robot deviating. If the robot deviates, it may lead to very big problems.

All parts of the project are in one direction: If work is done in two directions, it may cause big problems and a lot of effort because the crane needs a rotation axis. This increases the cost of the project and its inability to work. The reason is the heavy weight of the crane. Its rotation process is difficult.

Camera capture for aruco code: Providing a tutorial on how to learn OpenCV capture firmware and analyze aruco code easily and know the required robot ID

Constraints

Availability

Not all parts are available from the local market and due to the tight schedule, we are unable to obtain all the parts we want, in addition to their high cost and if you want them from abroad, they take up to a month to arrive with the difficult conditions the country is going through.

Inexperience

The challenge is connecting the system with the Raspberry Pi, Arduino, and ESP to each other, and we dealt with a complete system with more than one microcontroller.

Lake of funds

Some parts could have made a huge difference in the project in terms of

performance and speed, but one of the biggest challenges we faced was the price of these parts.

❖Future Work

- Make the robot multi-path to save a lot of space.
- Add an arm to transfer canceled orders to a place that makes it easy for the robot to take them and return them to the shelves.
- Add a tracking sensor to enable the admin to know the location of the robot in the store.
- 4-Increase the speed of the crane, but to increase the speed of the crane, the T8 Lead Screw must be changed, but it is not available in our country at the length we want.

❖ Conclusions and Recommendation

▪ Conclusions

Finally, this project is designed for stores that want to reduce labor errors and help in-store productivity. When the system finishes executing the order, the order becomes ready to be delivered to the user without the intervention of any external factor. This project can be expanded without changing the components of the project other than increasing the number of shelves. The project can increase the shelves if the admin wants to do so. This is what distinguishes the project it does not depend on one shelf and it can increase the number of shelves at any time. The distinction also came in the diversity of parts in the project, such as choosing components from the shelves and placing them on a production line if the owner wanted to cancel an item from the order. The last part is packaging the order to present it directly to the user. The project is distinguished by using most of the components of modern technology, which is the main goal of the project.

- **Recommendation**

Before starting the project, we planned and then studied how to assemble all the tools and components before the beginning of the semester because there was difficulty in providing the parts and waiting until they arrived. We studied how to use Raspberry Pi, Arduino, and ESP and how to deal with them. We always recommend planning each step before implementing it to make the project work successfully use all the time available to you and take advice from the supervisor because he has a lot of experience and guides you to the right path.

❖References

- Liang, C., Chee, K. J., Zou, Y., Zhu, H., Causo, A., Vidas, S., Teng, T., Chen, I. M., Low, K. H., & Cheah, C. C. (2015). Automated robot picking system for e-commerce fulfillment warehouse application. In *Proceedings of the 14th IFToMM World Congress*. Taipei, Taiwan. https://doi.org/10.6567/IFToMM.14TH.WC.OS13.077
- Loh, P. C., Ayob, J., Wahab, M. H. A., Md. Nor, D., Md. Taujuddin, N. S. A., & Ayob, M. E. (2007). An RFID warehouse robot. In *Proceedings of the 2007 International Conference on Intelligent and Advanced Systems*. Kuala Lumpur, Malaysia: IEEE. https://doi.org/10.1109/ICIAS.2007.4658428