An Najah National University
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Connect-4 Game Robot

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Disclaimer statement

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Chapter 1

Introduction

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Embark on an immersive exploration where hardware innovation and AI merge seamlessly. Join us in uncovering the heart of an AI-powered 4-connect game – a fusion of tradition and cutting-edge intelligence. This project showcases the synergy of human creativity and technological advancement, revealing how advanced algorithms conquer challenges once thought unique to human thinking.

1.1 General background

Explore the timeless allure of the 4-connect game, where players strategically place tokens in a grid to form sequences. This seemingly simple puzzle conceals a mental challenge that requires sharp thinking and precise moves. From its modest beginnings, the 4-connect game has evolved into a showcase of skill and strategy, uniting tradition with modern smart entertainment.

1.2 Objectives

2. Objectives of the Work: Our project seeks to enhance the 4-connect game experience by blending hardware and artificial intelligence. Our primary objective is to introduce an AI opponent, transforming the game into a strategic arena where human intelligence faces off against computational sophistication.

Additionally, we're committed to refining the user interface for a seamless blend of aesthetics and functionality. This enhancement will elevate the gaming experience while maintaining simplicity and accessibility.

Moreover, our project introduces a practical feature – the autonomous separation of red and yellow balls after a game concludes. This innovative functionality prepares the board for a fresh round of play, streamlining the process for players.

Our objectives reflect a balanced approach to enhancing game play, user interaction, and practical convenience. The combination of these elements embodies the core spirit of our project.

1.3 Significance or importance of your work.

This project goes beyond entertainment, marking a pivotal junction where artificial intelligence converges with classic gaming. It heralds an era of seamless human-technology collaboration, unveiling the intricate fusion of human creativity and cutting-edge tech. The revelation of AI's decision-making in gameplay serves as a window to the future, with implications spanning industries like finance and healthcare. This innovation leaves an enduring impact on progress beyond gaming.

1.4 Organization of the report

Our report is thoughtfully divided into key sections to guide you through the creation of an AI-powered 4-connect experience. Begin with the Theoretical Background and Previous Work for context, followed by the Methodology detailing our approach.

Transition to the Results and Analysis for empirical findings and interpretations. The Discussion section places results in a broader context, while Conclusions and Recommendations summarize achievements and suggest future directions.

The report concludes with References, acknowledging our sources. Join us on this journey as classic gaming meets AI innovation, showcasing the fusion of human ingenuity and AI's capabilities.

Chapter 2

Theoretical Background

Contents

2.1 2.1 Game Development and 4-Connect Gamer

2.1.1 Game Development Principles

Game development is a multidisciplinary field that combines elements of programming, design, graphics, sound, and user experience to create engaging interactive experiences. It involves creating rules, mechanics, and visuals that captivate players and provide a satisfying gameplay experience. Understanding the principles of game design, such as balancing challenge and reward, user engagement, and user interface design, is crucial in crafting an enjoyable game.

2.1.2 Connect Four Game

The 4-Connect game, known as Connect Four, is a classic abstract strategy game. Players aim to create a sequence of four colored discs in a row – horizontally, vertically, or diagonally – within a 7x6 grid. Despite its apparent simplicity, this game offers strategic depth, captivating players of all ages. The gameplay starts with an empty grid. Players alternate placing their discs from the top into columns. Discs fall to the lowest available spot. The goal is to form a sequence of four discs of one's color while preventing the opponent from doing the same. Each move demands careful evaluation of immediate and future winning opportunities, making every placement a strategic choice.

2.2 Artificial Intelligence in Gaming

2.2.1 AI in Game Opponents

AI algorithms play a crucial role in game playing, enabling computers to make intelligent decisions and compete against human players. Some common AI algorithms used in game playing include:

1-Minimax Algorithm: This algorithm is used to make decisions in two-player, zero-sum games (where one player's gain is another player's loss). The basic idea is to simulate all possible moves and their outcomes, considering both the player's and opponent's strategies. The algorithm aims to minimize the maximum possible loss for the worst-case scenario.

2-Alpha-Beta Pruning: Alpha-Beta is an optimization technique that enhances the minimax algorithm's efficiency. It reduces the number of nodes evaluated by not exploring certain branches of the game tree that are guaranteed to be worse than previously evaluated branches. This pruning is achieved by maintaining two values, alpha (the best value found so far for the maximizing player) and beta (the best value found so far for the minimizing player).

2.3 Interactive Hardware Systems

Interactive hardware systems involve designing physical interfaces that enable users to interact with software applications. These interfaces encompass buttons, switches, sensors, and displays that facilitate user input and feedback. Creating an intuitive and responsive hardware interface enhances the overall user experience and immersion in the game.

Chapter 3

Methodology

Contents

3.1 Introduction

This chapter outlines the methodology adopted for the design and implementation of the 4-connect game hardware project. The methodology encompasses adherence to engineering standards, consideration of design constraints, the design process followed, tools and technologies utilized, and project management strategies employed to ensure successful project completion.

3.2 Standards and Specifications (Codes)

We managed to follow Engineering standards in 4-Connect Robot project, going with Agile Method with weekly meetings and discussion about each of the features each step, Starting with the machine mechanics ending by the factory testing and modifying, we built the machine level by level, each level as a feature.

3.3 Constraints

Economy

Our commitment to fiscal responsibility was a guiding principle throughout the development of our AI-driven 4-connect game project. With a defined budget ceiling of $800, we navigated the design landscape with precision, ensuring that every financial decision contributed to the project's success without surpassing the established limit.

Budget Allocation Strategy The project's financial blueprint was strategically crafted to optimize costs while delivering an exceptional gaming experience. The breakdown of expenses showcases the pragmatic approach we adopted to ensure efficient resource utilization: Components produced via CNC machining incurred costs of approximately $130. This manufacturing process, known for its precision, contributed essential structural elements to our game, enhancing both stability and gameplay dynamics. Leveraging the cost-effectiveness of 3D printing, components produced through this method amounted to $140. These elements, while less mechanically stressed, remained integral to the overall functionality and aesthetics of the game.

Budget Adherence and Fiscal Excellence Staying well within our $800 budget constraint was a testament to our commitment to fiscal excellence. At each phase of the project, meticulous cost analysis informed our decision-making, culminating in a finely balanced allocation that maximized the project's value without exceeding budgetary limits.

Environment

In creating the 4-connect Robot game hardware project, we also took the environment into account. We made sure to use power efficiently by optimizing how the system uses energy. We worked on reducing noise, so the game doesn't create too much sound. When the game reaches the end of its life, we have plans to recycle its parts properly. Our project follows environmental guidelines, showing our commitment to making a fun game while also being responsible for the Earth.

Society

This project has societal relevance. It could be a recreational outlet for assisted living communities, benefitting disabled and elderly individuals. Privacy and data security measures are taken, even though user information isn't collected.

Politics

The project has political implications. Its inclusive design supports gender and race equality, . The engaging nature of the game might also foster problem-solving skills, contributing to addressing common issues. This project's impact extends beyond entertainment, aligning with social values.

Ethics

In terms of ethics, the project prioritizes safety and health considerations, ensuring a secure and enjoyable user experience. Additionally, a commitment to respecting intellectual property rights and maintaining user privacy underscores the project's dedication to integrity and responsible design.

Health and Safety

The 4-connect robot game project prioritizes public and consumer safety, adhering to strict standards. Worker well-being throughout manufacturing is also a key focus, ensuring comprehensive health and safety considerations.

Manufacturability

The 4-connect robot game project demonstrates manufacturability through designs aligned with current manufacturing technology. Its feasibility for physical implementation underscores a practical approach, enhancing the project's viability and potential impact.

Sustainability

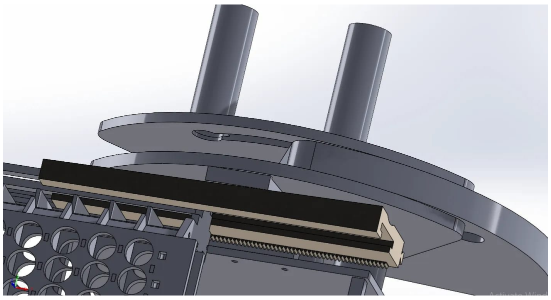
The 4-connect robot game project embraces sustainability by prioritizing design reliability and durability. Its adaptable framework supports future upgrades, while its resilience to diverse environmental conditions ensures a lasting and impactful user experience.

3.4 Design Process

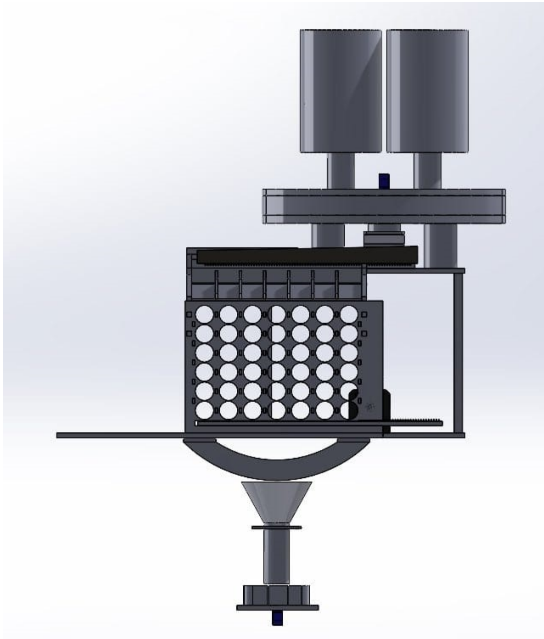
Our project consists of three main components, with the first part playing a pivotal role in this process. This involves releasing the balls from dedicated tubes and introducing them into the game grid through three specially designed pieces to drop the ball from the specified tube to the designated column. To accelerate the movement of the balls, a straight and slightly inclined piece is used at the top of the grid.

Players have two methods to drop their ball, and they must choose before the start of each round. They can manually drop the ball into the desired column using their hands, allowing for an active style of play. Alternatively, they can use the keyboard by selecting the column number they wish to play in. In this case, the robot independently places the player's ball in the chosen column. These choices add flexibility to the gaming experience and align with the preferences of different players..

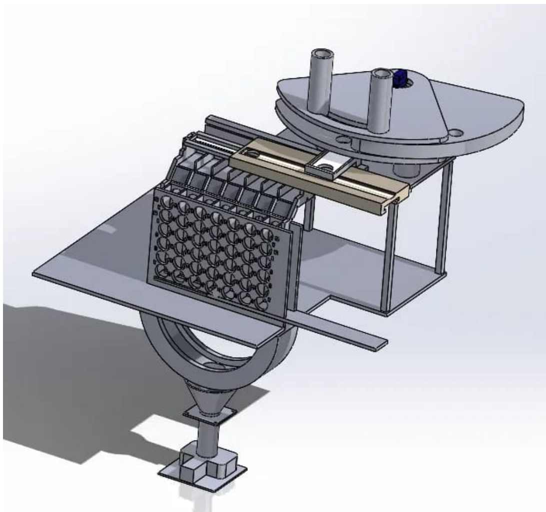
Firstly, there are three interconnected pieces. The first piece, featuring two openings (one under each cup), is placed under the cups and remains stationary. It is connected to a servo motor for moving the second piece located beneath it. This second piece is the only one that moves left or right based on the color of the next ball. After the ball is dropped inside the second piece, it moves to align with the opening in the third piece, where the ball is then dropped inside it. The third piece also has a single opening and remains fixed. This mechanism is designed solely to correctly transfer the ball from the cups to the game grid, depending on which cup the ball was released from. The purpose of the first piece is to secure the servo motor for movement, while the second piece is for transferring the ball after it's released from the cup to the opening of the third piece.



(a) The Main Part Closer

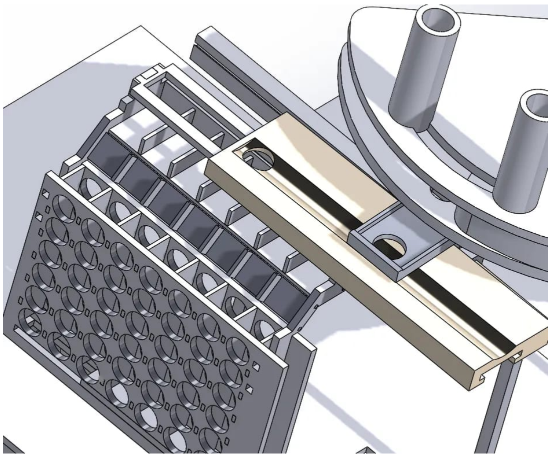


(b) The main part from the back



(c) The main part (front)

This represents the initial design of the main component, which underwent significant modifications later. Numerous details have been incorporated into the design.



(d) The main part

These diagrams provide a clearer depiction of the intricate details and interconnections between the components.

Figure 3.1: Main Part

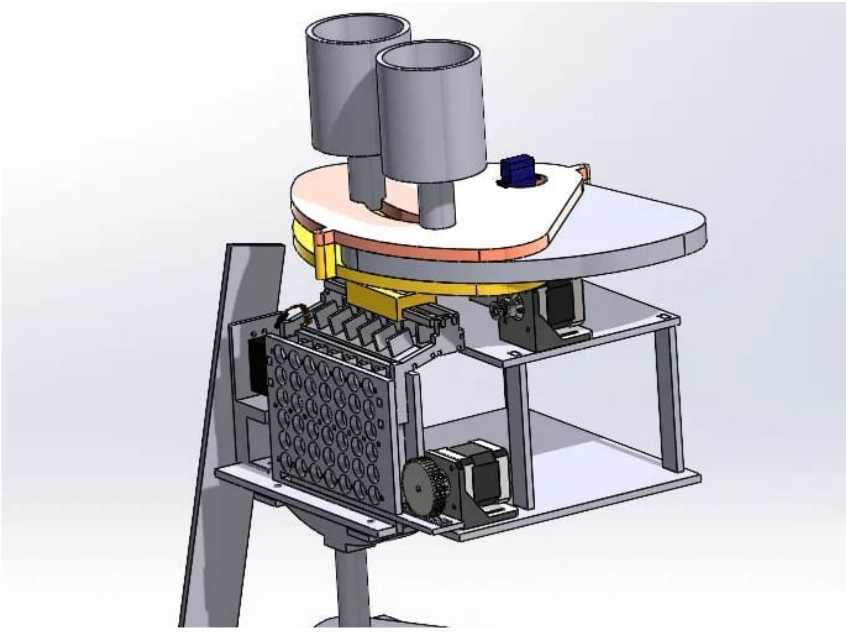
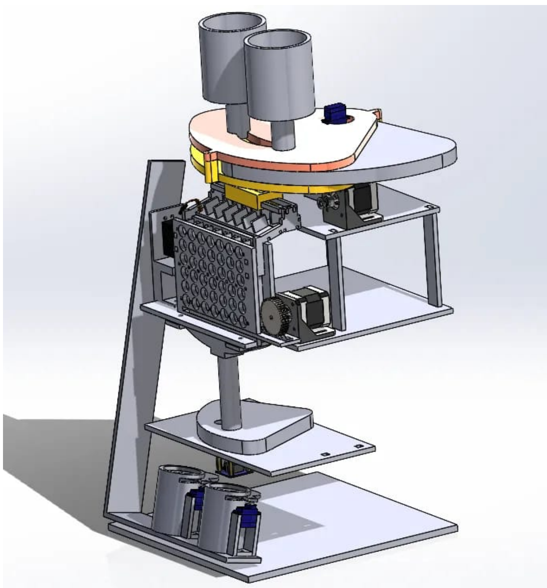
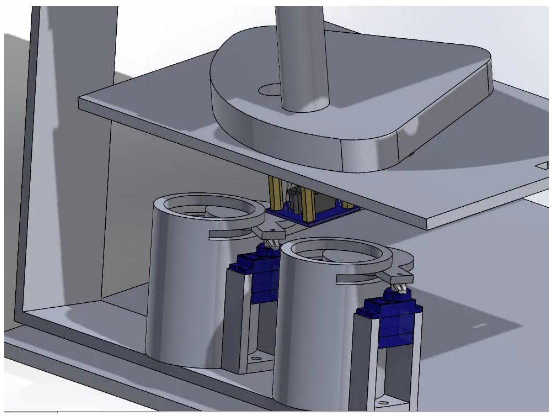


Figure 3.2: top part.

Two stepper motors are responsible for the core functions. The first motor, located at the top, moves the belt either left or right, thereby determining the desired column where the ball will be released. Initially, the column to drop the ball into is determined by the stepper motor, which moves the entire upper part of the mechanism. Then, the ball is released from the cup into the chosen column.



(a) The complete assembly.

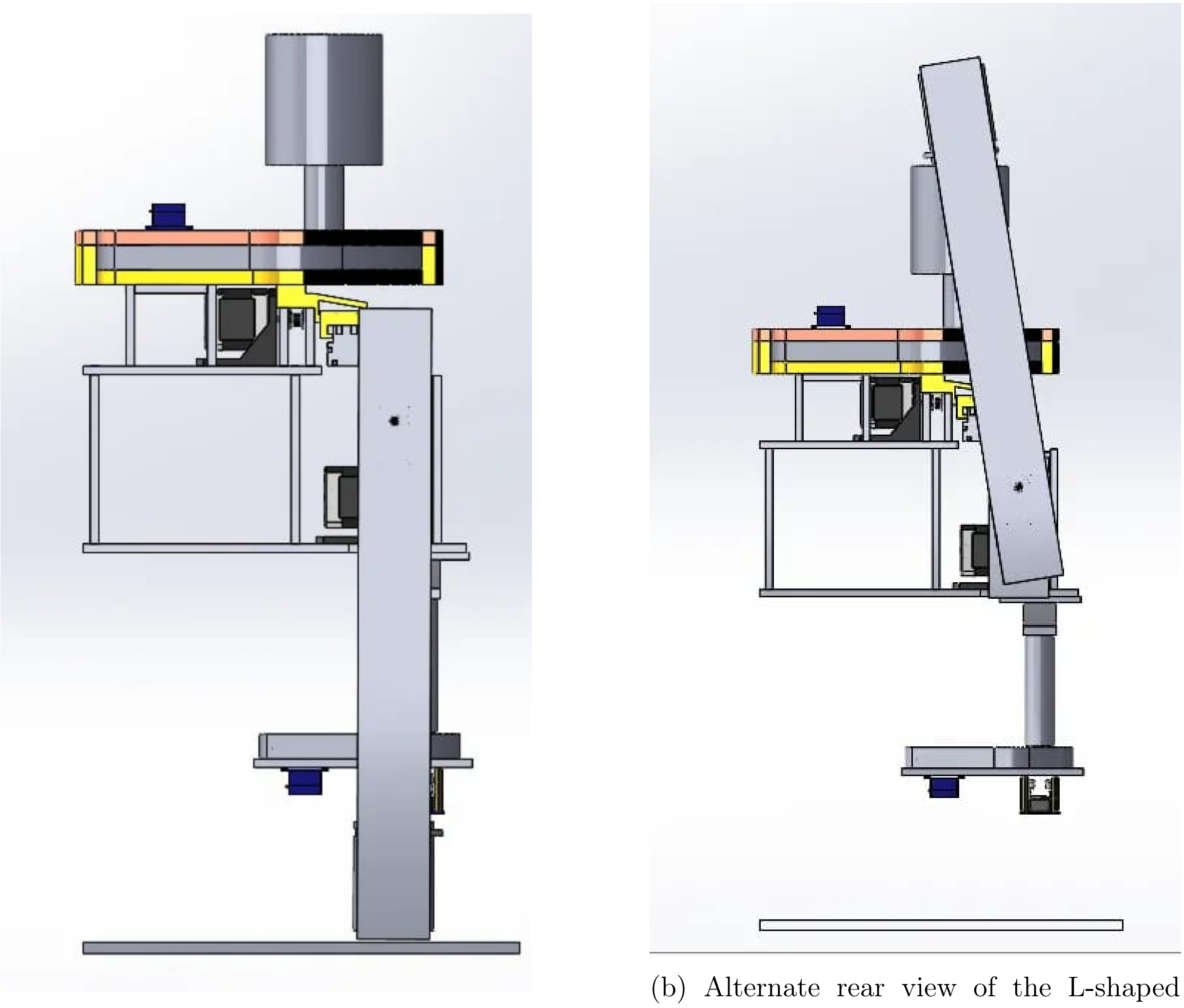


(b) The tubes with servo motors.

Figure 3.3: Second Part

After concluding the game, whether due to one player's victory or simply by pressing the ball sorting button, the second main phase of the project commences. This phase focuses on the process of sorting the balls after the match. To achieve this, the second stepper motor located at the base of the game grid is activated. This motor maneuvers a rod to the right across the column's width, facilitating the smooth discharge of the column by allowing its balls to descend smoothly through the funnel. Subsequently, the motor shifts one step further to the right, causing the release of the next column's balls, and this pattern continues. This process repeats sequentially until all seven columns are emptied of their balls.

Once the balls enter the funnel and drop into a circular hole located on a movable triangular piece at the bottom of the funnel, they are received by a color sensor. This sensor, separated from the triangular piece by another transparent piece, serves the dual purpose of carrying the triangular piece with the ball inside and holding the servo responsible for moving the triangular piece. It has two openings, each with a cup underneath to contain the separated balls. The color sensor analyzes the color of each ball. Upon color recognition, the attached piece at the end of the funnel is moved by a servo motor. This movement effectively guides each ball to the appropriate cup according to its color; red balls go into one cup, while yellow balls find their place in the other cup. This marks the completion of the second main phase of the project.



(a) Rear view of the L-shaped component.

(b) Alternate rear view of the L-shaped component.

Figure 3.4: The Final Part: Different Rear Views.

The third part of the project involves retrieving and lifting the balls from the bottom after the sorting process, sending them upwards through the large tubes for a new game.

This part might appear simple, and its execution straightforward, but in reality, it's not that straightforward. Initially, we considered various ideas to accomplish this task, such as using a robotic arm or a motor to blow air to lift the balls from below, or a motor to suction the balls from the bottom to the top.

While these ideas are intriguing, they are not the simplest and might require more time for execution and design complexity. However, the idea eventually implemented is simpler than what was mentioned earlier, despite its challenging execution.

It involves two pieces shaped like the letter "L." The upper part of the "L" is connected to a servo motor at the game grid level. The lower part of the "L," which serves as the base, holds the two cupss containing the sorted balls. Each cup's surface has a cover that is sealed after the sorting process using a servo motor located on each cup. After sealing the cups, the "L" structure rotates at a specific angle to invert the tubes from bottom to top. At the moment when the lower cups meet the upper ones, the covers are opened again, causing the red balls to fall into the first cup and the yellow balls into the second cup. The upper cupss are designed larger than the lower ones to accommodate the balls during the dropping process.

3.5 Tools and Technologies

Our AI-driven 4-connect game project was brought to life through a range of essential tools and techniques. These resources served as the catalyst for transforming ideas into a tangible, captivating product, while also enabling the harmonious convergence of hardware, software, and AI algorithms. In the following sections, we outline the core tools and techniques that underpinned our project's evolution and formed the bedrock of its achievement.

Arduino Mega

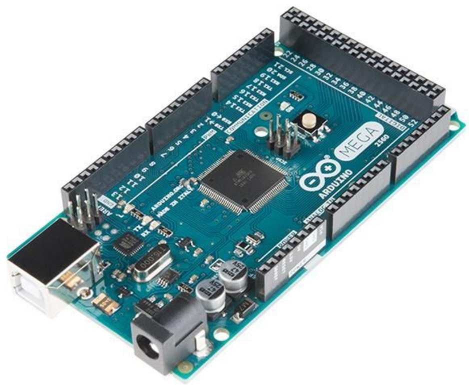


Figure 3.5: Arduino Mega.

Absolutely! At the core of our hardware project is the Arduino Mega, a microcontroller packed with 54 digital I/O pins, 16 analog inputs, and 256 KB of memory. These pins serve as the connectors for our game's components – buttons, LEDs, and sensors – enabling smooth player interaction and AI implementation. Through the Arduino Integrated Development Environment (IDE), we craft intricate code, bringing the game to life and controlling the AI's decisions using the Alpha-Beta algorithm. The IDE also facilitates real-time communication with the Arduino Mega, allowing us to upload and execute code seamlessly. This dynamic interaction between hardware and software forms the backbone of our game, where the Arduino Mega's adaptability and memory contribute to a responsive and intelligent gaming experience, truly showcasing the fusion of technology and entertainment.

NEMA 17 stepper motor 17HS4401

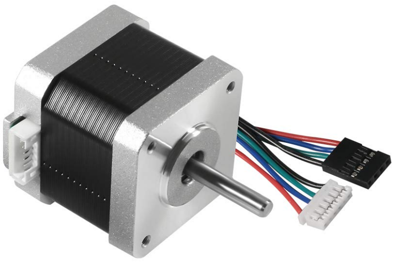


Figure 3.6: NEMA 17 stepper motor 17HS4401.

NEMA 17 stepper motor, such as the 17HS4401 model, is renowned for its precise control. It adheres to NEMA 17 standards with a 1.8-degree step angle (200 steps per 360-degree rotation). This motor boasts considerable holding torque—its static position maintenance force. It's widely used in precise positioning tasks like CNC machines, 3D printers, gimbals, and robotics.
Regarding its electrical needs, the 17HS4401 has specific current and voltage ratings for optimal performance. It adheres to NEMA 17 dimensions—42mm by 42mm faceplate, 5mm shaft. It comes in unipolar and bipolar coil setups, influencing wiring and control methods. Its popularity in maker and engineering communities stems from its versatile compatibility and integration ease.

TCS3472 color sensor

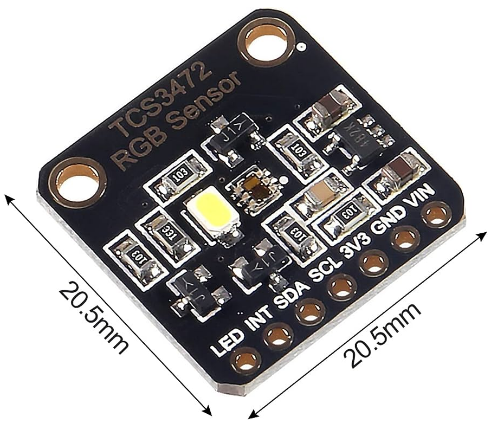


Figure 3.7: TCS3472 color sensor.

The TCS3472 is a compact color sensor module designed to accurately detect and measure colors in different lighting conditions. It incorporates red, green, and blue (RGB) light sensors along with a clear light sensor, converting the captured data into digital signals via an integrated analog-to-digital converter. Equipped with an IR blocking filter and suitable for various lighting scenarios, it communicates through I2C protocol, making it applicable in diverse fields like consumer electronics, industrial automation, healthcare, and robotics for tasks such as color sorting, display adjustment, and quality control.

High Torque Waterproof RC Servo

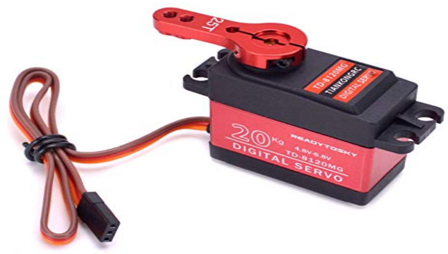


Figure 3.8: High Torque Waterproof RC Servo.

The 25KG High Torque Waterproof RC Servo is a robust and versatile servo motor renowned for its ability to deliver a substantial 25 kilograms-force centimeters of torque. This makes it a go-to choice for demanding tasks in remote-controlled vehicles, robotics, and various other applications where precise and powerful movement control is essential. Moreover, its waterproof design adds an extra layer of reliability, making it suitable for deployment in environments where exposure to moisture and water is a concern, ensuring continued performance even under challenging conditions.

SG90 servo motor

Figure 3.9: SG90 servo motor.

The SG90 servo motor is a compact and affordable device widely used for controlled rotational motion. With a rotational range of approximately 180 degrees, it operates via pulse width modulation (PWM) signals, enabling accurate positioning. Its small size and lightweight nature make it suitable for various applications, from hobby projects and RC vehicles to simple robotics and camera pan-and-tilt systems. While offering an accessible entry point into servo technology, the SG90 may have limitations in terms of torque and precision compared to larger and more advanced servo models.

Sensor IR

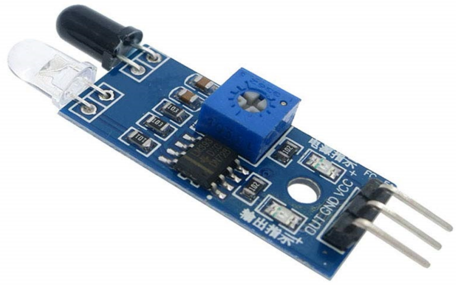


Figure 3.10: (IR) sensor.

An infrared (IR) sensor is a versatile component that detects infrared radiation in its surroundings, converting it into electrical signals. Commonly used in various applications, IR sensors can sense heat emitted by objects or detect motion based on changes in IR radiation. They find application in remote controls, proximity sensors, and security systems, among others. Depending on the specific type, IR sensors can detect objects, measure temperature, or capture movement, making them integral to a wide range of devices and systems.

l298n motor driver

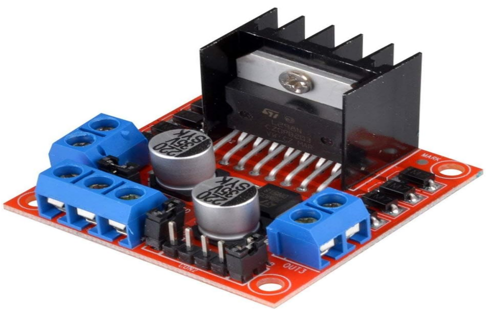


Figure 3.11: l298n motor driver.

The L298N motor driver module is a widely used dual H-bridge motor controller that enables the control of two DC motors or a single stepper motor. It is capable of driving motors with higher current and voltage requirements, making it suitable for various robotics and automation projects. The module offers both forward and reverse control for each motor and can handle peak currents, contributing to efficient motor operation. The L298N's compatibility with microcontrollers and ease of integration have made it a popular choice for driving motors in applications such as mobile robots, CNC machines, and remote-controlled vehicles.

LCD Display

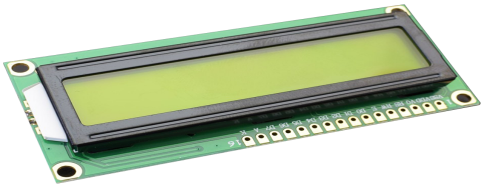


Figure 3.12: LCD Display.

An LCD (Liquid Crystal Display) is a flat-panel display technology that uses liquid crystals to modulate light and create images or text. LCD displays are commonly used in electronic devices such as televisions, computer monitors, smartphones, and digital clocks. They offer high-quality visual output with sharp images and a wide range of colors. LCDs consist of pixels that can be individually controlled to display different colors and patterns. They are energy-efficient and come in various sizes and resolutions, making them suitable for diverse applications including information displays, user interfaces, and visual output in electronic devices.

Keypad

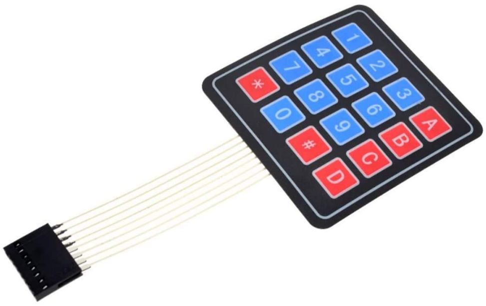


Figure 3.13: Keypad.

keypad, short for "keypad entry system" or "keypad input device," is a user interface component that consists of a set of buttons arranged in a grid or array. Each button typically represents a specific character, digit, or function. Keypads are commonly used for entering numerical data, text, or commands into electronic devices, security systems, and other applications. They can be found on devices like calculators, remote controls, security alarm panels, and ATM machines. Keypads provide a convenient and tactile way for users to input information, and they are often used in combination with other display technologies like LCDs to create user-friendly interfaces.

Power Supply

Figure 3.14: Power Supply.

A power supply is an essential electronic component that converts input voltage from a source, such as a wall outlet or a battery, into the required output voltage and current needed to operate various electronic devices. Power supplies provide the necessary energy to run everything from small gadgets to complex systems. They come in various forms, including AC-DC adapters for household devices, DC-DC converters for voltage regulation, and power distribution units (PDUs) for data centers. Power supplies ensure stable and reliable operation of electronics by delivering the appropriate and consistent electrical power for their functioning.

I2C module for lcd

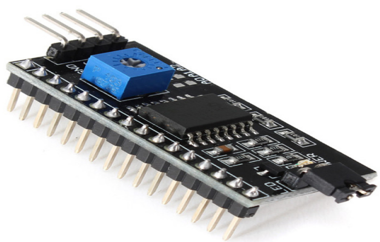


Figure 3.15: I2C module for lcd

An I2C module for LCD simplifies connecting and controlling an LCD screen using the I2C communication protocol. It reduces wiring by using fewer pins and is commonly used in projects with limited microcontroller pins. This module makes integrating LCDs into devices like IoT systems and robots easier and more efficient.

I2C Matrix Keypad

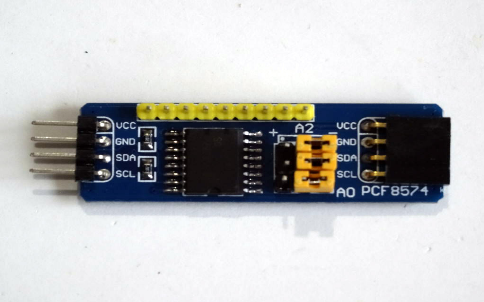


Figure 3.16: I2C Matrix Keypad.

An I2C matrix keypad with PCF8574 is a setup that links a matrix keypad to a microcontroller via the I2C communication protocol. The PCF8574 expander helps connect the keypad to the microcontroller using minimal pins. This is useful for projects needing user input, like electronic locks and industrial controls.

DC-DC buck converter

Figure 3.17: LM2596 DC-DC buck converter

The LM2596 DC-DC buck converter is a compact and efficient electronic component used to step down higher input voltages to a stable, lower output voltage. It operates by rapidly switching the input voltage on and off, then filtering and regulating it to produce a clean and reliable DC output. With the ability to maintain high efficiency, it's commonly employed in various electronic applications where precise voltage control is essential, making it a popular choice among hobbyists and professionals alike.

limit switch

Figure 3.18: limit switch.

The V-156-1C25 is a type of limit switch. Limit switches are commonly used in various industrial and mechanical applications to detect the presence or absence of an object, limit the movement of a mechanical component, or trigger a specific action when a certain position or condition is reached. The "V-156-1C25" designation likely represents a specific model or part number for this particular limit switch, which may have specific characteristics, such as its voltage and current ratings, actuation type, and mechanical dimensions. These details would be important for selecting and using the switch appropriately in a given application.

button with LED

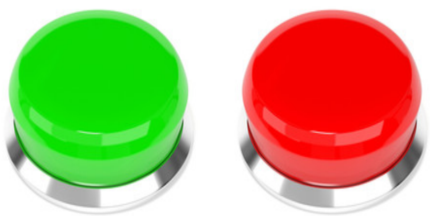


Figure 3.19: button with LED

A massive arcade button with LED is a visually striking and durable button commonly found in arcade games and interactive installations. Featuring vibrant LED illumination and a large, easy-to-press design, these buttons add both style and functionality to retro gaming setups, DIY arcade cabinets, and artistic projects, making them a popular choice for engaging user experiences.

3.6 Details of tool usage

SG90 Servo Motor

First Servo Motor

The project includes four SG90 servo motors, each designated for a specific task. This is the positioning and role of the first motor.

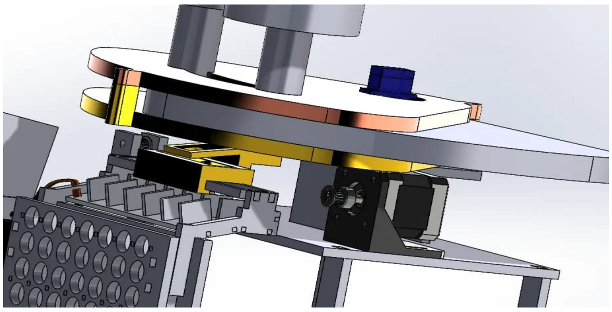


Figure 3.20: first servo SG90 in design.

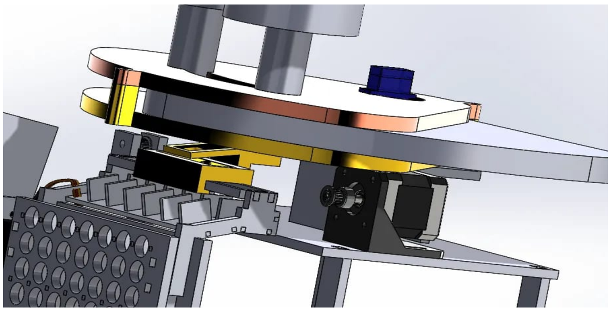


Figure 3.21: first servo SG90 in reality.

This motor shifts the central piece towards either the opening of the first tube or the second tube, depending on the drop location of the next ball. Subsequently, the motor repositions the central piece, aligning its hole with the hole in the stationary lower component. This alignment facilitates the ball's transfer onto a small platform affixed to the tape. This platform securely holds the ball before releasing it into the appropriate column.

Figure 3.22: the top component.

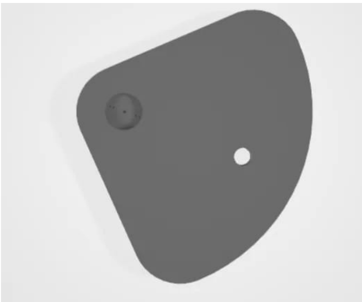


Figure 3.23: the middle component

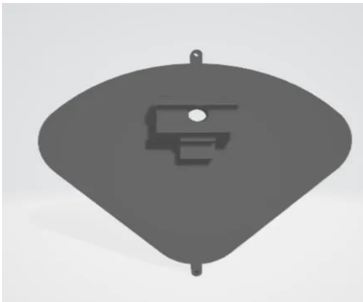


Figure 3.24: the bottom component.

Second Servo Motor

This is the positioning and role of the second motor.

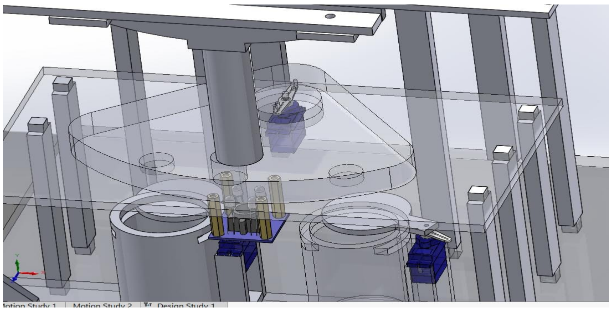


Figure 3.25: Second servo SG90 in design.

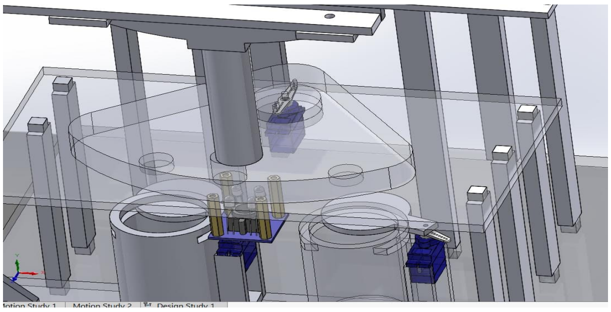


Figure 3.26: Second servo SG90 in reality.

This motor moves the triangular-like piece beneath the funnel. At the conclusion of the game and after the process of emptying the columns one by one, the column's balls fall through the end funnel. At the end of this funnel, there is a triangular-like piece with a single hole, into which the next ball from the funnel drops. Beneath this piece, there is a transparent rectangular piece that prevents the ball from falling. It has two openings: the first opening beneath it is for the red ball tube, and the second opening is for the yellow ball tube. The motor then moves the triangular-like piece to align its hole with one of the openings in the transparent piece, based on the color sensor's reading.

Figure 3.27: the funnel.

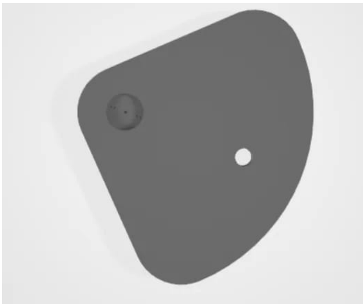


Figure 3.28: the middle component(triangle)

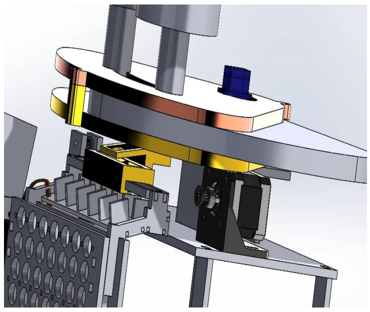


Figure 3.29: the transparent rectangular piece

Third & Fourth Servo Motor

This is the positioning and role of the third & fourth motor.

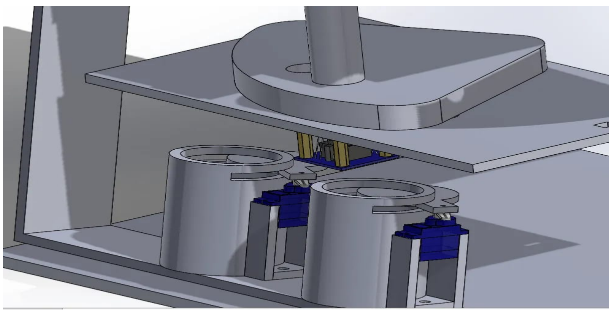


Figure 3.30: Third & Fourth Servo Motor in design.

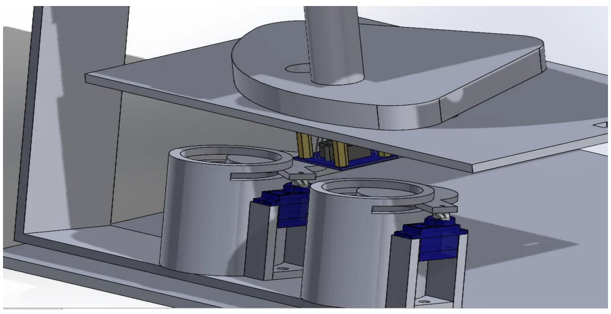


Figure 3.31: Third & Fourth Servo Motor in reality.

The two tubes that contain the balls after sorting, located on the "L" shaped piece, are meant to be sealed. Even when the "L" shaped piece moves upward, the balls should not fall. Hence, there is a motor for each of the two tubes, responsible for controlling their opening and closing. When a ball is dropped from the transparent piece, the tube's cover must be open. Once the sorting process concludes, the covers of both tubes need to be closed. When the balls are lifted upwards, the covers should be opened at the appropriate moment to allow them to fall into the upper tubes.

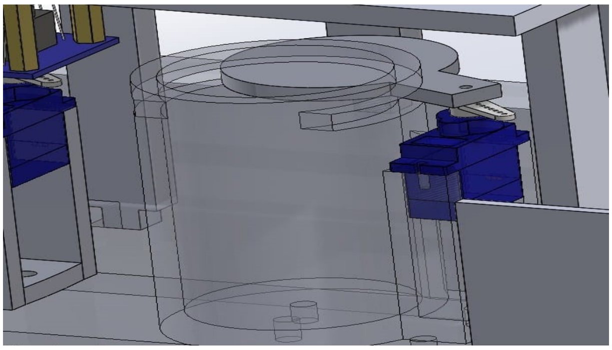


Figure 3.32: the cups

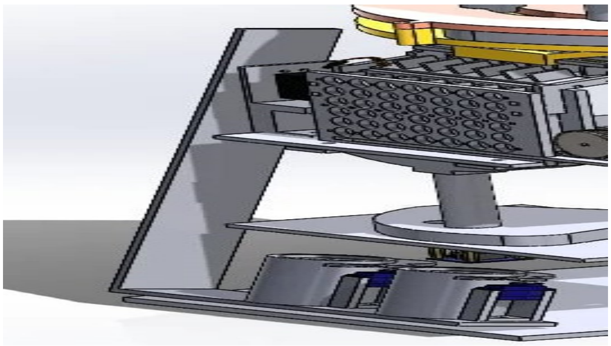


Figure 3.33: the L componant

NEMA 17 stepper motor 17HS4401

First stepper motor

The project includes Two stepper motor, each designated for a specific task. This is the positioning and role of the first motor.

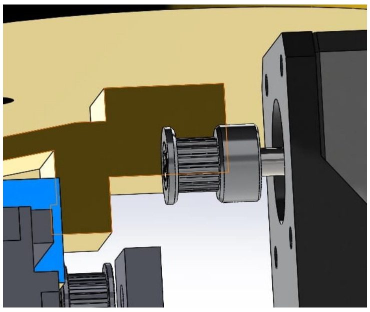


Figure 3.34: Close Look.

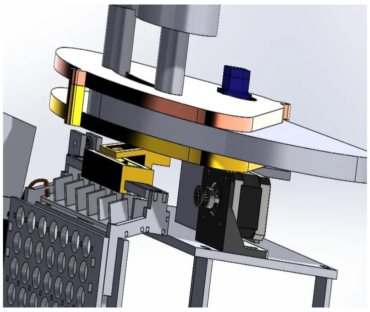


Figure 3.35: first stepper motor in design.

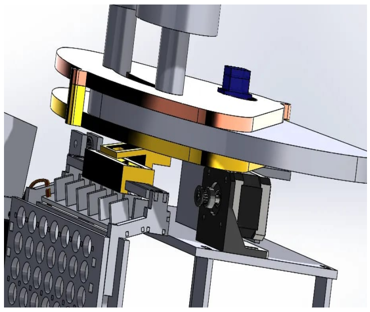


Figure 3.36: first stepper motor in reality.

his motor moves the belt to the right or left based on the player's or computer's movement, aligning it with the piece that will hold the ball in the desired column. The belt holds the entire upper part so that its movement controls all the parts involved in dropping the ball.

Figure 3.37: Timing Belt.

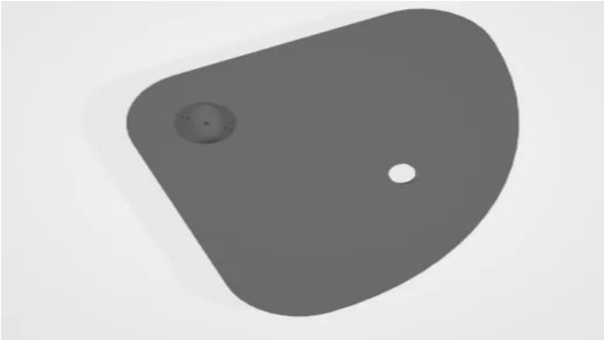


Figure 3.38: small platform

Second stepper motor

The project includes Two stepper motor, each designated for a specific task. This is the positioning and role of the Second motor.

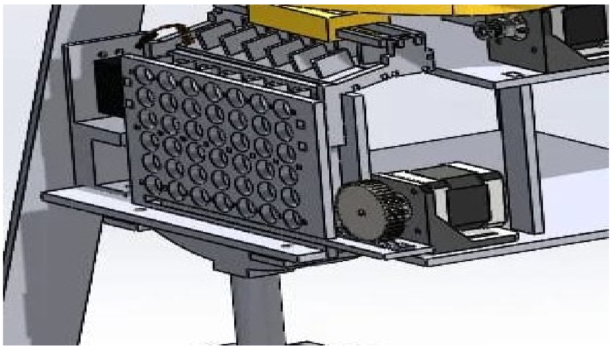


Figure 3.39: Second stepper motor in design.

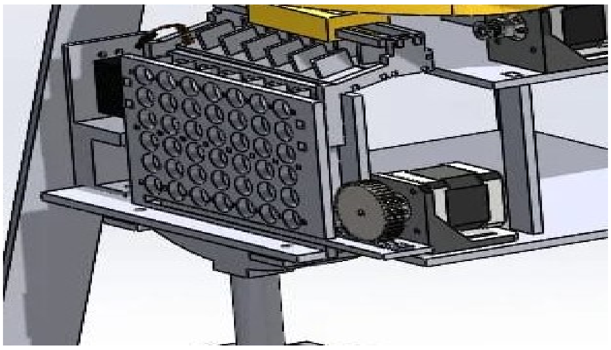


Figure 3.40: Second stepper motor in reality.

There is a long straight piece that serves to close the game grid from the bottom during gameplay. When the grid is being emptied of balls, the motor gradually pulls the straight piece. This allows the columns to be emptied one by one in sequence.

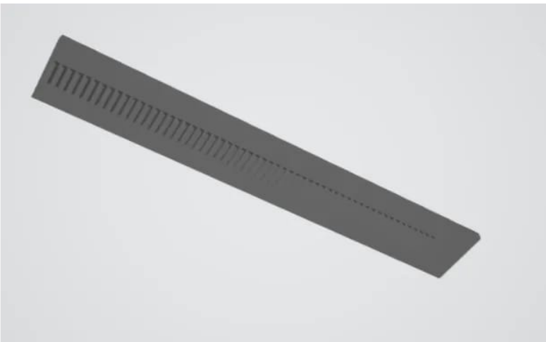


Figure 3.41: long straight piece.

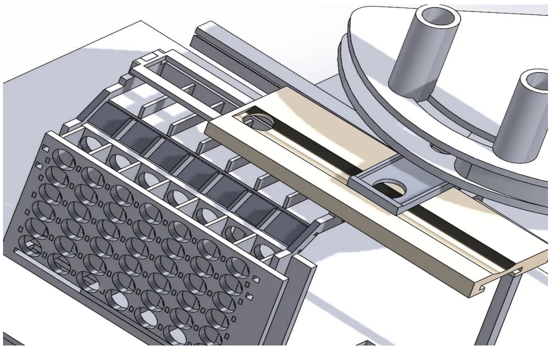


Figure 3.42: game grid

Sensor IR

The project includes Seven IR Sensors , all of them designated for the same task. This is the positioning and role of them.

Figure 3.43: 7 IR sensors

This sensor comes in seven pieces, as it is positioned at the beginning of each column in the game grid. This configuration is solely intended to send a signal when a ball is dropped into that specific column.

Color Sensor TCS3472

The project includes one color Sensors , This is the positioning and role of it.

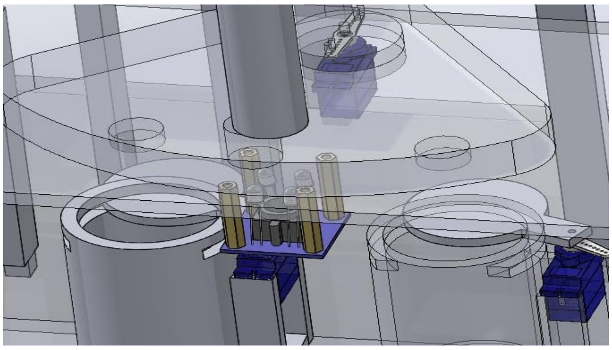


Figure 3.44: Color Sensor TCS3472

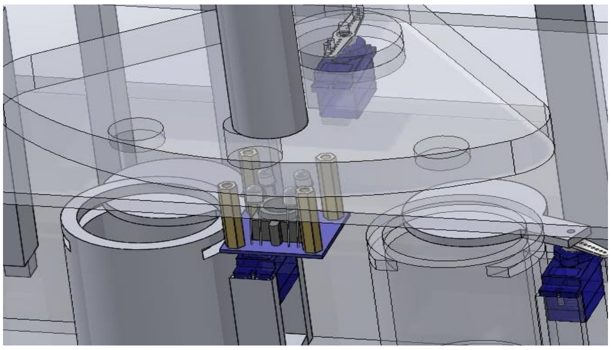


Figure 3.45: Color Sensor TCS3472

This sensor examines the color of the ball when it drops from the funnel onto the transparent piece. Subsequently, the piece containing the ball moves to the appropriate side.

High Torque Waterproof RC Servo

The project includes one Servo Motor mg996r , This is the positioning and role of it.

Figure 3.46: High Torque Waterproof Servo

Figure 3.47: High Torque Waterproof Servo in reality

This motor moves the "L" shaped arm to lift the tube upwards, returning the balls to the starting point.

3.7 CNC links

3.7.1 The thickness of the acrylic material is 8mm

base.dxf

stand1(X5).dxf

stand2(X6).dxf

3.7.2 The thickness of the acrylic material is 6mm

C_H.SLDPRT.dxf

C_S(X2).DXF

C_Sfd.DXF

face(X2).DXF

part1 (X2).DXF

part2.DXF

plate.DXF

plate33.DXF

plates stand(X4).DXF

pulley stand (X2).DXF

rotate.DXF

rotate2.DXF

sensor base.DXF

sensor.DXF

spur gear_din.DXF

3.7.3 The thickness of the acrylic material is 3mm

cover.DXF

lcdds.DXF

power.DXF

Part2.DXF

WALL(X12).DXF

3.8 3D printer links

curve-funnel (1).stl

cupX2 (1).stl

robot-top (2).stl

robot-slider (1).stl

rack (1).stl

mg996-brackets (1).stl

3.9 Acrylic material

Utilizing acrylic material offers distinct advantages in our project over plastic and wood. Its transparency enhances the visual experience, allowing players to observe ball movement. Acrylic's strength and durability ensure robust components, vital for reliable gameplay. Its lightweight nature eases integration, while its resistance to weather and customization capabilities further enhance suitability. Additionally, acrylic's color variety, chemical resistance, and safety features make it a superior choice for our project's aesthetic, longevity, and user engagement compared to plastic and wood.

Chapter 4

Conclusion

Contents

In this chapter, we present the outcomes of our project that focuses on a hardware-based 4-Connect game with AI using the alpha-beta algorithm. The collected data has been analyzed to provide insights into AI performance and user experience.

4.1 AI Performance

We assessed the AI's performance across three levels: Easy, Medium, and Hard. The AI's success rate was measured through wins, losses, and draws against human players. As difficulty increased, the AI's wins grew noticeably, while drawn games decreased. This trend highlights the AI's improving strategic abilities in more challenging scenarios.

Furthermore, we quantified the average time the AI took to make decisions for each level. Decision times extended with the game's complexity, reflecting the algorithm's deeper analysis in harder modes. Decision times ranged from X seconds (Easy) to Y seconds (Hard).

4.2 Circuit Connections

To better understand the integration of AI within the hardware setup, refer to Figure 4.1, which illustrates the circuit connections. The image below demonstrates the arrangement of components, showcasing how the AI-controlled gameplay is seamlessly integrated into the hardware system.

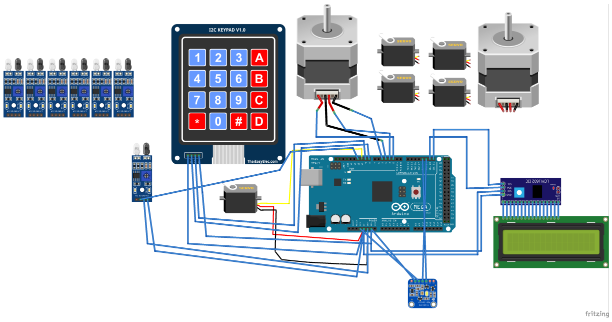


Figure 4.1: Circuit Connections

To conclude, our hardware-based 4-Connect game demonstrated favorable AI performance and user experience outcomes. The AI's proficiency improved with difficulty, leading to increased wins and longer decision times. User feedback highlighted engagement, with the Medium level proving most preferred. Technical functionality remained stable. This chapter emphasizes the successful implementation of our project and prepares the ground for discussions on implications and future work.

Chapter 5

Discussion

Let's pause to reflect on our journey. Our goal was to blend AI with the alpha-beta algorithm in our 4-Connect game. The game's difficulty levels showed us that as challenges grew, the AI stepped up—winning more and thinking longer. This points to the algorithm's success in shaping AI's smart moves.

Our contribution lies in weaving AI's theory into real hardware. Our game isn't just fun; it's a canvas where AI and playfulness meet. This harmony underlines AI's role in real-world experiences.

The road ahead glimmers with potential. We imagine AI growing smarter with advanced algorithms and personalized interactions. Still, we keep in mind the limit of AI decisions tied to search depth—a reminder of its boundaries.

This isn't an ending but a start. Our project opens doors to more adventures. As we close this chapter, we welcome the future with enthusiasm.

Chapter 6

Recommendation

Our journey concludes with clear insights. AI flourished in our game, guided by the alphabeta algorithm. Looking forward, enhancing AI algorithms and search depth promises smarter decisions and enriched experiences. This project teaches us that AI and hardware intertwine to create tangible innovation. The story doesn't end here; it's a prelude to more discoveries. Our project's success speaks of untapped potential, inviting further exploration at the crossroads of AI and hardware.

References

Arifin, J., Zulita, L. N., & Hermawansyah, H. (2016). *Perancangan murottal otomatis menggunakan mikrokontroller arduino mega 2560. Jurnal Media Infotama,* 12(1).

Budzier, H., & Gerlach, G. (2011). *Thermal infrared sensors: theory, optimisation and practice.* John Wiley & Sons.

Virgala, I., Kelemen, M., Gmiterko, A., & Lipták, T. (2015). *Control of stepper motor by microcontroller. Journal of Automation and Control,* 3(3), 131-134.

Karim, M. Z. B. A., & Thamrin, N. M. (2022, August). *Servo motor controller using PID and graphical user interface on Raspberry Pi for robotic arm. In Journal of Physics: Conference Series (Vol. 2319, No. 1, p. 012015).* IOP Publishing.

Drăgan, F., Holonec, R., & Copindean, R. (2018). *Digital Color Sensor based Solution for Recyclable material Sorting System. Acta Electrotehnica,* 58(4).

Cameron, N., & Cameron, N. (2019). Servo and Stepper Motors. *Arduino Applied: Comprehensive Projects for Everyday Electronics,* 157-176.

How to use water flow sensor. (n.d). Retrieved July 18, 2022 from https:// www.instructables.com/How-to-Use-Water- Flow-Sensor-Arduino-Tutorial/

IR Obstacle detection sensor data sheet. (2017). Retrieved August 8, 2022 from https://5.imimg.com/da 1833510 /arduino-ir-infrared-obstacle-avoidancesensor-module.pdf

Appendices

Appendix A: Flowchart of our project

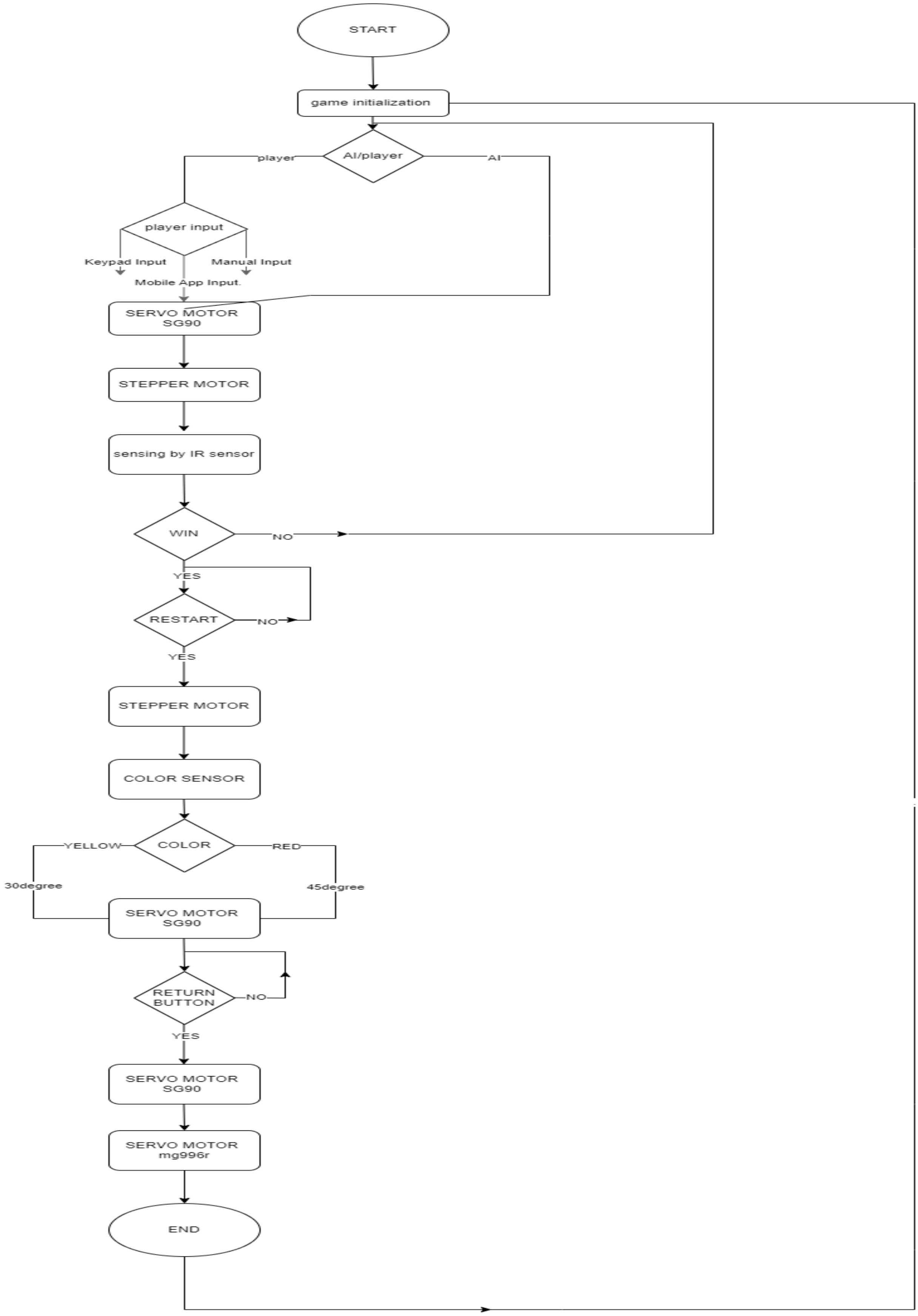


Figure 6.1: Flow Chart

Appendix B: Sample Raw Data

Ball Color	Column Number	Time Taken (ms)
RED	2	132
YELLOW	3	120
RED	5	119
YELLOW	7	108
RED	3	125
YELLOW	4	133
RED	1	120
YELLOW	6	118
RED	7	125

Table 6.1: A Sample Raw Data

Appendix C: Bill of Materials

Component	Quantity
NEMA 17 Stepper Motors	2
Servo Motors	4
Color Sensor	1
Arduino Board	1
keypad	1
lcd display	1
IR Sensor	7
button	3
limit switch	3
DC DC buck converter	2

Table 6.2: A Bill of Materials