

Mr. Pen

An automated approach to smart typing



PRESENTED

BY

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TO

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Disclaimer Statement

This report was written by Amr J. Eshtiwi and Ahmed A. Al-Qerem, students 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 students. 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.

Abstract

Nowadays, CNC machines are most widely used for many applications “cutting, drawing, etc ...” and to give solutions to people who want to do remote writing from this standpoint our Idea was launched.

In our graduation project, we will build a machine that is more like a CNC that have three modes, the first one is for drawing by the head by moving the head in four directions, and this mode is for people who have a problem with their hands so they can draw with their heads “using gyroscope sensor”, the second mode is a tic tac toe solver that plays with the human, the third mode that types what the user speaks. It’s a machine consisting of two stepper motors each of which moves in a single direction “ X and Y ”, the motor can take action to move from the gyroscope sensor in the first mode that is put on the head of the user which sends commands to the controller using Bluetooth and the controller can control in stepper motors to move in a specific direction, in the second mode, it read the play and takes the decision by the controller. The decision that the controller will take it will be done by applying one of the artificial intelligence algorithms after the human play that is done by voice, in the third mode, the system handles each letter by mapping it with the right Gcode.

Some similar projects have been done before like the user gives an image and the machine will draw it but the difference in our project is the remote controlling in which the user can draw remotely.

Chapter 1: Introduction

With the development of technology today, Robotics and CNC machines have become integral tools in manufacturing, design, and many other industries due to their ability to automate a wide range of tasks such as cutting, drawing, and more. However, these machines are not always accessible or practical for individuals with physical limitations, particularly when it comes to drawing. That's where our project comes in.

In addition, most robots and CNC machines are mostly aimed to create visual images by giving machines the image that humans need to draw, so our project aims to address this problem by developing a CNC machine with a remote drawing mode that utilizes a gyroscope sensor placed on the user's head. This will allow individuals with physical limitations to control the machine and create drawings without the need for manual dexterity.

Previous attempts at solving this problem have included the use of voice recognition software and other assistive technologies, but these solutions have proven to be inadequate due to limitations in accuracy and user-friendliness. Our project aims to provide a more effective solution by combining the precision of a CNC machine with the convenience of remote control and adding some of the previous attempts by adding voice recognition to make it more controlled.

The development of a CNC machine with a remote drawing mode has the potential to greatly improve accessibility and increase the opportunities available to individuals with physical limitations.

In addition, the gaming mode gives unique features for our CNC machine which as its ability to play tic tac toe against a human opponent. This mode of operation utilizes artificial intelligence algorithms to read the board and make strategic decisions on its next move, this feature adds an additional level of entertainment and educational value to our CNC machine, as it allows users to practice and improve their tic-tac-toe skills.

In order to function, the tic tac toe solver utilizes a combination of voice recognition and artificial intelligence algorithms "Alpha Beta algorithm" to make decisions. The machine is able to recognize without a camera the positions of the X's on the board and use this information to determine its next move.

The third mode gives our system more effective and valuable which makes it more useable for more wide people usage, the mode uses TextToGcode library from python which takes the word from the microphone, and the library made its own functionality on the word.

In order to achieve our project, the following tasks will need to be completed:

- Research and development of the remote drawing mode, including the design and testing of the gyroscope sensor and Bluetooth control system
- Research and development of the tic tac toe solver, including the selection and implementation of artificial intelligence algorithms
- Design and construction of the CNC machine, including the integration of the three modes of operation
- Testing and debugging of the machine to ensure it functions as intended

There are several constraints and limitations that may impact this project. These include a limited budget and timeline, as well as the availability of resources and expertise.

The deliverables for this project will include a fully functioning prototype of the CNC machine, as well as documentation and reports on the research and development process.

The significance of our project lies in its ability to provide a more inclusive and accessible solution for individuals with physical limitations to draw by moving their heads.

This report will include walking through all the process that was done to build this project, starting from the constraints and how they were handled, the standards and hardware modules that were used, then it describes the full methods and materials that were used, it then discusses the result and ends with a conclusion that summarizes the whole work.

Chapter 2: Constraints, Standards/ Codes, and Earlier course work

2.1 Constraints:

During the work on our project, we faced several constraints that may impact the successful completion of our hardware project. These include:

- The lack and high cost of the needed parts such as mechanical parts "MGN15".
- control limit switch was causing a hard limit error while drawing.
- The internal Bluetooth module of the Raspberry Pi wasn't able to connect to HC-05 which is connected to the CNC shield.
- MPU6050 has noise and multiple unknown values.

To overcome these constraints:

- we do our search for shops here in Palestine which put us at time risk, we found one, and we accept the high cost to buy mechanical parts.
- in the second constraint, we replace the control limit switch with a more accurate one.
- We found that the internal Bluetooth of the Raspberry Pi has a security protocol, so we use the Bluez tool to deal with the HC-05 connection after we use the Bluez tool we noticed that the same problem still occurred, so we replace the HC-05 with serial Bluetooth from ESP32.
- we use the filter algorithm "Kalman filter".

2.2 Standards, Codes, and Hardware Modules

The whole idea of our project is to use a gyroscope in the first mode. so we use the MPU6050 module to detect the movement of the head.

Reading from MPU6050 mainly depends on using the **Kalman filter** or **linear quadratic estimation (LQE)**.

in our project, we use two types of controllers:

1. Raspberry Pi 4: to make MPU6050 reading algorithm, voice recognition, tic tac toe algorithm, and scanning algorithm
2. Arduino UNO: to do the commands that come from Raspberry Pi

for communication between the Raspberry Pi and the Arduino one protocol was used "Bluetooth IEEE 802.15.1".

Arduino uses **grbl firmware** to implement the commands.

In the Arduino part of the system, we use

1. CNC shield: this is used to control stepper motors by grbl firmware it allows us to control 2 motors simultaneously by accepting specific commands to make the movement of the stepper motors and It uses removable A4988 stepper controls drivers. the connection of the CNC shield is simple as shown in Figure 1:

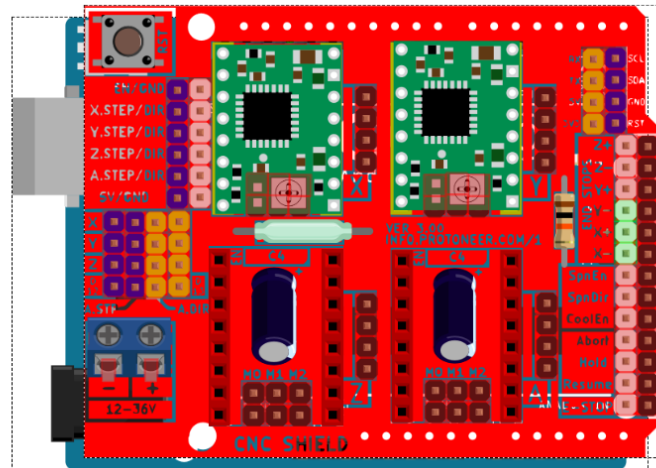


Figure 1. Arduino with CNC Shield and two A4988 drivers.

2. Two stepper motors: we used NEMO17 (40 mm) to reflect the movement of the head in two directions X and Y in which every movement can be made by “ G91 X{X} Y{Y} F200 ” in which X and Y are numbers of steps. The connection of the stepper motors with the CNC Shield is simply as shown in Figure 2:

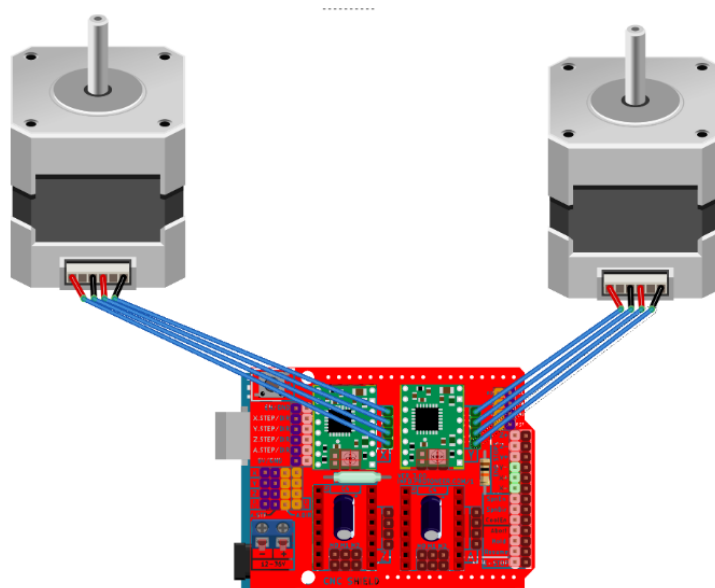


Figure 2. CNC Shield with X, and Y stepper motors.

- control limit switch: we use two control limit switches to detect the start point of the drawing area, the control limit switches are simply a switch that click when the system moved to the start point. The connection of the switches with the CNC Shield is simply as shown in Figure 3:

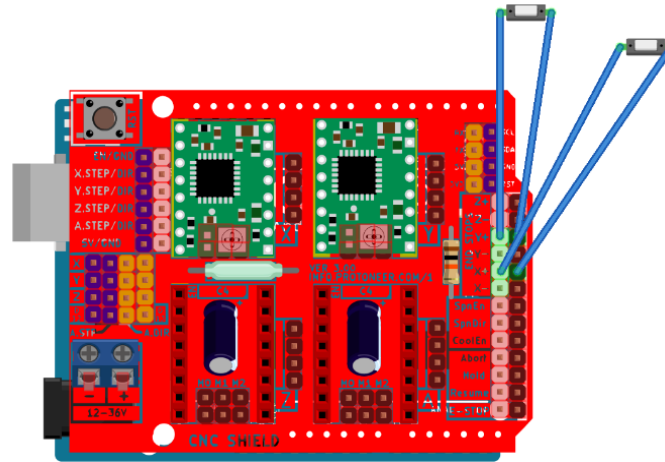


Figure 3. CNC Shield with control limit switch

- Servo motor: used to up and down the pen from the drawing through grbl command "M3 S45" which moves the servo at 45 degrees. The Servo motor is connected in the Z direction. The connection of the switches with CNC Shield is simply as shown in Figure 4:

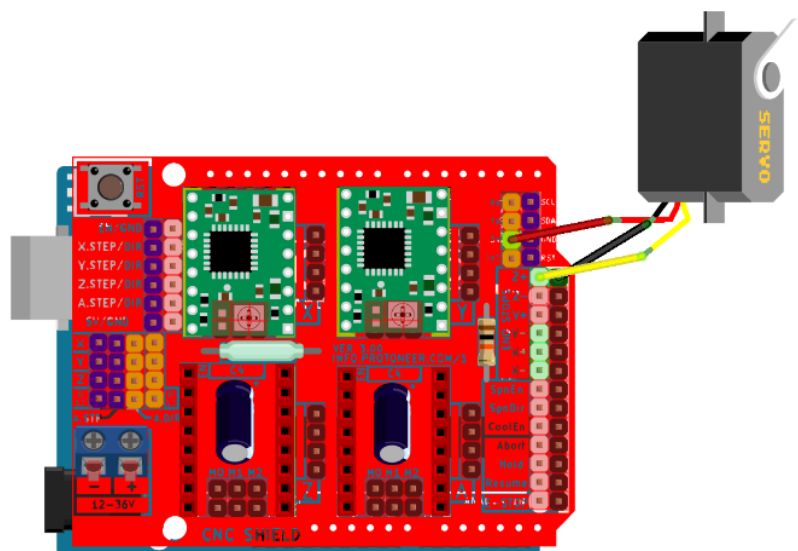


Figure 4. CNC Shield with servo motor

- Bluetooth Module: we use ESP32 to use the classic Bluetooth as a Bluetooth module it is connected to internal Bluetooth in the Raspberry Pi to receive the command from Raspberry Pi and then send the status of the system to Raspberry Pi. The connection of the HC-05 with the CNC Shield is simply as shown in Figure 5:

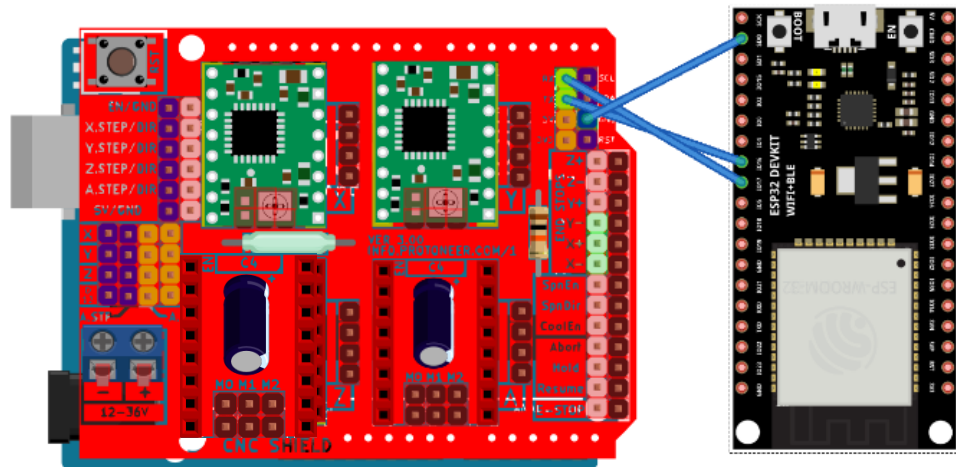


Figure 5. CNC Shield with ESP32

- Finally, in the Arduino Part, we need a power supply to give the stepper motors the power which one stepper needs to 1.5A to work correctly. so we connect the power source to the internal relay in the CNC Shield as shown in Figure 6:

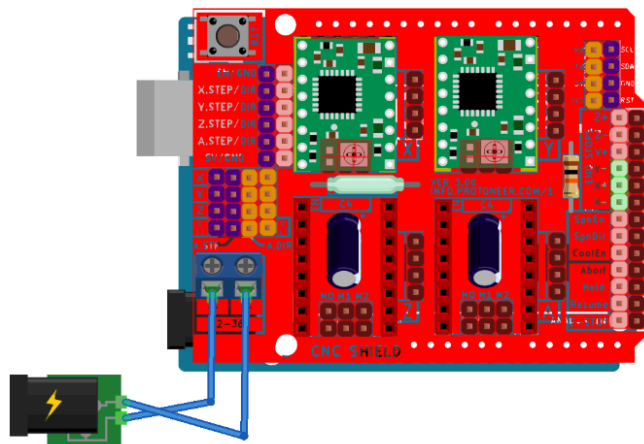


Figure 6. CNC Shield with power supply

In the Raspberry Pi part of the system we use:

1. Gyroscope sensor: we use the MPU6050 module to detect the movement of the human head in which we read the roll “rotation on the X-axis” and Pitch “rotation on the Y-axis” see Figure 7. And from these reading values, we calculate the Angel between the imaginary surface and the tendency of MPU6050.

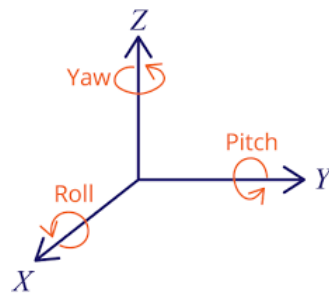


Figure 7 Roll,Pitch and Yaw.

and we check if the Angel is between 20 - 80 in all four directions then we will make move on the system in the specific direction. To reduce the noise reading from the MPU6050 we use the Kalman Algorithm which depends on taking a series of values and errors and then producing an estimated more accurate value. The connection of the MPU6050 with Raspberry Pi is simple as shown in Figure 8:

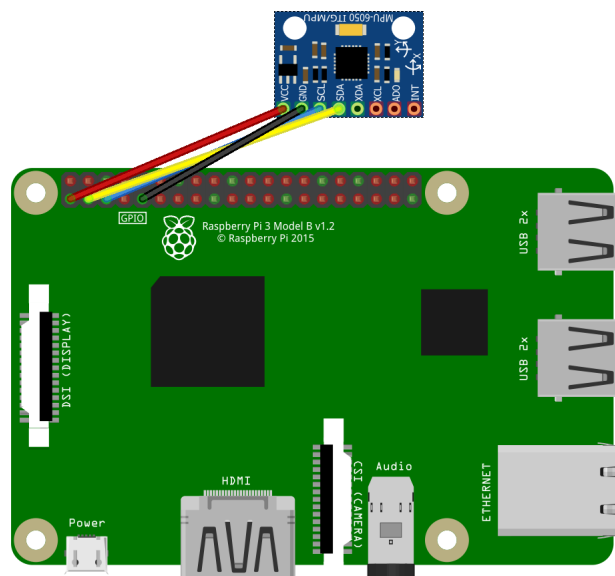


Figure 8 Raspberry Pi 4 with MPU6050.

2. Sound card: this is connected by the USB port in the Raspberry Pi to make voice recognition, then just connect the microphone of the headphones, we use the Speech_Recognition library to recognize words which lets us use google recognizer API, and we use PyAudio to use a microphone with python, we use FLAC encoder because the data is sent to Google API by FLAC format. We use voice recognition to change between two modes”mode1 and mode2”, Up and Down the pen, and disconnect the system.
See Figure 9 to see how we connect the sound card with Raspberry Pi:



Figure 9 Raspberry Pi 4 with sound card.

3. Tic Tac Toe algorithm: in the second mode of the system we use the AlphaBeta Algorithm to make decisions in which place should the system play.
4. We use the built-in internal Bluetooth to send the grbl command from Raspberry Pi to the CNC drawing machine
5. We use I/O devices “Keyboard and mouse” to control and write code on Raspberry Pi.

We use Arduino IDE to upload grbl firmware and thorny and VScode to write python code on Raspberry Pi.

2.3 Earlier coursework

In preparation for my current hardware project, we have completed a number of relevant coursework and experiences. These include

- A course in computer programming, which taught us the fundamentals of coding and debugging especially C++ and OOP.
- A project on artificial intelligence course gave us a deeper understanding of how these algorithms work and how they can be applied to practical problems.
- microcontroller course which gave us an entry into how to use microcontrollers like Arduino.
- A practical internship on Arduino controller which gave us a practical understanding of how to use multiple modules with Arduino
- Network course which gave us a full understanding of the protocols that we used in our project.
- Electronic circuit courses gave us a full understanding of different modules and dealt with the right wiring and finding the correct power source for each of them.

We believe that these experiences have prepared me well for the challenges and opportunities of my current project.

Chapter 3: Literature Review

The project was developed with three modes, the first mode is what distinguishes our project which helps users to draw from a distance through the movement of the head in the four directions, in which gyroscope sensors have become increasingly popular in recent years due to their ability to measure angular velocity and provide precise, real-time data on the orientation of an object. These sensors have a wide range of applications, including in robotics, virtual reality, and navigation systems.

In our hardware project, we are using a gyroscope sensor to control a CNC machine in remote drawing mode. To the best of our knowledge, this is the first time a gyroscope sensor has been used in this way. We expect that the precision and real-time data provided by the gyroscope sensor will allow users to accurately control the movement of the CNC machine and create high-quality drawings.

But many similar projects allow users to give the required drawing and draw it, unlike what our project does, which reflects the movement of the head on paper. In addition, we have made some improvements such as voice recognition, which make it widely used by disabled people.

Our tic tac toe solver utilizes an artificial intelligence algorithm, the Alpha Beta algorithm, which has been shown to be effective in decision-making tasks. We expect that our tic tac toe solver will provide a challenging and entertaining experience for users and that it will also have educational value as it allows users to practice and improve their tic tac toe skills.

mode three improves the facilities of our project which makes it usable with a wide range of people, in addition, can use with multiple applications such as writing from the teacher's voice during the lesson.

Chapter 4: Methodology

- Data Searching:

When we thought about the idea of the project, we started searching for similar projects, we found that this type of project was done before in different ways, so most projects that we found are built by giving drawings to the machine and it will draw it, but in our case that use MPU6050 as gyroscope, it's the first time that gyroscope uses in this type of projects.

- System Architecture:

In this section, we will describe our project deeply and how we build it along with design choices.

The project is divided into two parts two main parts: the mechanical part and the technical part.

In the mechanical part, we tried to build a machine that mimics the movement of the CNC machine. as illustrated in the figure below.

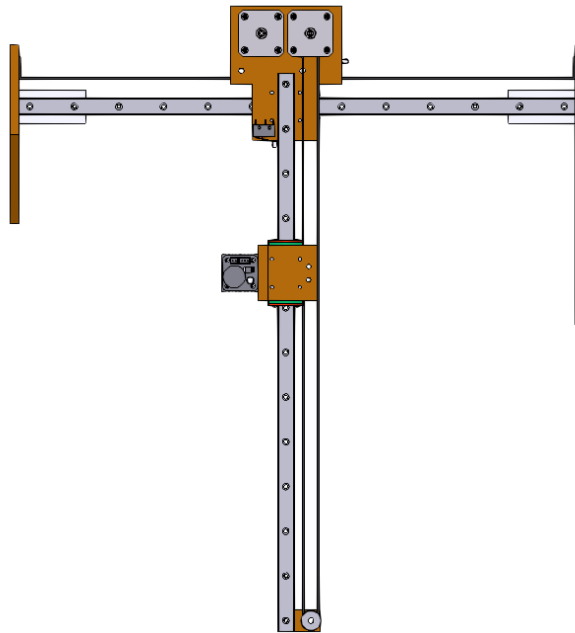


Figure 10, General design.

We built an X and Y slider by using two MGN20s for each direction see figure 11.

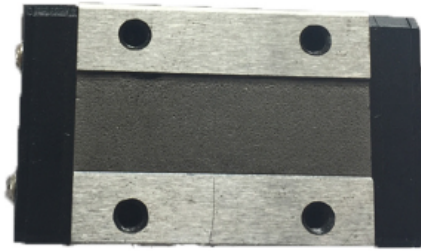


Figure 11, MGN20.

And we hooked the MGN20 on a steel pole dedicated to it, then we cut 6mm MDF wood within specified measurements to put the pole on it. For the X direction, we cut two pieces of MDF as illustrated in the figure below to hook the X axis on it.

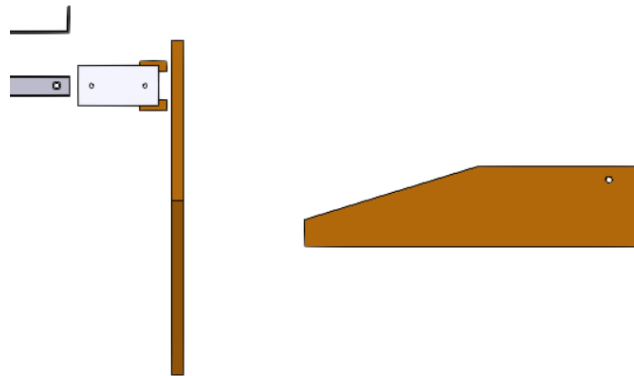


Figure 12, wood pieces to hook X axis.

then we hooked the Y axis in the MGN on the X axis as illustrated in the figure below.

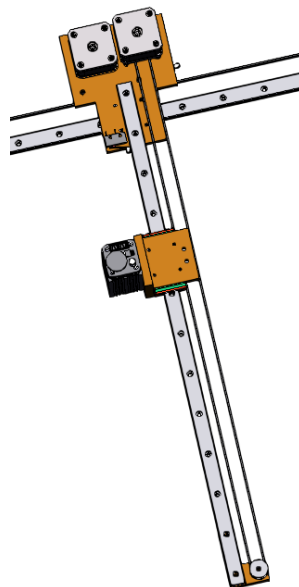


Figure 13, Y axis.

we hooked it on MGN20 by cutting wood with specific measurements and putting the stepper motors on this piece of wood. as in the figure below and figure 13

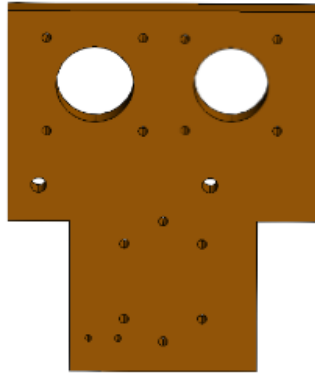


Figure 14, wood piece for Y axis.

To make the movement in each direction we use a GT2 belt that is tied with each MGN20, and we attached pulleys with GT2, and the pulleys make rotation when the stepper motor is rotated.

The Z axis we just need for the Down or Up pen so we got a 3D design for a pen holder to print it.

The design contains three components one as a pen holder, one as a slider that responds to servo movement, and the last component that is hooked on the MGN20 in the Y axis. all components as figures below.

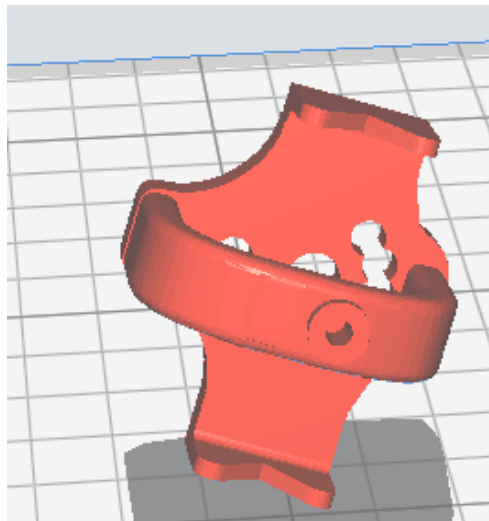


Figure 15, pen holder part 1.

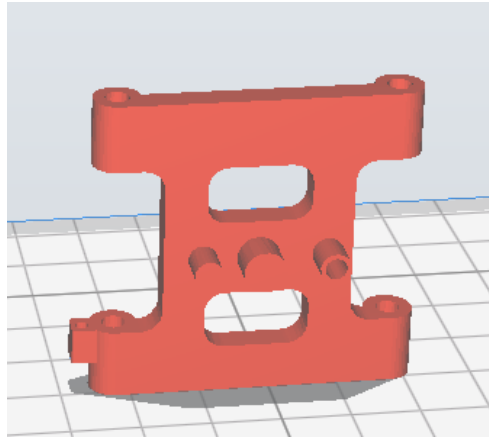


Figure 16, pen holder part 2.

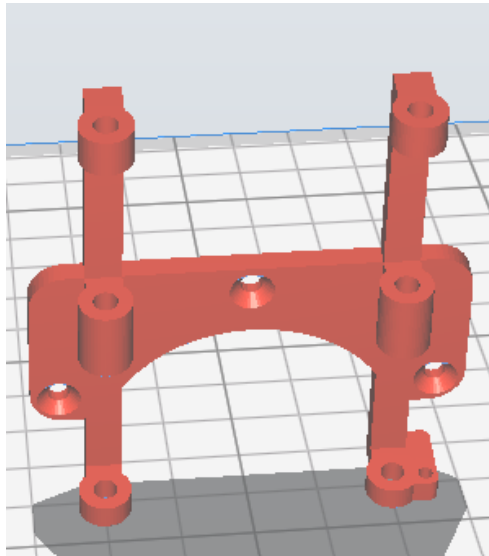


Figure 17, pen holder part 3.

After assembling the three pieces as figure below, Two metal rods were used to assemble the pieces, in addition to a spring that presses the pen down. see figure 18

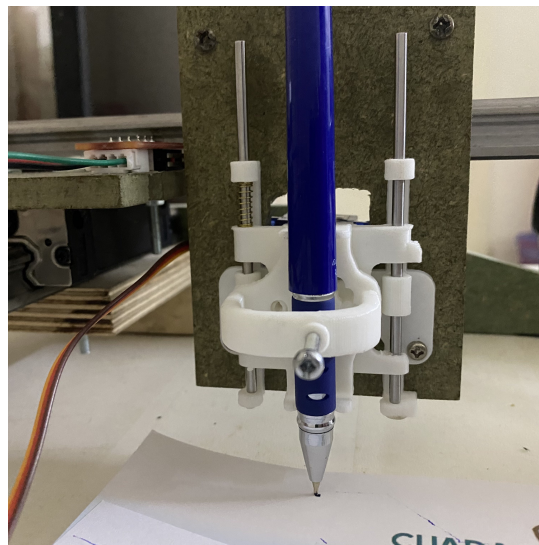


Figure 18, assembling pen holder.

For the technical part, we built a two-dimensional coordinate system, The system uses two stepper motors of type NEMO17, each of which pushes every MGN20 to move in its direction.

mainly our technical system is divided into two parts (algorithm part and executing part) and each part is divided into its own part as we will illustrate.

The algorithm part is put on Raspberry Pi 4 and it has three main components that work together: Recognize Voice, choose one of three modes, and process and send command to executing part. see figure 19

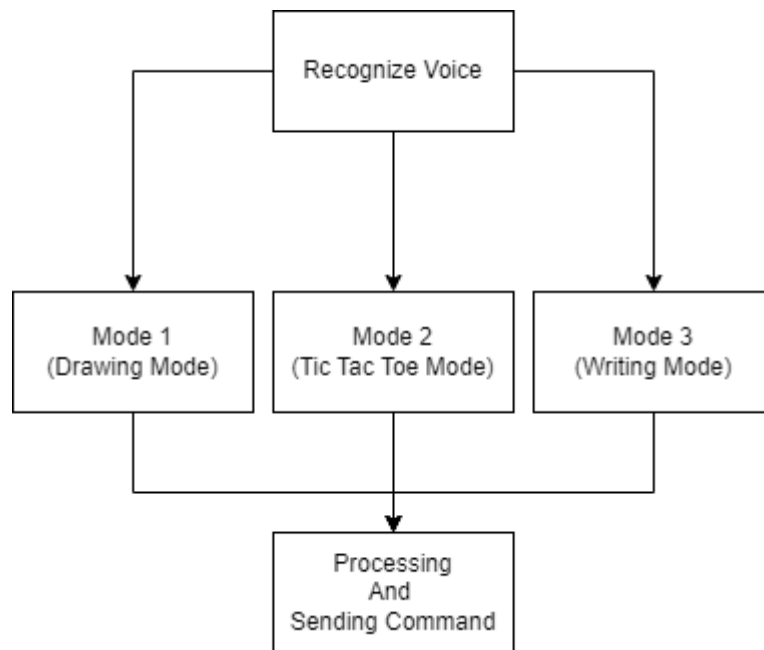


Figure 19, diagram for algorithm part.

Recognize Voice:

We do our research about how we can recognize the voice, we found a free API from google that can analyze the sound from a normal basic microphone in the headphone.

and we interface the headphone into the raspberry pi using a normal sound card.

we use google API to recognize the voice for several features that exist in the API:

1. High accuracy: Google's Speech-to-Text API is known for its high accuracy, which means that it is able to transcribe speech with a high degree of accuracy.
2. Easy to use: The API is designed to be easy to use, and it provides a simple API that developers can use to transcribe speech in a variety of formats.

3. Customizable: With the API, you can also fine-tune the transcription to your needs like adding custom words and phrases, adjusting the model to the specific noise conditions, etc

When the system starts running The recognizer will start to recognize the sound if the user talk (mode 1, mode 2 or mode 3) it will go that mode to do the processing for that mode.

while entering that mode the recognizer is still working to listen to the user if the user needs to down or up the Pen in mode one or disconnect to re-choose which mode the user wants. see figure 20

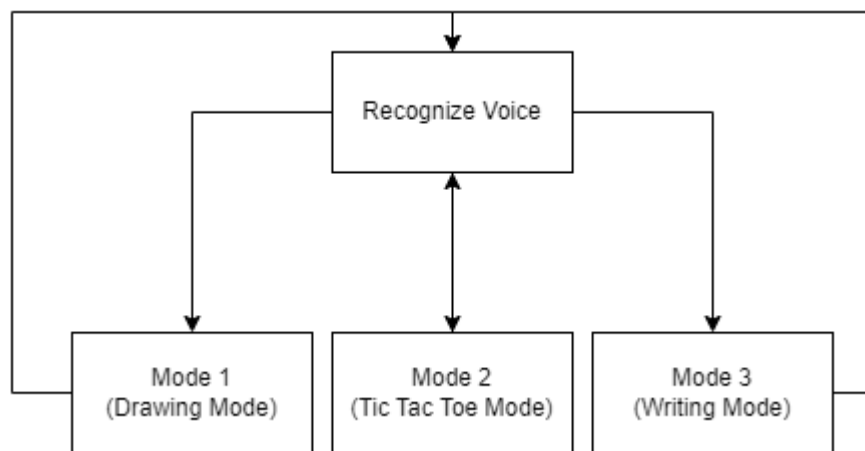


Figure 20, diagram for recogizing voice.

In mode 1 once the user says (Up or Down) the system will send to executing part, the command to move the servo motor up or down the pen to finish or start drawing, respectively.

In mode 2 the user specified in which the blink wants to put the X by saying “BOX#” in which # is the number of blinks.

In mode 3 when the user speaks the system will start writing what the user talks on the microphone.

Mode 1 (Drawing Mode):

We use MPU6050 as a gyroscope to read the rotation of the head. we use MPU6050 because it has multiple features which include:

1. Measurement of angular velocity: The 3-axis gyroscope of the MPU-6050 can measure angular velocity around each of the three axes (x, y, and z) with a high degree of accuracy. This can be useful for measuring the rotation or orientation of an object.

2. low power consumption: The sensor is designed to be low power and can operate on minimal power input, making it suitable for battery-powered devices.
3. Easy to interface: The sensor has an I2C interface which is relatively easy to interface with Raspberry Pi.
4. Small form factor: The sensor has a small form factor making it suitable for our project.

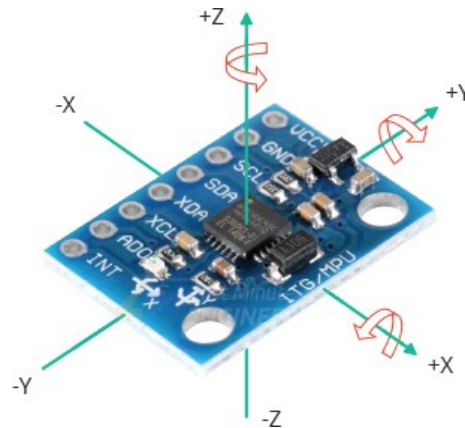


Figure 21, MPU6050.

By reading the roll (rotation on the x-axis) and pitch (rotation on the y-axis) we process the value that we have in three steps: filter Value, calculate the Angle between the sensor and imaginary surface, then check if the value in the specified range to send the command to executing part.

1. filter values: we found that the sensor is very sensitive and it responds to any movement, and make a high difference output, so we use the Kalman filter that takes a series of values and error and make some additional mathematical operation on that value.
Kalman filter responds to our criteria in which it can respond to any actual movement in the head.
2. calculate Angle: from the Angular velocity that the gyroscope gives it as output we can find the Angular rotation for the head.
3. sending the command: before sending the command for executing part, we check if the angle with a 20 - 80 range is the range for the head tilt, so if the range met the angle from the gyroscope we will send $G92 X\{x\} Y\{y\}$ in which x and y are increased by 10 if the head moved in one of that axis.

Mode 2 (tic-tac-toe mode):

when we entering to mode 2 we start drawing the board, then the system will start to recognize the voice to choose where the user wants to put his X and when the user plays the algorithm will start running the algorithm. see the below figures.

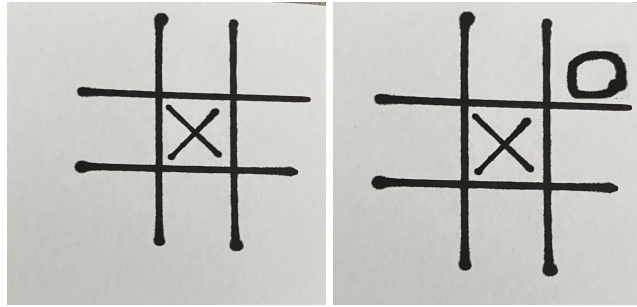


Figure 23, playing tic-tac-toe.

tic tac toe uses the Alpha Beta algorithm which has proven effective in solving this type of problem

we replace the usage of the camera, by using voice recognition which reduces the resources used, in which we achieved the same goal.

The system will re-read the board after the user plays by his voice, and then the system will draw the X on the board, The draw operation needs two things: which blink and the absolute coordinate for the blink. We got the coordinate by testing after we draw the board using (the chilipeppr Hardware Fiddle web application for testing grbl firmware) see figure 24

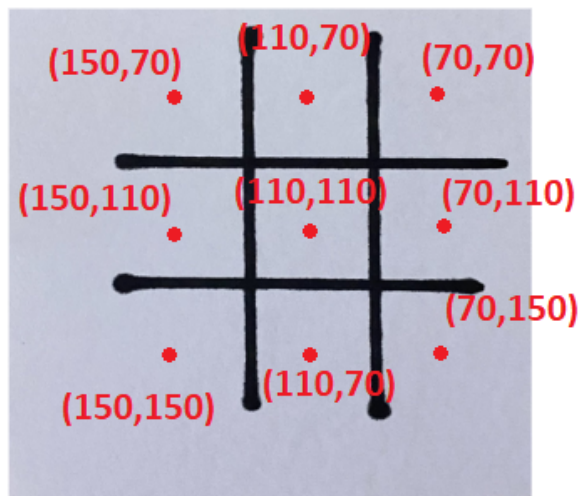


Figure 24, board coordinate.

Mode 3 (writing mode):

in this mode, the voice recognition will start working, so every word that the user will talk, the mode will start dividing the word into letters and every letter has it's own Gcode that can be sent to executing part to write the word that the user talk.

This process is done by TextToGcode which is provided by the Python language. see figure 25

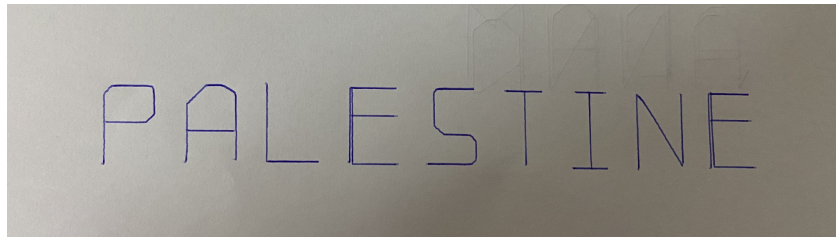


Figure 25, writing mode.

In the executing part, we have an Arduino controller that we upload on it GRBL firmware on it.

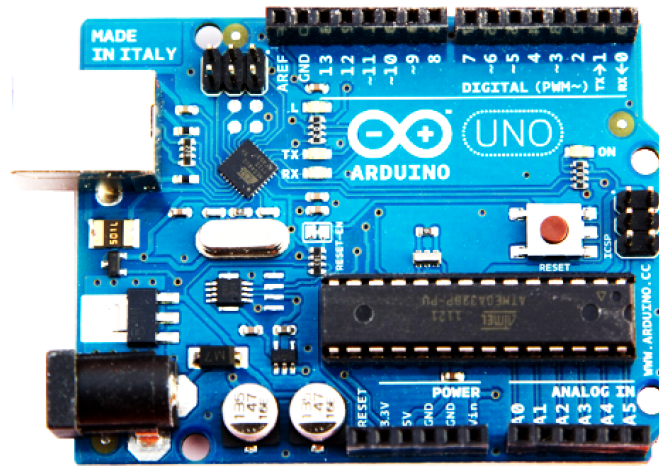


Figure 26, Arduino.

GRBL firmware is a popular open-source firmware for controlling CNC machines. It is known for its reliability, stability, and ease of use. It is compatible with a wide range of controllers and can be used to control a variety of different machines, including 3-axis CNC mills and routers. Additionally, it is actively developed and maintained, meaning that bugs are regularly fixed and new features are added. Overall, using GRBL firmware can provide a stable and easy-to-use control solution for your CNC machine.

Then we connect a CNC shield with Arduino because using GRBL firmware with a CNC Shield can provide a cost-effective and easy-to-use control solution for your CNC machine. The CNC Shield is a board that sits on top of an Arduino microcontroller board, and it allows you to connect stepper motors, limit switches, and other devices to your machine. By using GRBL firmware on the Arduino board, you can control the stepper motors and other devices connected to the CNC Shield, which allows you to control the movement of your CNC machine.

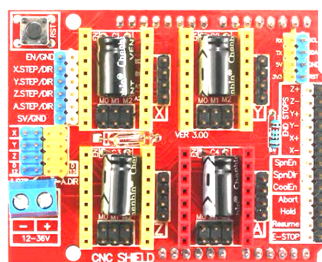


Figure 27, CNC shield.

Additionally, the GRBL firmware has built-in support for the CNC Shield, which means that it can be easily configured to work with the shield. This allows you to take advantage of the many features and capabilities of GRBL, such as homing, jogging, and G-code interpretation, without the need for additional software or configuration.

In summary, using GRBL firmware with a CNC Shield can provide a cost-effective, easy-to-use, and feature-rich control solution for your CNC machine.

We use stepper motors of type NEMO17 because it is a high-performance stepper motor that is designed for use in demanding applications such as CNC machines, 3D printers, and other precision motion control systems.



Figure 28, NEMO17 stepper motor.

NEMO17 has multiple features that pushed us to use it which are:

1. High torque: NEMO17 stepper motor has a high torque output, which allows it to handle heavy loads and high speeds.
2. High accuracy: NEMO17 stepper motor has a high step accuracy, which means it can move with high precision, making it ideal for use in applications that require high precision.
3. High reliability: NEMO17 stepper motor is known for its high reliability, it can handle a high number of steps per revolution and high temperatures.
4. Low noise: NEMO17 stepper motor has low noise emissions, which makes it suitable for use in noise-sensitive environments.
5. Wide range of options: NEMO17 stepper motor comes in a wide range of options, such as size, step angle, holding torque, and so on, which means you can find the perfect motor for your application.

It's worth noting that the NEMO17 stepper motor is a high-end option and it might be more expensive than other stepper motor options. However, our project requires high performance, high precision, and high reliability, so the NEMO17 stepper motor can be an excellent choice.

To control the stepper motors we use a G-code command that is supported by GRBL firmware, which is a series of instructions that tell the stepper motor driver, such as A4988, how to move the motor. The most common G-code commands used to control stepper motors in CNC machines include:

1. G0: Rapid movement command, this command is used to move the stepper motor at the maximum speed possible, it's used for homing and jogging.
2. G1: Linear movement command, this command is used to move the stepper motor in a straight line at a specified speed and to a specified position.
3. G28 / \$H: Homing command, this command is used to set the stepper motor to the machine's origin point.
4. G92: Absolute position command, this command is used to set the stepper motor to a specific position.
5. M3 and M5: Spindle control command, this command is used to turn the spindle on and off, the spindle is connected to the servo motor for the pen to draw.

We connect the A4988 driver to the CNC shield that is suitable for our project, because

1. Easy to use: The A4988 is relatively easy to use and can be controlled directly by an Arduino or other microcontroller, making it a good choice for beginners or those looking for a simple solution.
2. Low cost: The A4988 is an inexpensive option, which makes it a good choice for those on a budget.
3. High compatibility: The A4988 is compatible with a wide range of stepper motors and can be used to control both bipolar and unipolar motors.
4. High reliability: The A4988 is a widely used and well-proven component with a good track record for reliability.
5. Built-in protection: The A4988 has built-in protection against over-current and thermal overload, which can help prevent damage to the driver and your stepper motor.

We connect two limit switches for each direction that set the system at the start point in which when the user enters any mode it will send the \$H command and home the system so that will move the pen to the start point.

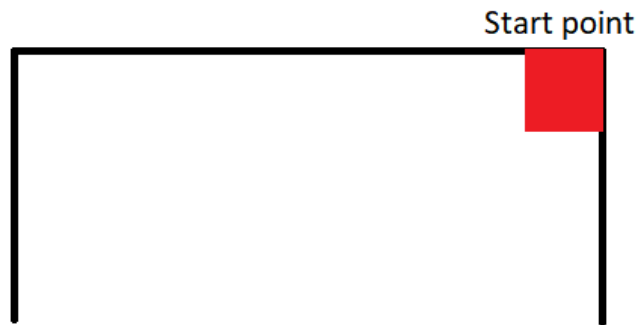


Figure 29, Homing.

For the communication between the algorithm part and executing part, we use Bluetooth as a link between Raspberry pi and Arduino, so we use the classic Bluetooth from ESP32.

So while the MPU6050 from Raspberry Pi starts moving, it will start sending the command by Bluetooth to Arduino and that command will tell to A4988 driver to make a movement in the stepper motors.

in which the probabilities expected to move the head, it's 8 moves.

1. Forward movement of the head: this movement will affect the movement of the CNC machine and the stepper of the Y direction will start moving and will send G92X0Y10 command for Arduino.

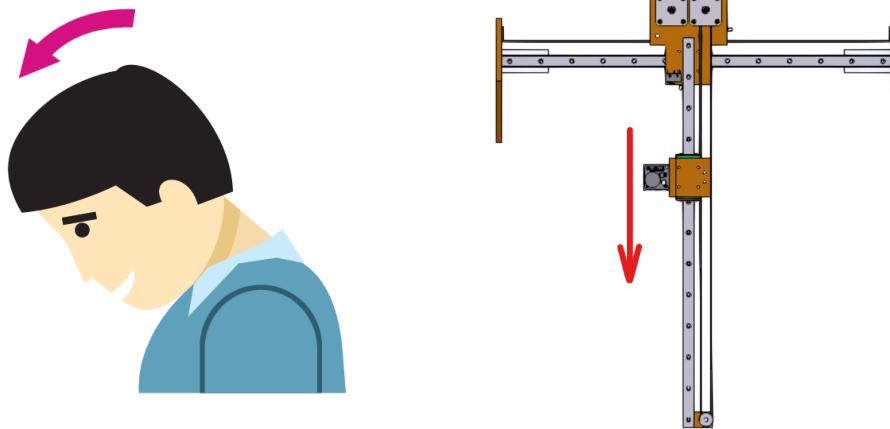


Figure 31, Forward movement.

2. Forward movement of the head: this movement will affect the movement of the CNC machine and the stepper of the Y direction will start moving and will send G92X0Y-10 command for Arduino.

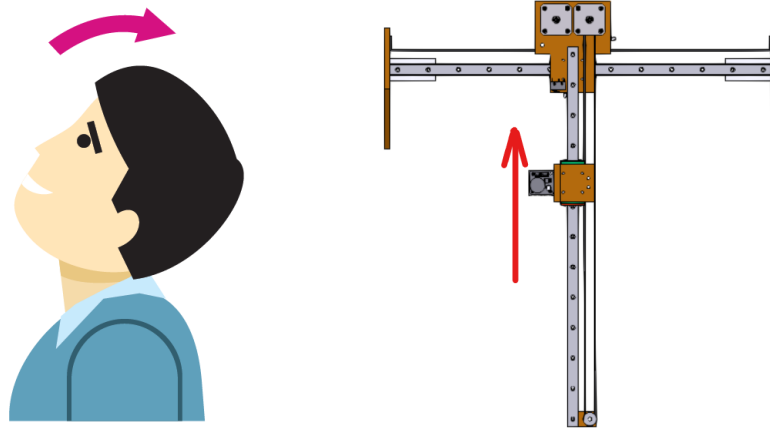


Figure 33, Backward movement.

3. left movement of the head: this movement will affect the movement of the CNC machine and the stepper of the X direction will start moving and will send G92X10Y0 command for Arduino.

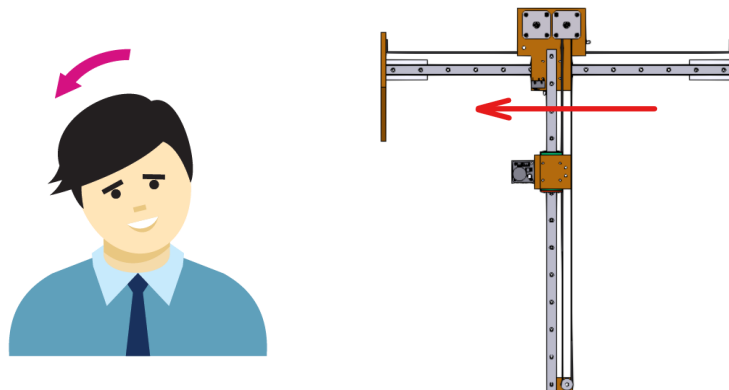


Figure 35, left movement.

4. Right movement of the head: this movement will affect the movement of the CNC machine and the stepper of the X direction will start moving and will send G92X-10Y0 command for Arduino.

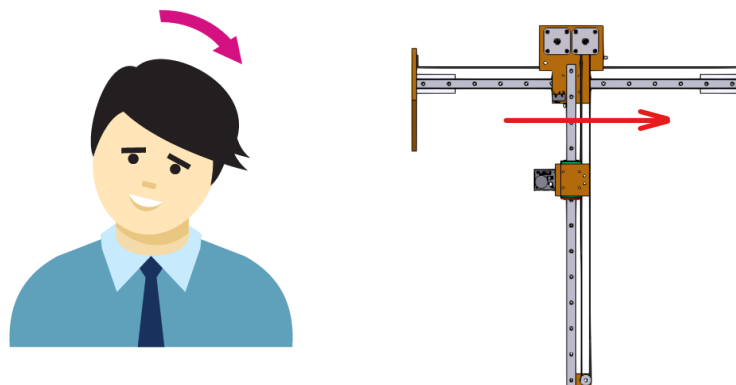


Figure 37, Right movement.

5. Four common directions: this movement will affect the movement of the CNC machine and the stepper of the X and Y directions will start moving and will send $G92X\{x\}Y\{y\}$ command for Arduino in which x and y may be 10 or -10 depending on the direction.

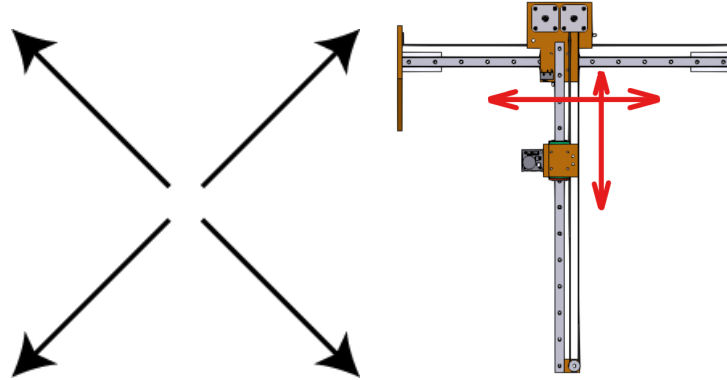


Figure 39, Common direction movement.

In tic-tac-toe mode, the algorithm part sends to executing part where should the CNC draw O in the Grid, the draw position in this mode work on absolute positioning by sending the (x,y) coordinate for blank in the grid by knowing the coordinate in advance.

after testing that we draw something like the below figures:

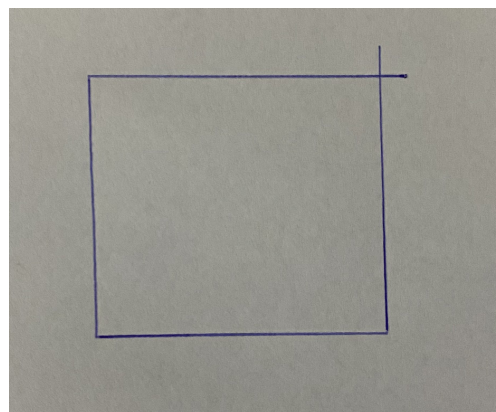
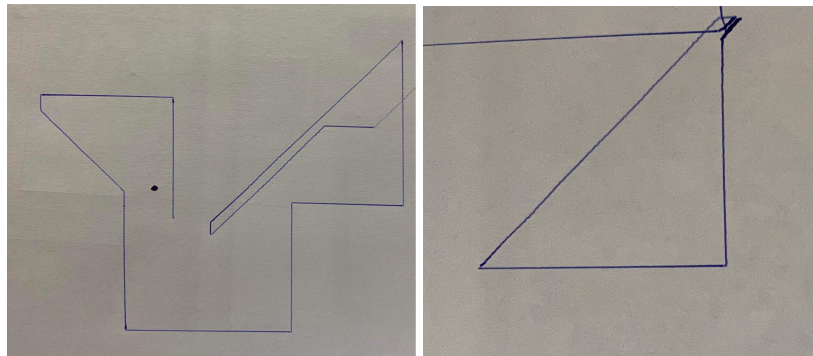


Figure 42, mode 1 examples.

Chapter 5: Result and Discussion

- Testing:

The testing process starts with testing the right command to the Arduino that deals with the CNC shield in which we start drawing draws to test that the CNC machine work correctly.

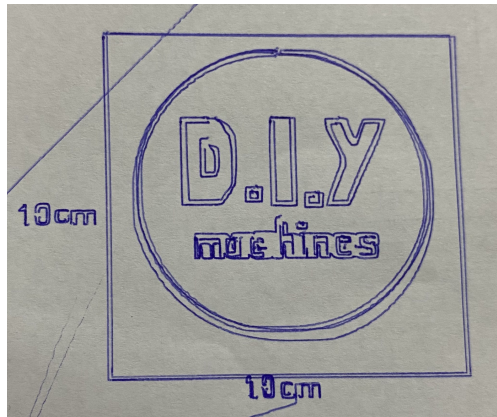


Figure 43, testing example.

Then we test If every component works correctly, so we test the Bluetooth module if it's working correctly and test the microphone, by building a simple application that deals with every component alone.

- Challenged faced:

Control limit switch:

The challenge that we faced is that the system sometimes gives and “hard limit error” that's because of the vibration that happened by the system when it moves, which leads to making a debounce the control limit switch because the quality of that switch, we try to replace with one better quality than the previous one, we reduce the problem but it still happened, we disable the hard limit property from the GRBL firmware because we just use the limit switching in homing so we don't any signal from switches while the system is moving. And the problem was fixed.

- Summary

The system was able to draw from a distance by moving the head in addition to playing the XO with humans.

The process of drawing through the head is working fine, and writing from the user's voice is working correctly.

Chapter 6: Conclusion

The project exploits the head movement through a gyroscope to make a draw, which is this is the first time that a gyroscope uses in this type of application. in addition, to make the system full control with voice by playing tic tac toe and writing what the user spoke, we reduce the resources and we achieved the same goal

- Things we learned:

To build this project, we learned about Arduino programming and Arduino UNO and how it fits our project because it deals with CNC shield.

In addition to the python language that we use to program algorithms in Raspberry Pi.

We also studied a lot about gyroscopes and how they work and their types of them and what is suitable for our project. In addition to studying image processing, modules, and sensor interfacing.

In addition to learning about many mechanical operations that we need in our project, and studying CNC systems.

- Future work:

development on the project to become more accurate, which enables us to use it on a larger scale, so that we can replace the pen holder with a drill to drill BCI boards

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