
# An-Najah National University

Faculty of Engineering and Information Technology

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Claw Machine

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## ❖ Dedication

This work is devoted to our families, who provided the motivation to see our efforts through and inspired us to achieve this milestone. It is also dedicated to all those who supported us, even with a single word of encouragement. Lastly, we dedicate this work to ourselves, as a testament to our perseverance and dedication.

## ❖ Acknowledgement

We would like to thank our supervisor Dr. Luai Malhis and Dr. Samer Arandi, for their guidance that helped us accomplish this work in the best possible way. We would also like to thank Dr. Raed Al-Qadi for teaching us the basics of embedded systems and Microcontrollers, and finally we would like to thank Dr. Mahmoud Assad Dwikat who taught us critical thinking and research skills course, which provided us with the required skills for writing good reports and research papers.

We would like to thank our families who supported us with financial and moral support to reach what we have reached. Loving, motivating and patient mothers. Our fathers who suffered to see our progress and success in life, and our friends for being there for us.

# ❖ Table of Contents

# ❖ Table of Figures

## ❖ Abstract

A claw machine is an enjoyable type of vending machines, it can be found in arcade shops, malls and movie theatres, this machine could be considered as a challenge versus time, in this game a person can control how many minutes he wants to play and he wins the items he gripes in that specified time. This machine gives the player the opportunity to play in one of these options, the first one is using joystick While the second one is from mobile phone application and at last using hand gestures through camera and image processing. This machine is divided into four parts: control, logic control, mechanics and playing area. The logic control consists of Arduino mega as a main controller, five HY-DIV268N-5A motor drivers, ESP8266 for mobile control, orange pi for LTS (single board computer) for hand gestures control, Arduino Uno, SD card module for storing sounds, and power supply for the system. Control part consists of lcd for displaying game instructions and remaining play time, joystick to control the gripper position before gripping item, keypad to specify the time and choose the game control mode (1: joystick, 2: mobile application, 3: hand gestures using camera), RFID for payment and start/catch button. The mechanics part consists of gripper that carried by motor and rope which this motor can be moved through (x, y) plane and the gripper that tied with rope is the z axis, one stepper motors for x movement, two stepper motors for y movement, one stepper for z movement and the last stepper for the gripper, stainless steel rods. The playing area contains the items that the player can grip, speakers for sounds and RGB led strips.

# ❖ Introduction

## ➢ Problem

Claw machine is not new idea ,actually it's one of the most common games in arcades and shopping malls, although its popularity everyone know that its gripper is not the best or we can say that its designed to be not accurate and strong ,so we were intrigued by the challenge of designing and building a functioning arcade-style game from scratch that has a better gripper that catches every time if you aim it correctly .Also from the first time it was invented it remained in the same traditional mechanism and way of playing ,so we decided to take the game into a new modern level that satisfies nowadays technology.

## ➢ Objectives

This project aims to provide the user with a new play experience using mobile application ,or through hand gestures using camera and image processing .Also we aimed to design a new gripper that solves the problems of the traditional gripper, by making it stronger and more reliable, we also aimed to make it more interactive by providing dynamic music and lights, and we also provided the user with the opportunity to customize the game to his preferences from movement speed ,playing time and playing mode .

## ➢ Significance of The Work

The significance of this work lies in its contribution to the field of arcade-style gaming machines. By designing and building a functioning claw machine with a better gripper, this project provides a new and improved play experience for users. Additionally, by incorporating modern technology such as mobile application and hand gesture control through image processing, the project brings the traditional claw machine into the modern era. The project also showcases the application of various skills and knowledge acquired through the students' studies, such as mechanical design, electronics, and programming. Ultimately, this project demonstrates the students' creativity, innovation, and problem-solving abilities in developing a fun and interactive gaming experience.

- **Organization of The Report**

The report begins with the first chapter, Introduction, providing a comprehensive background on the research topic. Chapter 2, Constraints and Earlier Coursework, highlights the challenges faced during the project and outlines the solutions and strategies employed to overcome them. It also acknowledges the contribution of previous courses that assisted in the development of the application.

Moving on to the third chapter, Literature Review, an in-depth examination is conducted to establish a thorough understanding of the current research landscape. This section also investigates any similar projects that have been previously undertaken, shedding light on their methodologies and findings.

The fourth chapter, Methodology, presents a systematic plan devised to address the problem at hand. It encompasses the detailed process involved in constructing the robot, including the utilization of specific software tools and hardware equipment. This chapter serves as a comprehensive guide for replicating the project.

Next, in the fifth chapter, Results and Discussion, the gathered data is summarized and subjected to statistical analysis. The findings are then compared and contrasted, facilitating a deeper understanding of the project's outcomes. This section encourages meaningful discussions and interpretations of the results.

Finally, the sixth chapter, Conclusion and Recommendation, encapsulates the final project summary, incorporating all the valuable lessons learned throughout the journey. Additionally, it offers recommendations for further improvement and enrichment, suggesting potential features and subsystems that could enhance the project's capabilities.

In essence, the report structure follows a logical progression, starting with an introduction and background, addressing constraints and earlier coursework, delving into a literature review, outlining the methodology, presenting results and facilitating discussions, and culminating in a conclusive summary and recommendations for future work.

These courses and practical experiences greatly enhanced our skills and apply theory in practical applications.

## ➢ Constraints and earlier work

- Constraints

Price: due to the limited budget we had and since the project actually was a bit on the pricy side, we chose to make the machine from wood so the final machine was not an actual product like we see in real life.

Size of the machine: also, the size of the machine is not the same as in real life because this is just a representative example of the real game with more options and features.

- Earlier Work

The micro-controllers course played a vital role in enhancing our understanding of micro-controller systems and their significance in controlling hardware components. Through this course, we gained valuable insights into the principles and techniques involved in effectively utilizing micro-controllers.

Similarly, the micro-processor module provided us with valuable knowledge and skills in handling integrated circuits (ICs) and modules, specifically in terms of understanding their behavior with respect to current and voltage. This module equipped us with the necessary understanding to work with complex electronic components and their functionalities.

Another instrumental course was the CPU lab, which greatly contributed to our practical skills in wiring, soldering, and debugging hardware parts. The hands-on experience gained in this lab was invaluable in honing our abilities to effectively troubleshoot and rectify hardware-related issues.

The critical thinking and scientific research component of our curriculum significantly improved our research skills and the ability to write professional papers. This module provided us with the tools and techniques needed to conduct thorough research and present our findings in a structured and professional manner. Furthermore, the utilization of writing editors like LaTeX enhanced our ability to create high-quality technical documents.

## ❖ Literature review

The idea of having claw machines is very common, since it's an amusing game that could be found in different places as we said above. The purpose of this paper was to discuss how to make claw machine but not just in the traditional way, but also by adding two other ways of playing it.

As we said this game is very common, but what's new in our project? Our project in addition to the traditional playing mode it has two other modes, the first one is by using hand gestures, and the second by using mobile phone application. we also gave the user the opportunity to decide the speed of movement in the game and playing time.

# ❖ Methodology

## ➢ Overview

First of all, we designed the mechanism of mechanical part of the machine to move gripper along x, y and z axes, then we designed ASM for the machine and specified the required components for controlling it such as inputs, microcontrollers, motors and so on, we will explain each part later, after building the machine and assemble the mechanic parts we assemble the ASM based controlling system for this machine and finally testing it.

## ➢ Mechanical Components

- stainless steel shaft rods 60cm length 8mm diameter
  The use of 8mm stainless steel shaft rods in mechanical applications offers several advantages. Stainless steel is known for its excellent corrosion resistance, making it suitable for environments where exposure to moisture or chemicals is a concern. The 8mm diameter provides sufficient strength and stability for many applications while still being relatively lightweight.

  Stainless steel shaft rods are commonly used in various industries, including robotics, automation, manufacturing, and machinery. They are often employed as linear motion guides, axles, support shafts, or rotational components.

*Figure 1 stainless steel shaft rods*

- Linear Ball Bearing Block 8mm
  A linear ball bearing block with an 8mm inner diameter is a component used in linear motion systems. It consists of a housing or block that contains a linear ball bearing, which allows smooth and precise linear movement along a shaft or rail.

*Figure 2 Bearing Block*

- Shaft Block Type SK
  The Shaft Block Type SK refers to a specific type of shaft support block used in linear motion systems. It is commonly used in applications where smooth and precise linear motion is required, such as CNC machines, industrial automation systems, and robotics.

*Figure 3 Shaft Block*

- Bearing
  a bearing refers to a device that supports a rotating or moving part of a machine and helps reduce friction. Bearings are often used in various applications, such as in motors, wheels, and gears, to facilitate smooth movement.

*Figure 4 Bearing*

- Bore
  is a type of pulley specifically designed for use with a timing belt. It is commonly used in machinery and mechanical systems where precise power transmission and synchronization are required. The timing belt connects the pulley to another rotating component, such as a camshaft or a crankshaft, and ensures accurate timing between them.

*Figure 5 Bore*

- Timing Belt
  A timing belt, also known as a toothed belt or synchronous belt, is a flexible belt with teeth on its inner surface. It is used in machinery and engines to transmit rotational motion and ensure precise synchronization between the driving and driven components.


*Figure 6 Timing Belt*

- Custom 3D Printed Parts
  For assembling the mechanical parts

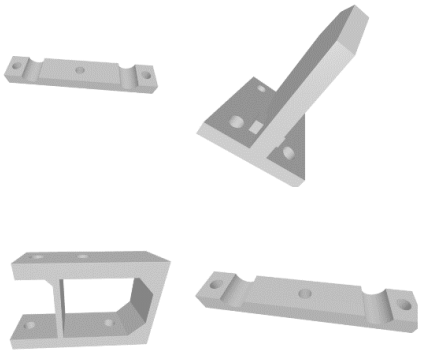

*Figure 7 Custom Shaft 3D Printed Parts*

## ➢ Gripper Components

- Custom 3D Printed Parts

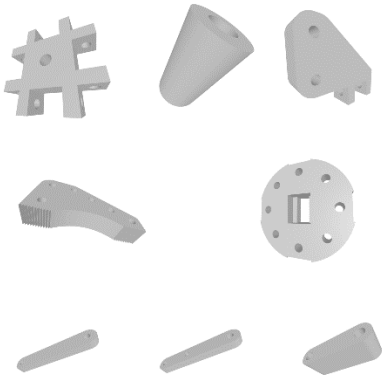

*Figure 8 Custom Gripper 3D Printed Parts*

- 10cm M4 Screw

*Figure 9 M4 Screw*

## ➢ Hardware Components

- Arduino Mega 2560
  - The Arduino Mega 2560 is a versatile microcontroller board that boasts an impressive array of input/output (I/O) capabilities. With a total of 54 digital I/O pins, including 15 that can function as PWM outputs, it offers ample options for connecting and controlling a wide range of devices and sensors. In addition, it provides 16 analog inputs for precise analog measurements. The Mega 2560 also features 4 UARTs (hardware serial ports) for seamless communication with other devices. the Mega 2560 is a reliable and feature-rich platform for exploring and developing electronics projects with extensive I/O requirements.
  - We used it as main controller.


*Figure 10 Arduino Mega*

- Arduino Uno
  - The Arduino Uno is a popular microcontroller board used for electronics projects. It features a 16 MHz ATmega328P microcontroller, 14 digital I/O pins, 6 analog input pins, and a USB interface for programming.
  - We used it to control RGB led stripe and play dynamic sounds, it receives commands from the mega.


*Figure 11 Arduino Uno*

- ESP 8266
  - The ESP8266 is a popular and affordable Wi-Fi module that can function as a standalone microcontroller. It offers built-in Wi-Fi connectivity, GPIO pins for interfacing with other components, and is programmable using the Arduino IDE.
  - We used it for connecting to WIFI and receives commands from mobile application to control machine and send them to the mega.

*Figure 12 ESP 8266*

- Orange Pi 4 LTS
  - The Orange Pi 4 LTS is a single-board computer (SBC) developed by the orange Pi community. It is designed for various applications and offers powerful performance and expandability. The Orange Pi 4 LTS features a quad-core ARM Cortex-A55 processor, Mali-G31 MP2 GPU, and up to 4GB of LPDDR4 RAM. It has built-in Ethernet, Wi-Fi, and Bluetooth connectivity, as well as USB ports and GPIO headers for peripheral connections.
  - We used it to detect hand gestures using image processing and a trained model, to control machine and send commands to the mega.

*Figure 13 Orange Pi 4 LTS*

- FTDI
  - It allows devices with a USB interface to communicate with serial devices. This chip is often used to enable USB connectivity in various electronic devices, such as microcontrollers, development boards, and other embedded systems. FTDI's USB-to-serial converters are popular due to their reliability, ease of use, and broad compatibility with different operating systems and development environments.
  - We used it for allow USB interface of the orange pi to communicate serially to the mega.

*Figure 14 FTDI*

- Stepper Nema 17
  - The NEMA 17 stepper motor is a widely used motor in robotics, 3D printers, and automation systems. With its standardized 1.7-inch frame size and 1.8-degree step angle, it provides precise positioning and control. These motors come in various configurations, including different holding torque ratings and wiring options. NEMA 17 motors are known for their compatibility, reliability, and versatility, making them a popular choice for many applications.
  - We used it for movements along x, y and z axes and for opening and closing the gripper.

*Figure 15 Nema 17*

- HY DIV268N Stepper Driver
  - The HY-DIV268N is a commonly used stepper motor driver module. It is a bipolar stepper motor driver capable of driving stepper motors with a maximum current of up to 5A. The module supports various micro stepping modes (full-step, half-step, etc.) and provides step and direction control inputs for motor control.
  - We used it to drive stepper motors.


*Figure 16 HY DIV268N Stepper Driver*

- Limiting Switch
  - Limit switches are essential components used in automation systems to detect the physical limits or positions of moving parts. They provide a signal when an object reaches a predetermined position or encounters an obstruction. Whether they are mechanical switches or proximity sensors, limit switches play a crucial role in ensuring safe and accurate operation of machinery and robotic systems. By detecting the limits of movement, these switches help prevent overtravel, protect equipment, and provide positional feedback, contributing to the overall reliability and efficiency of the system.
  - We used it to detect movement limits for x, y and z axes and for opening and closing limits of the gripper.

*Figure 17 Limiting Switch*

- Push Button
  - A push button is a commonly used switch that completes an electrical circuit when pressed and opens it when released. It is often used for momentary operations and can be found in various electronic devices and systems for functions such as powering on/off or triggering actions.
  - We used it as start button for the game and to claw item

*Figure 18 Push Button*

- LCD 20*4
  - The LCD 20x4 is a popular alphanumeric display with four lines, each capable of showing up to 20 characters. It is commonly used to display text, numbers, and symbols in electronic projects and devices.
  - We used it to display game setup instructions and time.

*Figure 19 LCD 20*4*

- Camera
  - We used it as real time video input stream in camera mood to control movement by using image processing and trained hand gestures model.

*Figure 20 Camera*

- Joystick
  - is an input device that allows users to control and interact with Arduino-based projects using manual input. It typically consists of a movable stick or lever and one or more buttons. The joystick uses potentiometers to measure the position of the stick or lever along with button switches to detect button presses.
  - We used it for joystick mood to control movement.

*Figure 21 Joystick*

- PIR
  - PIR stands for Passive Infrared Sensor. It is a type of motion detection sensor that detects changes in infrared radiation within its field of view.
  - We used it to detect if item is dropped in the prize hole to send a signal to start winning lights effect and sound.

*Figure 22 PIR*

- RFID
  - Arduino boards can be paired with RFID modules to create systems capable of reading and interacting with RFID tags. RFID tags are small electronic devices that contain unique identification information and can be attached to objects or embedded in cards. With Arduino RFID, you can build projects that involve access control systems, inventory management, attendance tracking, and more. By integrating RFID technology with Arduino, you can create interactive and automated solutions that leverage the benefits of wireless identification and data capture.
  - We used it to simulate payment using cards.

*Figure 23 RFID*

- Keypad 4*4
  - A keypad is an input device that consists of a set of buttons arranged in a grid or matrix formation. Each button typically represents a specific character, number, or command. Keypads are commonly used for entering data or making selections in various electronic devices and systems.
  - We used it as input for setting up the game (mood, time, speed).


*Figure 24 Keypad 4*4*

- SD Card Module
  - An SD card module is a device that allows an Arduino or other microcontroller to interface with an SD (Secure Digital) memory card. It provides a convenient way to store and retrieve data from an SD card using the SPI (Serial Peripheral Interface) communication protocol.
  - We used it to read sound files from SD card.


*Figure 25 SD Card Module*

- Speakers
  - We used it for streaming sound effects.

*Figure 26 Speaker*

- RGB LED Stripe
  - We used it for light effects.

*Figure 27 RGB Led Stripe*

- Resistors
  - We used resistors for voltage divider circuit in connection between orange pi and mega also for ESP and mega, to convert logic from 5V(mega) to 3.3V (Orange pi, ESP).
  - Also, we used it in led stripe current driving circuit.

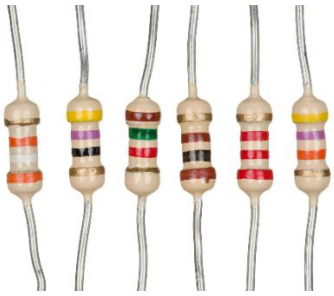

*Figure 28 Resistors*

- IRLZ44N
  - The IRLZ44N is a high-performance power MOSFET commonly used for fast switching applications. With its low on-resistance and high current handling capability, it is suitable for a range of tasks including motor control, power supplies, LED lighting, and solenoid driving.
  - We used it to drive a current for led stripe.


*Figure 29 IRLZ44N*

- PCB Screw Terminal
  - We used it to convert female pins in mega to screw pins for better wire connections.

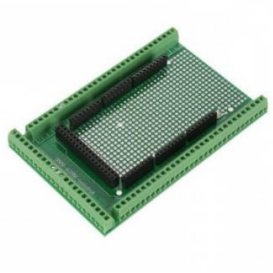

*Figure 30 PCB Screw Terminal*

- Screw Terminal
  - We used it for wire connections with soldering board.

*Figure 31 Screw Terminal*

- Soldering Board
  - We used it to make a simple board that has output voltage with different values (5v, 12v) for components, System Ground, current driving circuit for led stripe, LCD potentiometer and voltage divider circuit.

*Figure 32 Soldering Board*

- Power Supply
  - To supply enough voltage and current with different values for components.


*Figure 33 Power Supply*

## ➢ Process Of Work

- ASM Design
  - In the beginning, we determined the desired specifications and the mechanism that the machine will have, and then we determined the behavior of this machine and how to interact with it, then we obtained the ASM then based on it we conclude the required controller component.
  - When the game powered on the first thing, we make sure the gripper is in the initial position and opened.
  - There are three moods: joystick, mobile app and hand gestures.
  - You can customize your game from the wanted playing time through movement speed and the mood you can use the traditional joystick or you can use a mobile application to play or you can play by using hand gestures.
  - You can pay using card (simulation).
  - After setting up the game and start it, it behaves based on commands based on the chosen mood to control movements and claw items.
  - When you try to claw the gripper go down then close and go up then back to initial position and opens automatically.
  - Also, there are dynamic RGB lights and sound effects, based on the status of game you are in like winning item, game over and when moving and try to claw something.

- ASM Design Cont.

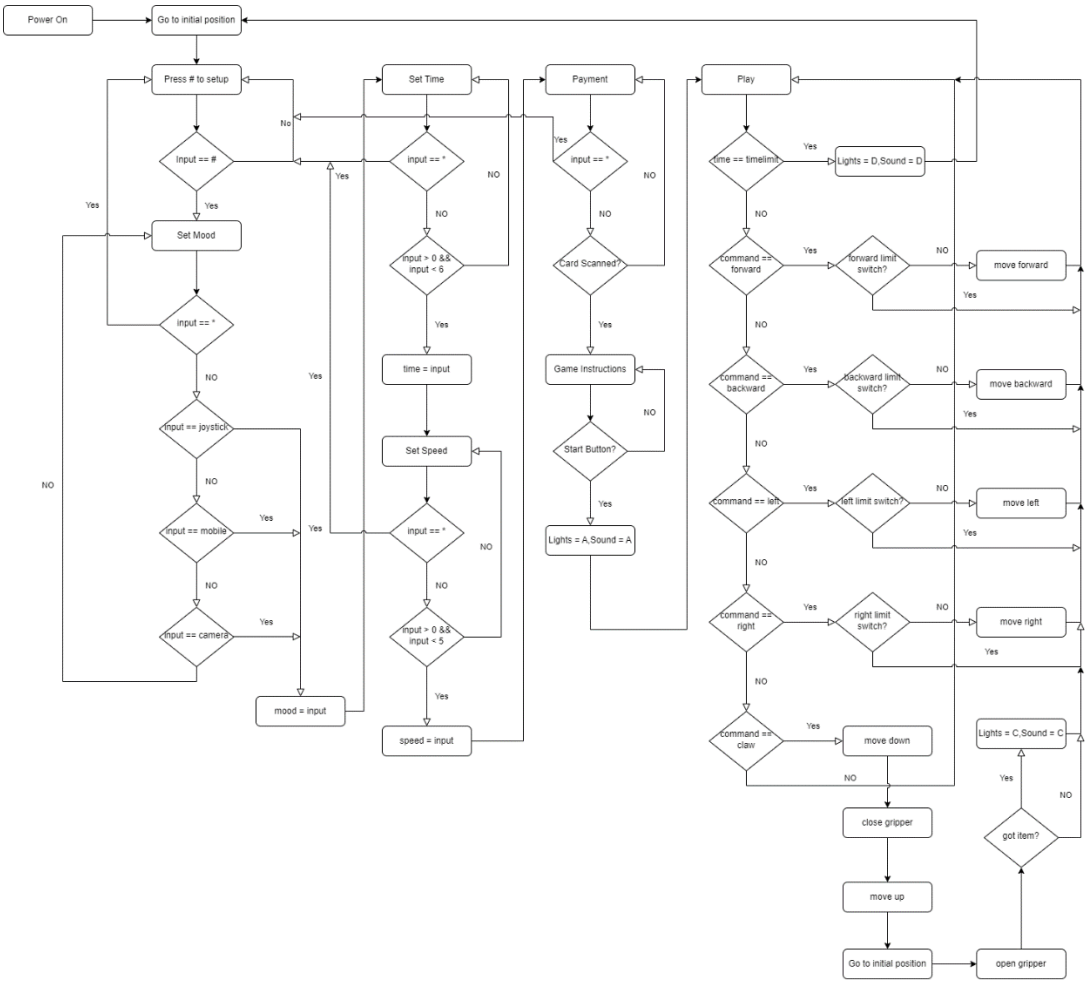


*Figure 34 ASM*

- Controller Design
  - Based on the previous steps we decide to choose the components shown in the figure below:

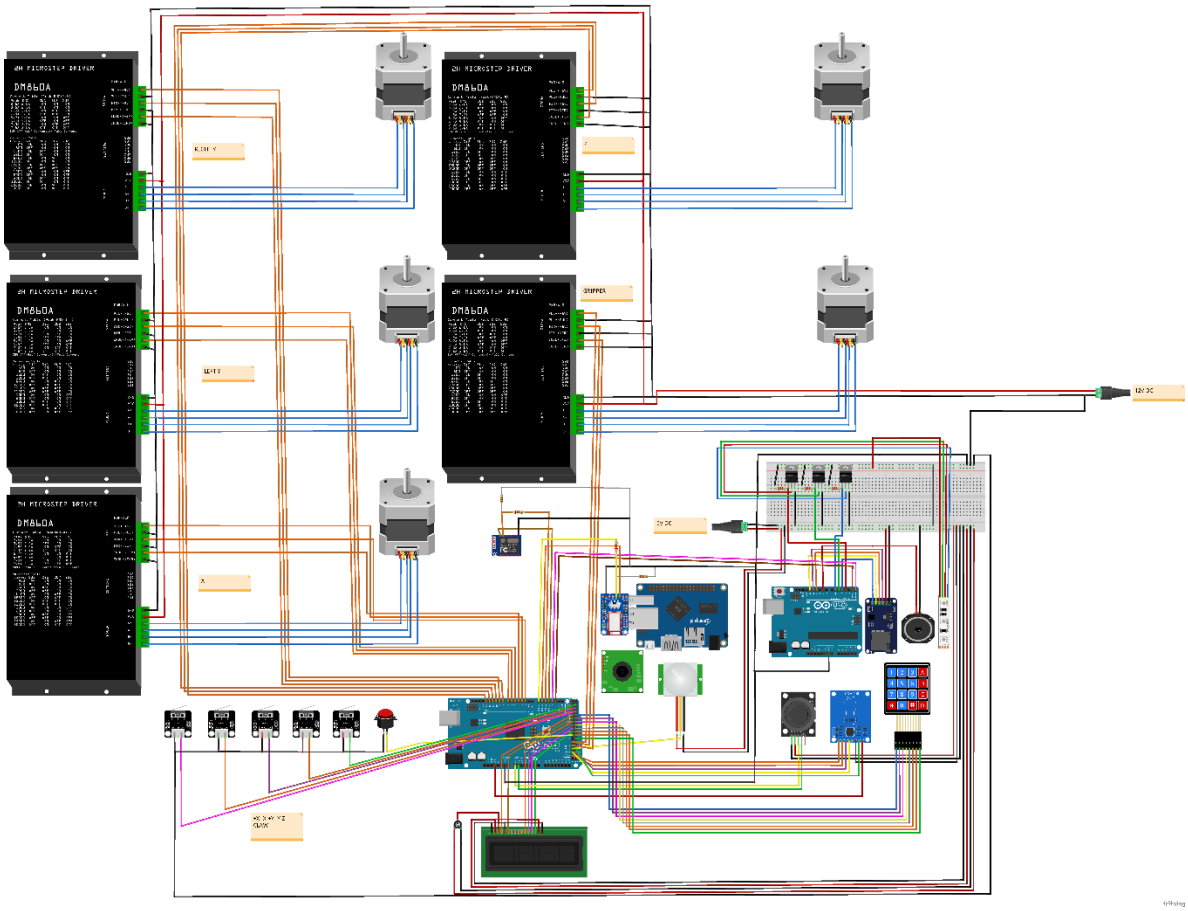

*Figure 35 Controller Circuit*

  - The Arduino mega is the main controller which controls the game from setup to the end.
  - The Arduino uno for light and sound effects it receives command serially from the mega that select the effect that should be on, we decide to make this done using Arduino uno due to two reasons, the first one is light effects required amount of delay which is not accepted in the main game program in mega because its real time game there should be no delay when playing and the second one is sound libraries reserve a lot of memory space which may affect the main program due to high memory usage but when split sounds and light from mega to uno everything is working fine and perfect.

- The ESP communicates with blynk server that our mobile app is connected to and sends commands through server to the ESP and from ESP serially to Arduino mega.

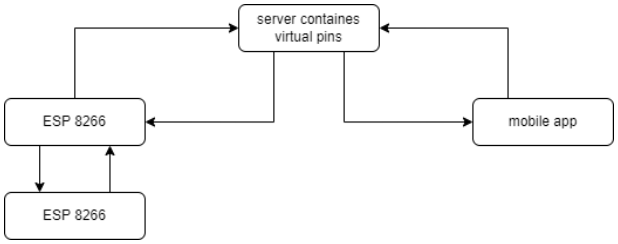


*Figure 36 ESP And Mobile Communication*


*Figure 37 Mobile Application*

- we should take into account that ESP is 3.3V logic while the Arduino is 5V logic so we used voltage divider circuit for logic conversion like shown in the figure below:

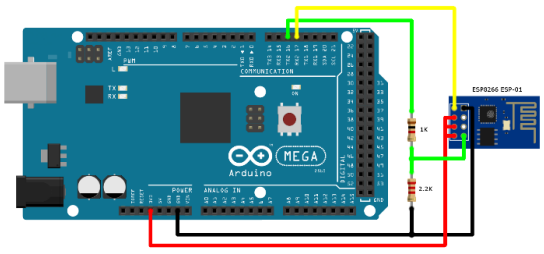


*Figure 38 Mega and ESP Connection*

- the orange pi is responsible to detect hand gestures using image processing and mediapipe model, but this still single board computer and to maximize its performance for the processing we did some steps, we know that its CPU is ARM Cortex-A55 which supports hardware acceleration which means it supports SIMD (single instruction multiple data) so we enabled hardware acceleration on it, then we cloned the entire open cv library and build it so we have pre compiled version of the open cv which its performance is better than the regular one, then we define region of interest so you don't have to process all the frame you just put your hand inside it and process the sub part of the whole image matrix which its size already reduced and finally we did parallelizing in code we assign a video capture task to thread and the processing of each frame in another thread.

- The orange pi is the same as ESP its 3.3V logic so we did logic conversion using voltage divider like we did with ESP.

- We used limit switches to detect movement limits and stop motors from rotating if the desired switch is triggered.

- We used pir sensor to detect if an item falls in the prize hole to send a signal to Arduino mega to send an effect command to Arduino mega for displaying the desired light and sound effect.

- The lcd to display time and game setup and instructions, we did interaction with setup and lcd using keypad.

- For RGB led stripe its long and require an enough current to operate so we used a driving current circuit that based on IRLZ44n transistors like shown in the following figure:

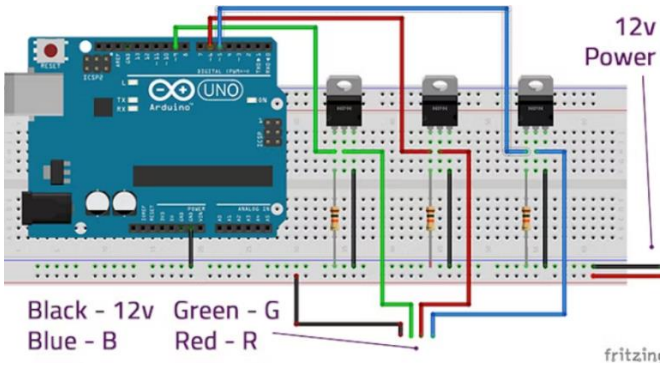


*Figure 39 Current Driving Circuit*

- We made a soldered board that contains output voltage (12 ,5) for components, voltage divider circuits, current driving circuit, system ground, potentiometer for lcd:

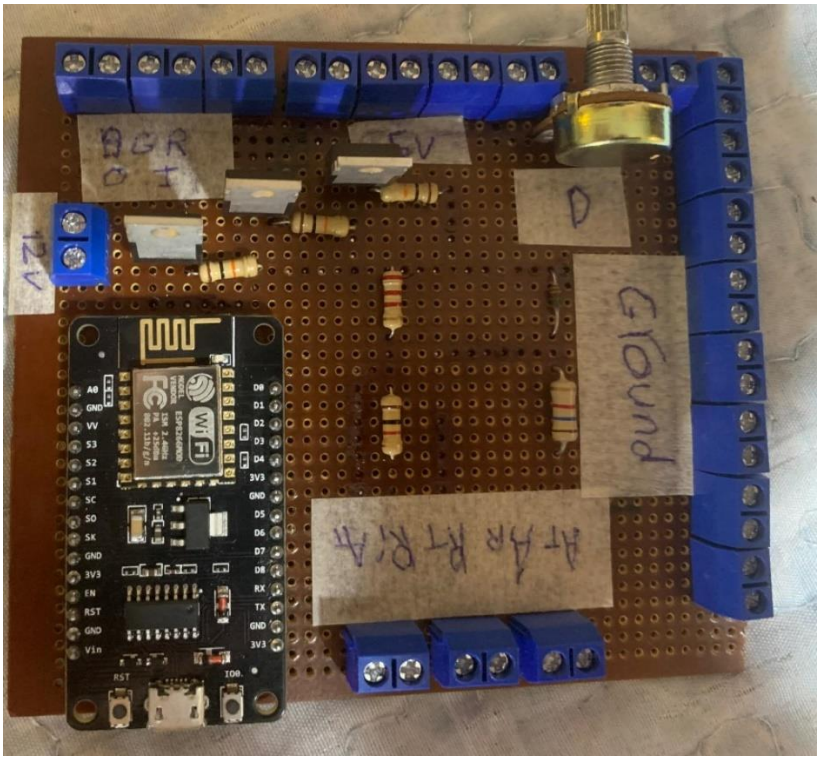

*Figure 40 Soldered Board*

- Mechanical Design
  - At first, we assemble the x axis part which consists of two stainless steel rods each one of them carries a bearing block which carries a custom designed wood part to carry x and z motors.
  - At the end points of the x axis part, we attach to each end by using custom 3D printed parts a bearing block to mount the whole axis on Y axis.
  - Also, at each bearing at end points we attached a stand and holder for timing belt this holder made using 3D printer.

*Figure 41 X Axis*

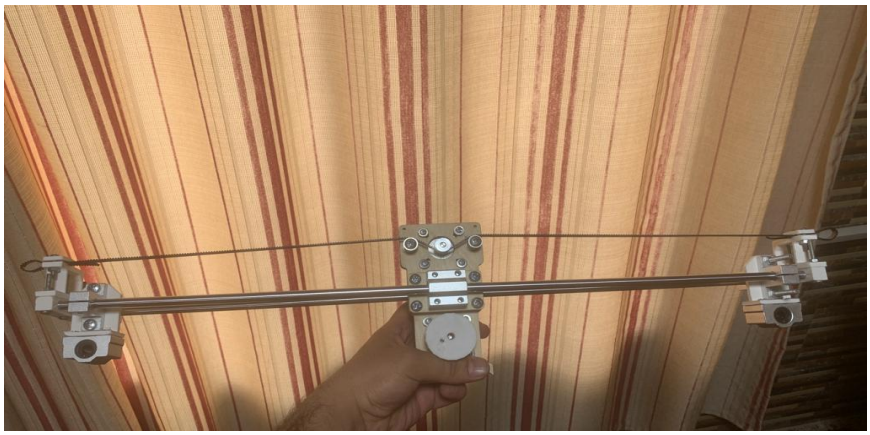

*Figure 42 Complete X Axis*

  - As we can see in the previous figures when motor rotates clock wise the gripper vehicle moves right and it moves left when motor rotates counter clock wise.

- Mechanical Design Cont.
  - Before mounting X axis on Y axis rods, we want to attach to it the Y Steppers.
  - Due to long of X axis we need two steppers for moving along Y axis.
  - We used custom designed wood part for mounting Y Steppers and attach this part at X axis end point as shown in the figure below:

*Figure 43 Y Stepper*

  - We should take into account that we used two steppers for Y axis each one is at end point of X axis so they are face to face, that's means when we want the whole X axis moves forward Along Y axis one of the steppers should rotates clock wise and the other should rotates counter clock wise, and to move backward we reverse each stepper rotation direction so the first one rotates counter clock wise and the other rotates clock wise.

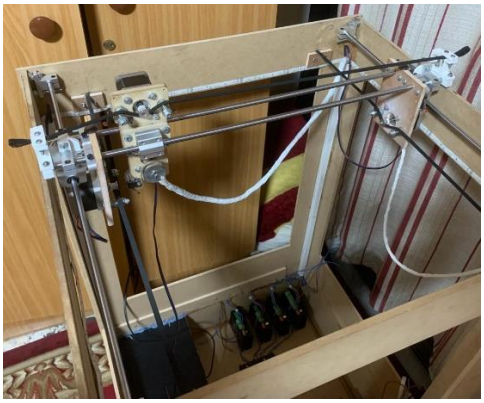

*Figure 44 X Y Axes*

- Mechanical Design Cont.
  - Finally, the Z axis motor is carried below X motor in the vehicle.
  - We attached the gripper with Z motor using rope and special bore for rope rotations.

*Figure 45 Z Axis*

  - When Z motor rotates clock wise the gripper goes up and when rotates counter clock wise the gripper goes down.

- Gripper Design
  - We need to design a gripper that open and close smoothly, and hold an item tightly.
  - We start searching and reading about how grippers designed.
  - We didn't find anything that satisfy the requirements.
  - We asked some experts in mechanics and they suggest us to see an tool called "jaw puller" it's used to remove gears, pulleys, wheel hubs, all kinds of hard to remove parts.

*Figure 46 Jaw Puller*

  - Its mechanism is simple you just have to rotate the centered screw clock wise or counter clock wise to open and close its arms.

- Gripper Design Cont.
  - We designed this four-arms gripper:

*Figure 47 3D Printed Gripper*

  - It consists of four arms that's each one of them is controlled by muscle that each one joins its arm with a vehicle that contains a nut.
  - we attached the vehicle with screw through its nut and when it rotates counter clock wise it travels down which make arms open and when it rotates clock wise it travels up which make arms close.
  - We should control the rotation of screw so we will use stepper motor.
  - We used limiting switch for the it to control opening and closing limits.

*Figure 48 Gripper*

# ❖ Design

*Figure 49 Claw Machine*


*Figure 50 Control Panel*

*Figure 51 Power and External Peripherals*

*Figure 52 Mechanical Part*

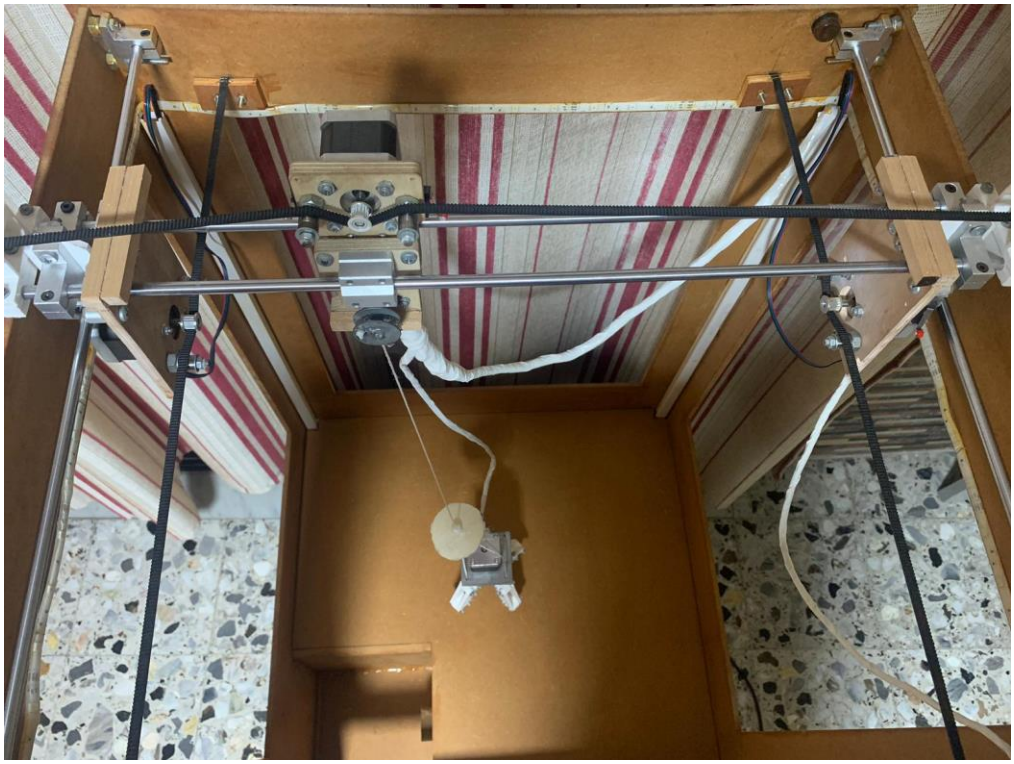

*Figure 53 Top View*

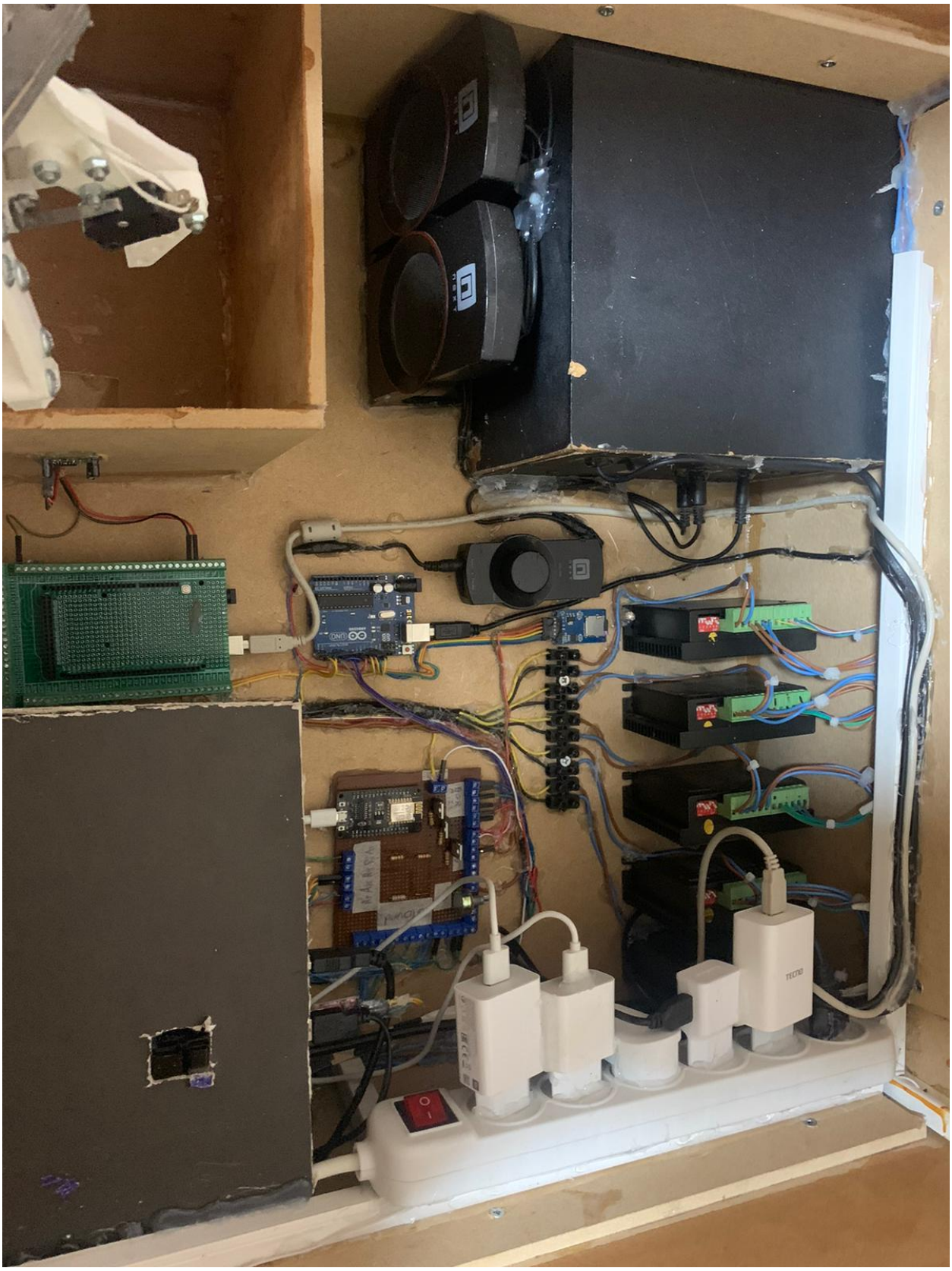

*Figure 54 Controller*

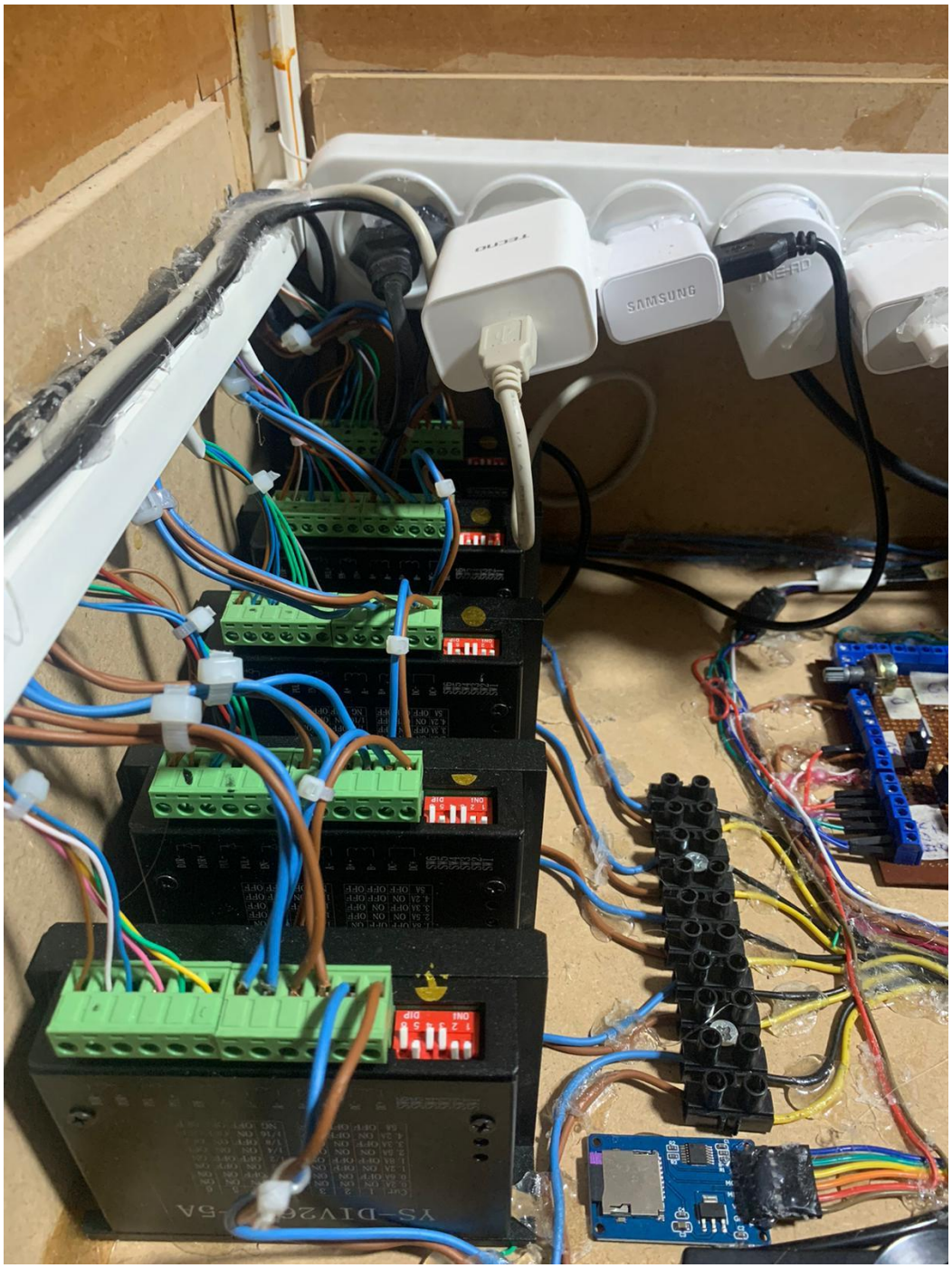


*Figure 55 Drivers*

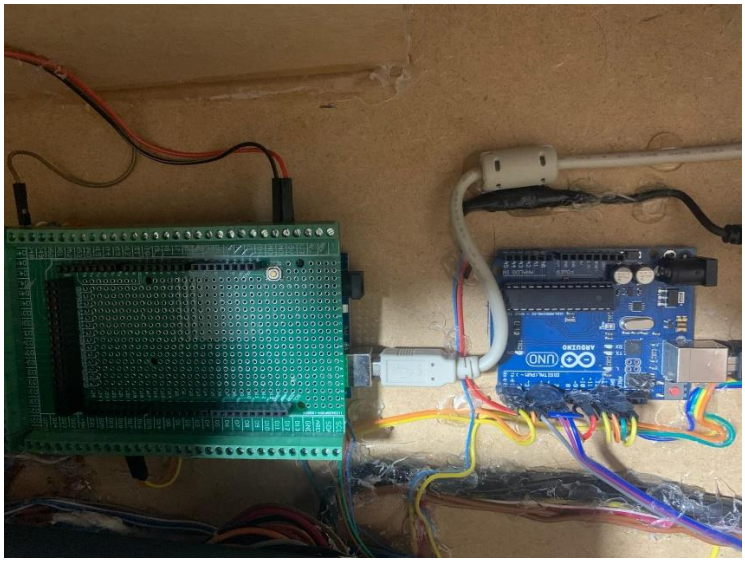

*Figure 56 Mega and Uno*

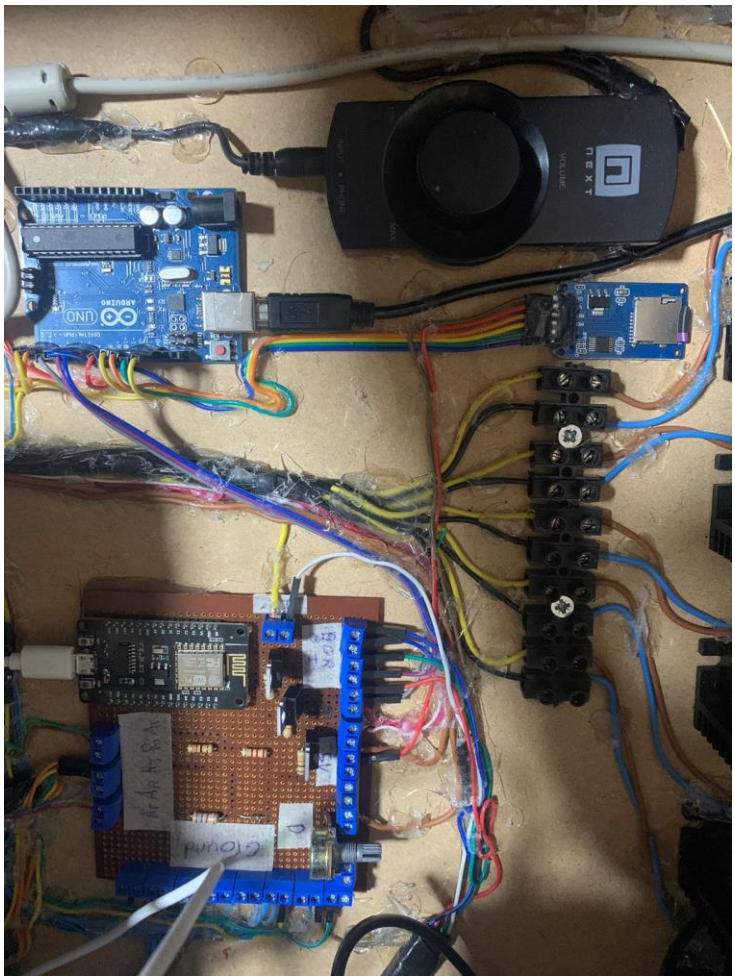

*Figure 57 Soldered Board*


*Figure 58 Amplifier and Speaker*

*Figure 59 Motion Detector*

## ❖ Future Work

-Adding coin accepter for those who wants to pay using money

-Adding voice system for people with disabilities so they can give instructions for the game by voice.

-Adding a new feature, the tends to make the game more as a griper, in this feature we give the machine a picture of what we want and it searches for it and grips it.

# ❖ Conclusions and Recommendation

## ➢ Conclusion

In conclusion, this project aimed to enhance the traditional claw machine game by incorporating modern technology and addressing its limitations. The objectives were to provide users with a new play experience through a mobile application or hand gestures using camera and image processing. Additionally, the project aimed to improve the gripper mechanism by making it stronger and more reliable. The inclusion of dynamic music and lights added an interactive element to the game, while customization options allowed users to personalize their gaming experience by adjusting movement speed, playing time, and playing mode. Through these objectives, the project sought to elevate the traditional claw machine into a more engaging and contemporary form.

## ➢ Recommendation

Before delving into our project, we devoted a substantial amount of time to mastering the Arduino language. We also invested significant effort into sourcing the necessary electronic components and understanding their functionalities. This preliminary experience proved invaluable, leading us to stress its importance for any hardware project. We wholeheartedly recommend that fellow students prioritize gaining this knowledge before embarking on their own endeavors. Furthermore, we attribute a significant portion of our project's success to the early selection of our idea, well in advance of the scheduled semester for the graduation project. This emphasis on pre-planning allowed us to maintain focus and streamline our work. Thus, we encourage students to engage in meticulous planning to maximize their chances of achieving their project goals.

## ❖ References


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