

AN-NAJAH NATIONAL UNIVERSITY



FACULTY OF ENGINEERING AND INFORMATION
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Graduation Project II

Tic Tac Toe Robot

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Disclaimer

This report was authored by Mai Shelbayeh and Dema Khalili, both affiliated with the Computer Engineering Department within the Faculty of Engineering at An-Najah National University. The report remains unaltered and unedited, aside from editorial adjustments, as per the assessment requirements. It's important to note that the report may contain language and content errors. The opinions presented within, as well as any findings and recommendations, solely reflect those of the students. An-Najah National University bears no responsibility or liability for any repercussions resulting from the utilization of this report for purposes beyond its original commission.

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Abstract

Tic-Tac-Toe Solving Robot is an advanced and intelligent machine designed to play and solve the game of tic-tac-toe, also known as Xs and Os. This summary provides an overview of the innovative features, functions, and potential applications of this remarkable automated system.

Features included in the project:

1. **Boundary Drawing Mode:** A dedicated mode allows users to easily define the boundaries of the game, ensuring accurate gameplay setup.
2. **Multiple Difficulty Levels:** Players can select from a range of difficulty levels, tailoring the game to their skill level and preference.
3. **Voice Guidance:** The inclusion of voice prompts provides helpful guidance to players, enhancing their understanding of the game's dynamics.
4. **Advisory Mechanism:** The system intelligently advises players on the most suitable mode based on their skill level, offering a personalized gaming experience.
5. **Result Display:** A mechanism is in place to efficiently showcase the game's outcome, enabling players to quickly assess their performance.
6. **Camera Scanning:** Utilizing a camera, the system scans the grid on the game board, allowing for accurate interpretation of the game's progress.
7. **3D Printer Integration:** The project employs a 3D printer equipped with a pen to effectively transfer Pc movements onto the physical game board, ensuring precise gameplay.
8. **RGB LED Indicators:** The incorporation of RGB LEDs simplifies user engagement by visually signaling the player's turn during gameplay.
9. **Authorized & Payment Mode :**by using Wiegand reader which connect to ESP to allow us to connect with PhpMyAdmin server.

These diverse features collectively contribute to an immersive and comprehensive gaming experience. By merging technological innovation with strategic gameplay elements, the project not only streamlines the process of playing but also introduces new dimensions of interactivity and guidance.

Report Organization

- First chapter: In this chapter, we will go through the introduction of the project including the problem statement, objectives, scope and significance of the project.
- Second chapter: We will list the constraints we faced and mention earlier coursework that proved to be helpful during the work on this project.
- Third chapter: We will briefly discuss the areas our project covers and some information about how these areas relate to the project in other papers.
- Fourth chapter: In this chapter, we will go into details of how the project works including all the algorithms and hardware parts and tools we used.
- Fifth and final chapter: We will show the contribution of this project and discuss the results

Chapter 1: Introduction

1.1: Statement of the problem

The game of tic-tac-toe, also known as Xs and Os, is a classic and widely recognized two-player game that involves strategic placement of X and O symbols on a 3x3 grid. While seemingly simple, the game poses challenges in terms of optimal decision-making, especially for players aiming to achieve a win or a draw against an opponent or an automated system.

The traditional approach to playing tic-tac-toe relies on human intuition and strategic thinking. However, there exists a need to explore and develop a technological solution that can not only play the game but also exhibit a high level of intelligence and efficiency in decision-making, particularly with regard to strategic moves.

1.2: Objectives and Scope

- The objective that this project seeks to achieve are:

Objective 1: Develop an Interactive Game-playing System

Objective 2: Implement Image Processing Capabilities

Objective 3: Incorporate Multiple Difficulty Modes

Objective 4: Enhance Decision-making Algorithms

Objective 5: Provide Real-time Feedback and Interaction

Objective 6: Foster Learning and Skill Development

Objective 7: Ensure User-friendly Operation

Objective 8: Promote Innovation and Technological Integration

Chapter 2. Constraints and Earlier Coursework

2.1: Constraints

2.1.1 Limited Funding Impacting Precision:

The project encountered a challenge concerning financial constraints, particularly with regards to procuring high-precision motors. Due to budget limitations, we had to opt for less accurate motor models, resulting in compromised accuracy in the 3D printer's performance and subsequent drawing precision.

2.1.2 Resource Scarcity and External Dependencies:

Throughout the project, we faced obstacles due to the scarcity of suitable external libraries and scripts to accomplish specific tasks. Tasks such as image manipulation and drawing 'X' without relying on GCODEs proved challenging due to the unavailability of dedicated libraries. This scarcity necessitated extra time investment in finding alternative approaches.

2.1.3 Quality Compromises in Components:

A significant constraint was the utilization of certain components in suboptimal conditions due to our choice of using pre-owned parts to economize costs. An instance of this was the PiCamera, which displayed diminished image quality and color distortions. Additionally, the stepper motors' sluggish performance slowed down the 3D printer's drawing process, demanding extended periods for execution.

2.1.4 Lack of technical knowledge:

A constraint emerged as the requirement to acquire new technical skills to ensure the project's success. Learning Python became essential for proficient image processing, and mastering tools like EAGLE was necessary for PCB design. The learning curve for these skills contributed additional complexity to the project's development process.

2.2 : Earlier Coursework

2.2.1 Digital Image Processing

The course was a big part of the project, most of the process used to get the image from the camera and into the machine learning model was made of things we learned in the course.

2.2.2 Microcontrollers and PIC

All the basics of the Raspberry, Arduino, and basic serial communication were taken in these courses.

2.2.3 Artificial Intelligence

The main parts of the project are the solving and generating algorithms. To solve a Tic-Tac-Toe game, we needed to use a Alpha-Beta algorithm to get to the solution.

2.2.4 Operating Systems

We used the Raspberry Pi OS, which we flashed on the Raspberry and used the Linux command line to install libraries and packages needed for the project. All those are some things discussed in the course.

2.2.5 Networks and Communication

We implemented the knowledge from this course in many aspects, like setting up a ssh connection with the Raspberry Pi to control it from a laptop, we also needed the knowledge to manage the connection between the Raspberry Pi and the Arduino and ESP32 modules using WI-FI protocols.

2.2.6 Critical Thinking and Research Skills

The research and the writing of this report was done using the knowledge gained from this course.

2.2.7 Electronic circuits courses

These courses highly contributed in dealing with different modules and finding the right power sources and connection for each of them.

2.2.8 Programming courses

Mainly C++ and OOP for writing the codes and algorithms.

2.2.9 WEB Programming:

We implemented the knowledge from this course in many aspects, like we use Xampp as a Server And connect it to the Database

Chapter 3. Literature review

Doing mathematics, and thinking about how you are doing it at the same time, are not the easiest things to do. It is even more difficult if students are not aware that they should be attempting both processes at the same time. They are likely to concentrate on the immediate task of "doing" the mathematics, rather than trying to access the deeper process. Yet it is this deeper process that is really at the heart of mathematics. In turn, accessing this deeper process requires in part some command of the appropriate rational/logical language so communication with yourself and others can proceed effectively and efficiently. This Project discusses the possibilities of using students' explorations of the traditional strategy game "tic-tac-toe," and some extensions, to set up situations for students to discuss and examine this process.

There have been several past research studies that have tackled various aspects related to this project.

In terms of image processing, there have been studies that have focused on techniques for accurately recognizing and interpreting images of Sudoku puzzles. These techniques include image thresholding, edge detection, and pattern recognition. These techniques have been shown to be effective in recognizing the grid and digits in the puzzle.

In terms of puzzle solving algorithms, constraint satisfaction and search algorithms have been widely used to efficiently and accurately solve Sudoku puzzles. These algorithms have been shown to be effective in finding the solution to a puzzle and can be optimized to improve the solving speed.

In terms of puzzle generating algorithms, mathematical algorithms have been proposed to create valid and challenging Sudoku puzzles. These algorithms aim to create puzzles with specific levels of difficulty and constraints to provide a wide range of challenges for the players.

Research related to the use of mobile application, handwriting recognition and puzzle generation have been also done in the past, However, the proposed project is unique in its combination of all the mentioned features and the use of CNC machine with a pen to fill the results on paper in solve mode and to print the puzzle in puzzle mode.

Chapter 4. Methodology

This section is intended to show detailed information about the parts, methods and techniques used to develop the robot and displaying the results

4.1 Image Capturing and Digit Recognition

4.1.1 Image capturing

To get an image of the board, we used PiCamera to capture the image and store it on the Raspberry Pi to access it and extract the information. This was done using the *open cv* library.



Fig (1): Raspberry Pi Camera rev1.3



Fig (2): Raspberry Pi 4

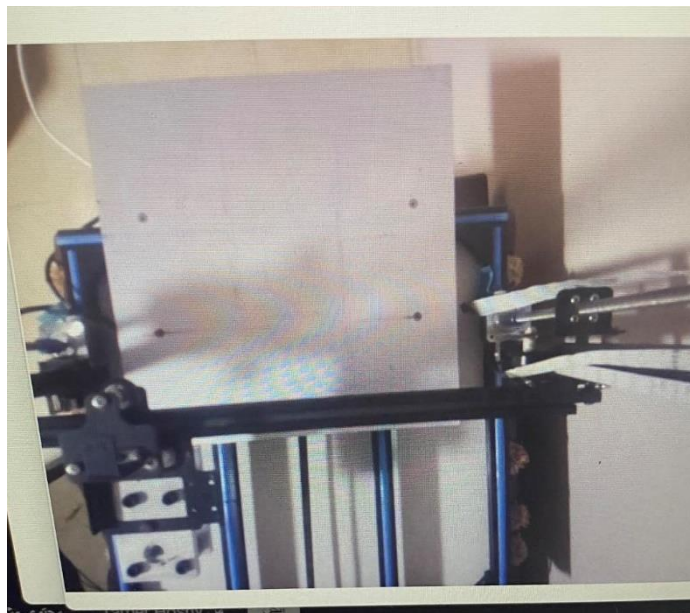


Fig (3): Image Captured by Camera

4.1.2 Image Processing

To analyze the board and detect the user movement to take the best decision for robot movement. Many techniques were used. We will look at them in detail:

1. Importing the image and resizing

The image is imported into the python code using OpenCV and resized to enclose the play area.

2. Detect 'O'

detect O by using circle detection from "photo. Shape" library

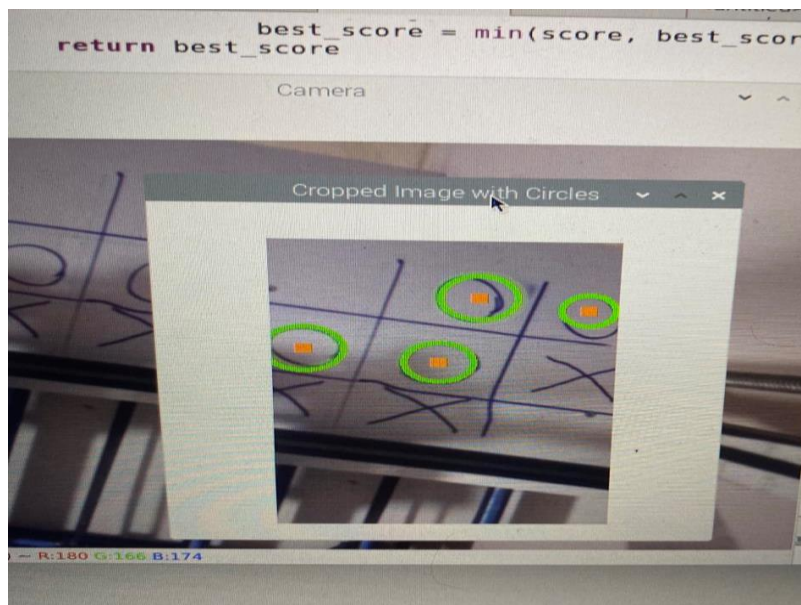


Fig (4): apply detection & cropping for original photo

4.2 Algorithms

The robot operates in three solving modes: hard ,medium and easy
And we have mode to predict the most suitable level for the player.

4.2.1 Hard mode

Alpha-beta pruning is a technique used in game tree search algorithms, such as the minimax algorithm, to improve the efficiency of searching through possible moves in games like tic-tac-toe. It helps reduce the number of nodes that need to be evaluated by pruning branches of the game tree that are guaranteed to not affect the final decision.

Here's a brief explanation of how alpha-beta pruning works in the context of playing tic-tac-toe:

Minimax Algorithm:

The minimax algorithm is used to determine the best move for a player by exploring the game tree up to a certain depth. It works by alternating between two players: the maximizing player (often called "Max") and the minimizing player (often called "Min"). Max tries to maximize the score of the board state, while Min tries to minimize it.

Alpha and Beta Values:

The alpha-beta pruning technique introduces two values, alpha and beta, to keep track of the minimum score that the maximizing player is assured of (alpha) and the maximum score that the minimizing player is assured of (beta) along the path being evaluated. These values are initially set to negative and positive infinity, respectively.

Pruning Branches:

As the algorithm explores the game tree, it updates the alpha and beta values for each node based on the values of its child nodes. If the algorithm determines that a player has a better choice (higher score) elsewhere in the tree, it can prune the remaining branches of the current node. For the maximizing player (Max), if the beta value becomes less than or equal to the alpha value, the remaining branches are pruned. For the minimizing player (Min), if the alpha value becomes greater than or equal to the beta value, the branches are pruned.

4.2.2 Easy mode

In this mode we don't use algorithm just let the robot detect empty places and chose one of them randomly

4.2.3 med mode

In this mode we make mixture between hard and easy mode so We call them mutually (50 % easy ,50%hard)

4.2.4 predict the level

in this mode we make a small calculation which is we take the number of losses game &wins game for this player then the robot will tell the player about his level

4.3 Mechanical Part

This subsection explores the mechanical details and parts that work together to deliver the output to the user. This includes the 3D printing machine.

For the microcontroller, we used an Arduino MEGA with ACCELSTEPPER library modified to match the needs of our 3D printer machine.

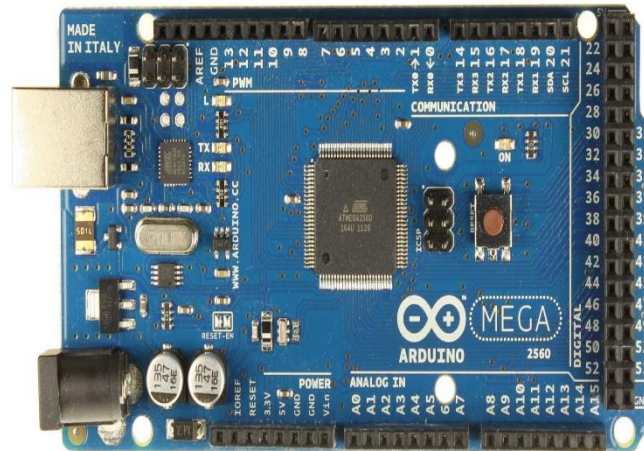


Fig (5): Arduino Mega

For the 3D printer machine itself, we used motor drivers of type YS-DV268N-5A. which is Stepper motor driver based on the system TB6600 allows you to control the motor with a coil with the voltage from 12 V to 48 V. It has six control modes: full-step, noncircular 1/2, 1/2, 1/4, 1/8 and 1/16.



Fig (6): Stepper motor Driver

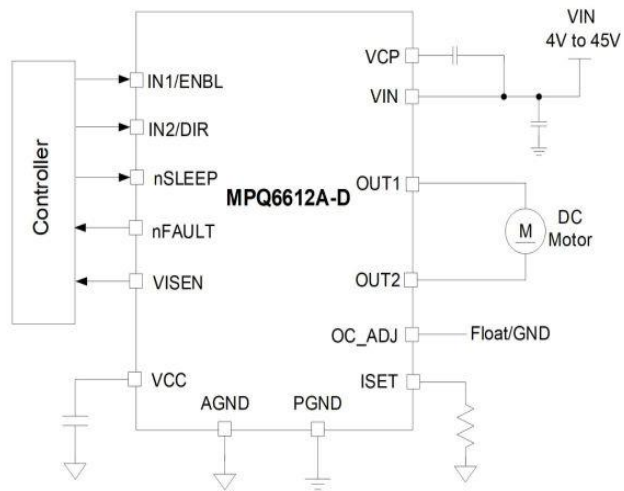


Fig (7): DV268N Driver Connection

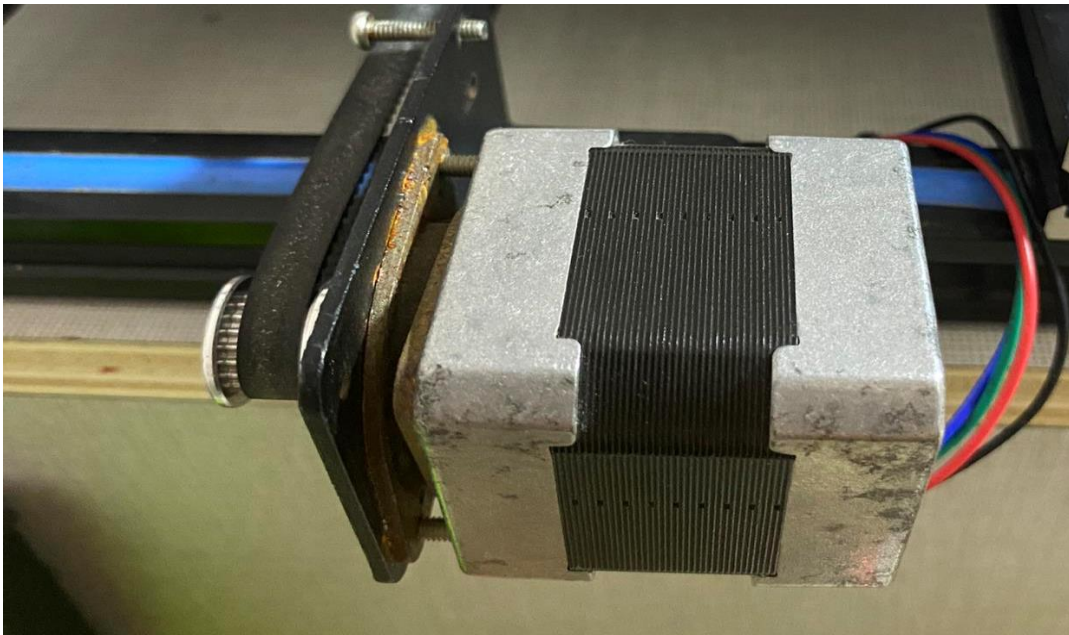


Fig (8): Stepper Motor

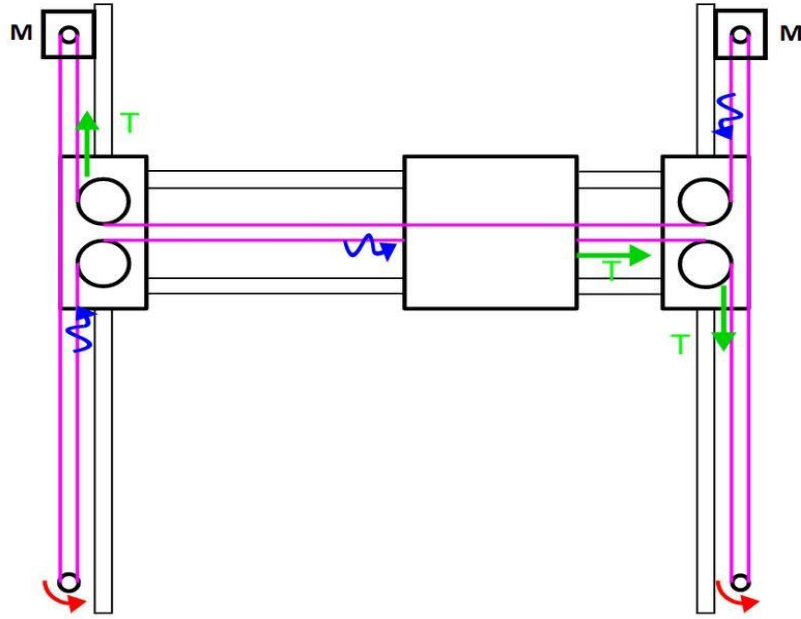


Fig (9): Movement of 3D printer in X, Y and Z direction

We use Wiegand to read the player card for registration process



Fig (10): Wiegand reader

We use them to select the difficulty of game



Fig (11): push buttons

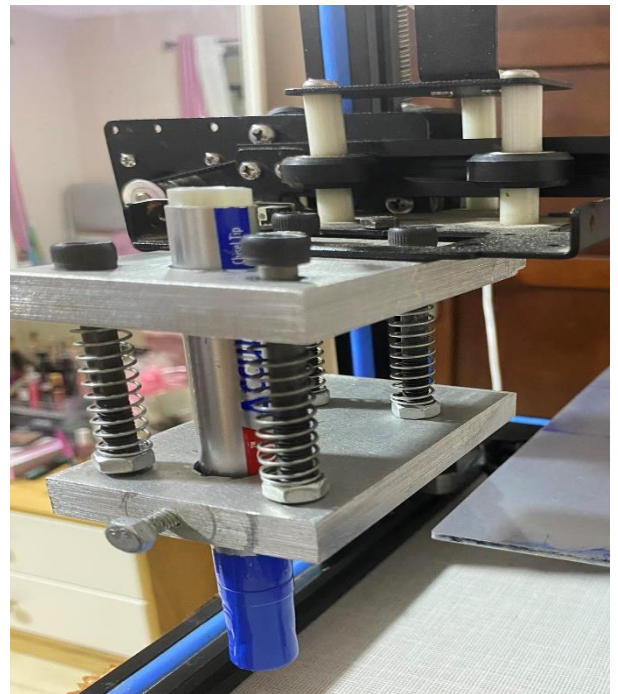
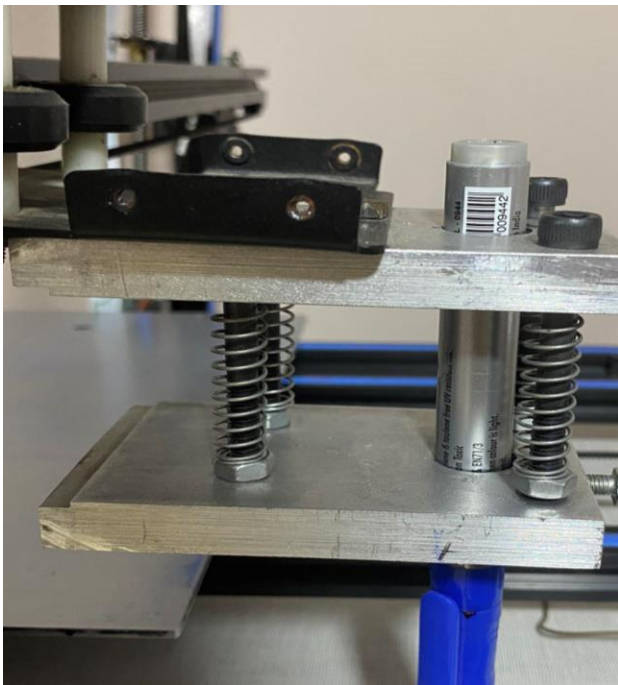


Fig (12): Pen Holder

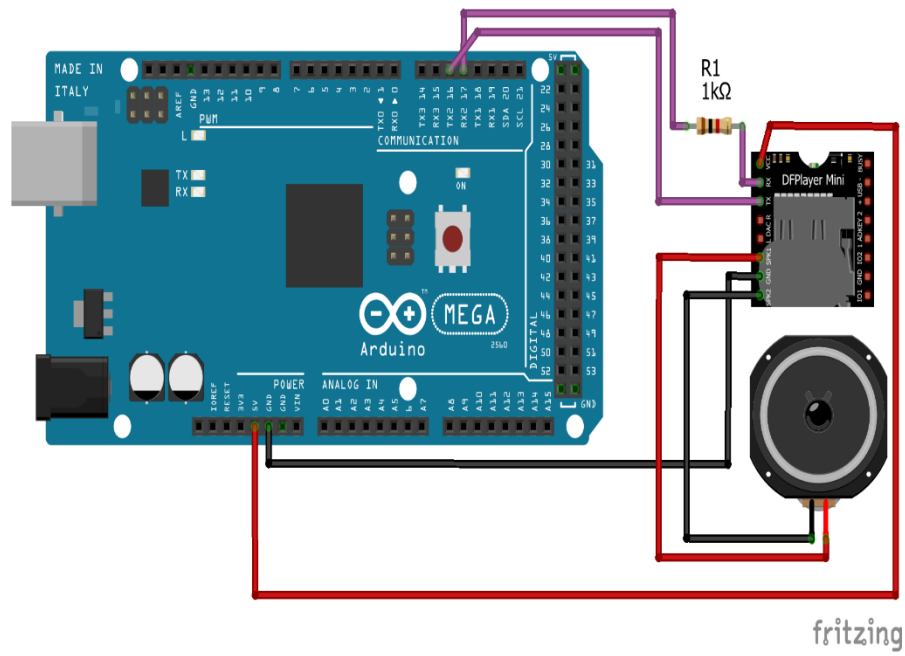


Fig (13): mp3 connection

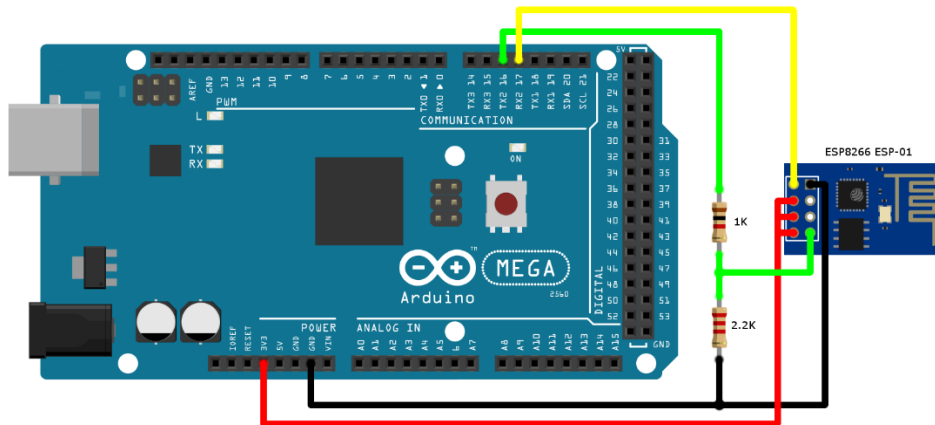


Fig (14): ESP connection

Other parts shown below include: Bearings, 8mm steel bar, belt, 3mm screw, 3mm nut, 4mm screw, 4mm nut, threaded bar, 10mm nut



Fig (15): Other 3D printer Parts

4.4 LED Matrix

4.4.1 Connect LEDs

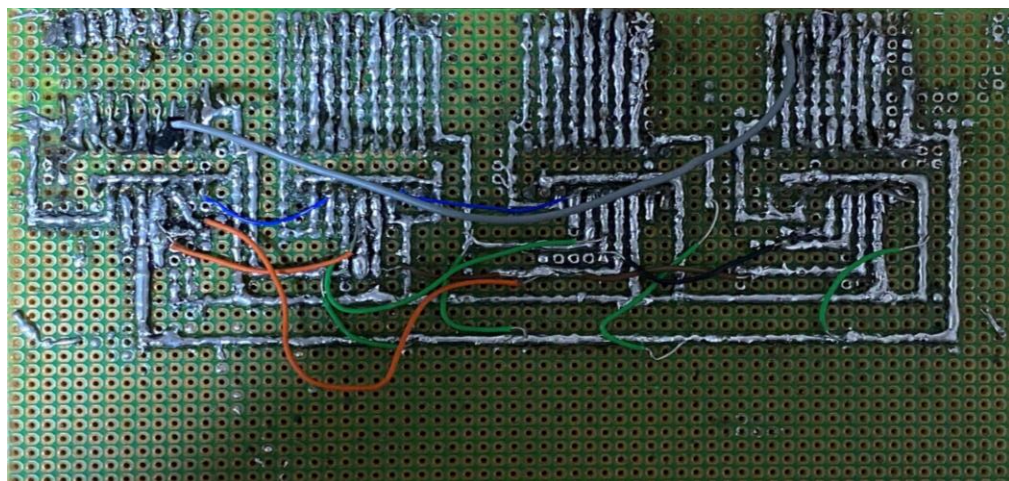
Initially, we embarked on crafting a bespoke LED Matrix from its very foundations. The matrix consisted of a total of 192 LEDs, meticulously soldered together to form a cohesive unit. Each LED was interconnected according to a specific arrangement.



Fig (16): Handmade LED MATRIX

4.4.2 The Circuit

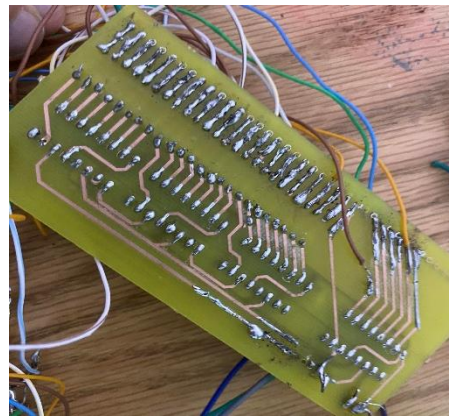
Regarding the electronic circuitry governing the behavior of the LEDs, we utilized a configuration comprised of four 74595 shift registers. Out of these, one was dedicated to controlling the rows, while the remaining three assumed the responsibility of managing the columns. We methodically crafted this circuit by meticulously soldering the components together, closely adhering to the schematic diagram depicted in the figure. Despite our best efforts, the circuit did not perform as anticipated, failing to yield the desired outcome.



4.4.3 Alternative Solution

Subsequently, owing to the intricate nature of the initial circuit, we reached a decision to embark on a reconstruction endeavor. Opting for a more streamlined approach, we resolved to adopt a PCB (Printed Circuit Board) design. The creation process commenced with the utilization of the Eagle program, meticulously crafting the layout and interconnections. However, an unfortunate delay ensued during the printing phase, overseen by the university, which extended beyond the expected deadline to August 22nd.

Given the constrained timeframe, the practicality of completing the project within the stipulated period was jeopardized. Faced with this challenge, we pivoted to an alternative solution – the adoption of pre-fabricated dot matrix modules. This strategic shift allowed us to navigate around the time limitations and proceed with the project despite the obstacles encountered during the earlier stages.



In our pursuit of assembling the dot matrix, we systematically undertook the following steps:

For building this part we use Arduino Nano, Dot Matrix MAx7219.

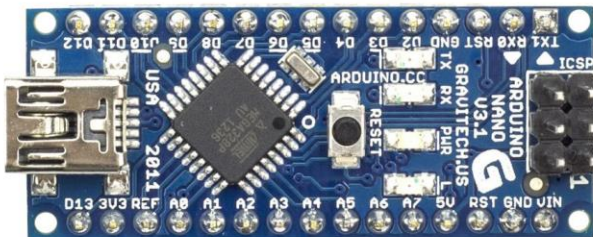


Fig (18): Arduino Nano & Dot Matrix

In order to establish the necessary connections for the matrix, we engaged with a set of five wires. Among these, two wires were designated for powering the matrix - one for VCC and the other for grounding. The remaining three wires were earmarked for integration with the Nano board. These connections involved associating the CS pin with D10 on the Nano, the CLK pin with D13, and the DIN pin with D11. Incorporating this setup, our objective revolved around enabling a specific text to elegantly scroll across the matrix, thereby breathing life into the display.

Chapter 5. Results and Discussions

5.1 Testing

To ensure the seamless functionality of our Tic Tac Toe-playing robot, our project commenced with the meticulous assembly of the requisite components for configuration. Beginning with the external model housing the precision-engineered stepper motors, we embarked on a systematic approach to activate each motor individually. This process was initiated through the utilization of the Arduino Mega platform, allowing us to methodically set the motors into motion, one by one.

Regarding the process of inscribing the X symbols, our development team ingeniously crafted a custom code within the Arduino IDE application. This carefully constructed code underwent meticulous refinement to ensure its impeccable drawing accuracy. Subsequently, the code's effectiveness was methodically assessed by executing it within each of the nine distinct game squares, ensuring precise and consistent X symbol rendering. This process was undertaken in a systematic progression, commencing with the inception of the foundational code responsible for outlining the game boundaries.

Image Processing and Recognition Testing:

Ensure the acquisition of accurate images and their meticulous analysis to facilitate informed decision-making.

Integration Testing:

Following the comprehensive analysis, the pivotal phase of integration unfolds, orchestrating a seamless interaction between the player and the robot. Once the player completes their turn, the transition to the robot's role commences. This transition is marked by the transmission of a tailored serial command containing the designated square number in which the robot is poised to make its move.

Conclusion and Recommendations

Conclusion

As we near the culmination of this enriching journey, we find ourselves standing at the crossroads of a new experience that seamlessly marries the realms of technology and gaming. Along this path, we encountered our fair share of challenges and setbacks, each of which presented an invaluable opportunity for growth and learning. As we reflect on this transformative process, it becomes evident that our efforts to bridge the gap between innovation and recreation have not only led to novel discoveries but also shaped us as individuals and as a team. In the face of errors and obstacles, we persevered, paving the way for a harmonious fusion that resonates with the spirit of progress and determination, by following the suggested recommendations, we hope to achieve a more accurate experience

Recommendations:

Amidst the dynamic fusion of technology and entertainment that our tic-tac-toe robot embodies, it's worth acknowledging the impressive strides we've already achieved. However, as we stand on this advanced threshold, there lies an exciting realm of possibilities waiting to be explored. These recommendations hold the potential to propel our innovation to even greater heights, enhancing its capabilities and forging a path toward uncharted territories of excellence:

Upgrading Stepper Motors for Improved Accuracy:

To achieve enhanced precision and accuracy, it is recommended to consider upgrading the stepper motors to newer versions. Modern stepper motor models incorporate advanced technologies that offer finer control and more precise movements. and provide players with a more engaging and satisfying interaction with the robot.

Improving Image Detection for Enhanced O Recognition

While the initial model demonstrated impressive accuracy during the training phase, its performance in real-world scenarios fell short of expectations. The intricacies of recognizing handwritten or drawn characters, such as the "O," require a more intricate and refined approach.

Extending Camera Wire Length for Flexibility

When integrating a camera for real-time monitoring and decision-making, it's essential to ensure that the wire connecting the camera to the Raspberry Pi is of sufficient length. A longer camera wire provides greater flexibility in positioning the camera, enabling optimal coverage of the game board and ensuring that the robot captures all relevant gameplay moments.

FUTURE WORK

Interactive Integration with ESP Module:

Consider integrating the tic-tac-toe robot with an ESP module, like developing smart app control, that communicates with players, allowing them to control the robot remotely. Players could make moves, initiate games, and even receive real-time updates and notifications.

Dynamic Gameplay Modes:

Designing different gameplay modes. Consider incorporating variations like larger boards, time-based challenges, or even multiplayer options to cater to different preferences and skill levels.

Teaching Mode:

Creating an educational mode where the robot offers tips, strategies, and insights on optimal moves could turn the game into a learning opportunity, especially for younger players.

Advisory Mechanism:

Intelligent mechanism to advise user of the best mode depends on the skills and development play.

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