CM1900
Intelligent Machines Inspirational Project

Final Report
CARD MASTER

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1. Introduction

The increasing use of Artificial Intelligence (AI) and robotics in daily life has opened new possibilities for human-machine interaction. This project introduces **CardMaster**, an intelligent robotic system designed to play the Sri Lankan card game **Omi** as one of four players at the table. It aims to simulate realistic gameplay by combining **computer vision**, machine learning, **decision-making algorithms**, and mechanical systems to identify, analyze, and physically interact with the game environment in real time.

The robot is designed to be fully autonomous in recognizing its own cards using an **internal camera** and a trained **card detection model**, mapping each card to one of eight physical slots while simultaneously observing the game table with an **external camera** to monitor the moves of other players. Based on the observed state of the game, it employs a custom **strategic decision-making algorithm** to select and play the most suitable card physically through its mechanical card-handling system while maintaining smooth interaction with human players. A unique feature of this project is the **mobile/desktop application** that allows a **remote user** to join the game from a different location. The app connects to the robot and enables the remote player to participate as the fourth player in a traditional four-player Omi game. The robot acts on behalf of the remote player, bridging physical and digital interactions. The robot also uses two small displays to show blinking eyes, making the interaction more friendly and engaging for human players.

This report documents the complete development process of the system, including the **literature survey**, **system design**, **hardware and software implementation**, **testing**, and **feature analysis**. The project not only explores the use of robotics in traditional gaming but also emphasizes the importance of real-time interaction, strategic gameplay, and user engagement.

Compared to existing robotic game systems that are often limited to digital platforms or one-on-one interactions, CardMaster stands out by providing a **fully physical, multiplayer, AI-driven gaming experience** with a focus on **social interaction** and **cognitive engagement**.

1.1 Aim

The aim of this project is to design and develop an AI-powered interactive robot capable of playing the card game **Omi** with human players, by identifying, analyzing, and physically playing cards using computer vision, decision-making algorithms, and mechanical systems.

1.2 Objectives

- To design a physical robot that can hold and play eight cards
- To develop a card detection system using internal and external cameras
- To build a machine learning model for identifying playing cards
- To implement a rule-based decision-making algorithm to choose optimal cards
- To test the system in a real multiplayer Omi game setting

2. Literature Survey

Over the years, many projects have explored the use of **AI in games**, especially in decision-based strategy games such as **chess**, **poker**, and **Go**. Well-known systems like **IBM's Deep Blue** and **DeepMind's AlphaGo** demonstrated the power of machine intelligence in competitive settings. However, these systems were mainly virtual and lacked physical interaction with human players.

Some research has gone into building **game-playing robots** that can interact with physical game elements. For example, robotic arms have been used to play chess using vision systems and actuators. However, most of these are limited to **two-player** games and do not involve **real-time multiplayer dynamics** or **human-robot communication**.

In the area of **card recognition**, computer vision techniques like **template matching** and **Convolutional Neural Networks (CNNs)** have been used to identify playing cards. These systems often face challenges like lighting variations and card overlaps. Moreover, few systems have explored mapping recognized cards to **physical slots** for gameplay execution.

Emotion-expressing robots have also been studied, especially in **education** and **therapy**, where the robot's facial expressions or screen-based emotions are used to engage users. These ideas have rarely been applied in **social games**, where both strategic behavior and emotional interaction are important.

Most existing card-playing robots are **limited in functionality**, requiring human input for card recognition or move decisions. They typically **lack autonomy**, **real-time decision-making**, and **player engagement**.

In contrast, **CardMaster** brings together AI, computer vision, and mechanical control in a **multiplayer physical environment**. It recognizes and stores cards automatically, watches the game in real time, and makes **strategic decisions** during gameplay. While earlier systems focused solely on automation and gameplay logic, "Card Master" introduces an emotional layer using blinking digital eyes, helping build better engagement and human-robot interaction during gameplay. Additionally, the project takes a step forward by introducing a robotic card player that works in tandem with a **remote-access game app** These features highlight the potential of combining **robotics and AI with traditional gaming**, paving the way for **innovative approaches to social interaction and cognitive engagement** in multiplayer environments.

3. Analysis and Design

3.1 Problem in brief

The "Card Master" project tackles several important challenges in card gaming. Card games like **Omi** are typically enjoyed with four players, but in many cases, only three players may be physically available. This limits the ability to start a full game. Additionally, some players may be located remotely, making it impossible to participate in physical games. Additionally, there is often a difference in skill levels among players, which can create an unfair gaming experience and discourage less experienced participants.

Current solutions such as digital card games lack the feel and interaction of physical gameplay. Since the project also aims to reduce feelings of loneliness and isolation by providing a robot that can play cards with users, offering companionship during gameplay. Furthermore, it encourages mental engagement by promoting strategic thinking and decision-making during the game Moreover, there is little to no integration of **remote play with physical robotic systems**, and AI-driven card players are rarely designed to work in real time with both **humans and a remote participant**.

By addressing these challenges, the "Card Master" robot seeks to create a more enjoyable and inclusive environment for all card game enthusiasts.

3.2 Proposed Solution

The proposed solution for the "Card Master" project involves creating an interactive robot designed to play the card game "Omi." By integrating computer vision and mechanical systems, the robot can recognize playing cards, allowing it to understand the game's context. It uses machine learning algorithms to analyze the game state and make strategic decisions based on factors such as the current trump suit, cards played by others, and its own hand of cards. This combination enables the robot to blend traditional card gameplay with advanced AI and robotics, offering a unique solution that enhances social interaction, improves accessibility, and promotes cognitive engagement. As one of four players, the robot manages its own hand of eight cards while making informed decisions, creating an engaging and challenging experience for all participants.

The proposed solution for the "Card Master" project is an interactive robot capable of playing the card game Omi alongside human players. The robot integrates computer vision to recognize playing cards on the table and uses mechanical systems to physically pick and place cards. It analyzes the game state using a rule-based decision-making system, considering factors like the current trump suit, cards already played by others, and its own hand of eight cards to make strategic decisions.

To enhance social interaction, the robot features two digital displays as blinking eyes making the robot feel more interactive and human-like during gameplay.A key part of the solution includes a mobile/desktop application that allows a remote user to participate in the game. The robot acts on behalf of this remote player, physically playing their cards and displaying their moves to the others.

This combination enables the robot to blend traditional card gameplay with advanced AI and robotics, offering a unique solution that enhances social interaction, improves accessibility, and promotes cognitive engagement. As one of four players, the robot manages its own hand of eight cards while making informed decisions, creating an engaging and challenging experience for all participants.

3. 3 Features

1. Cards Insert Mechanism

Develop a precise, motor-driven slot mechanism to smooth insertion.

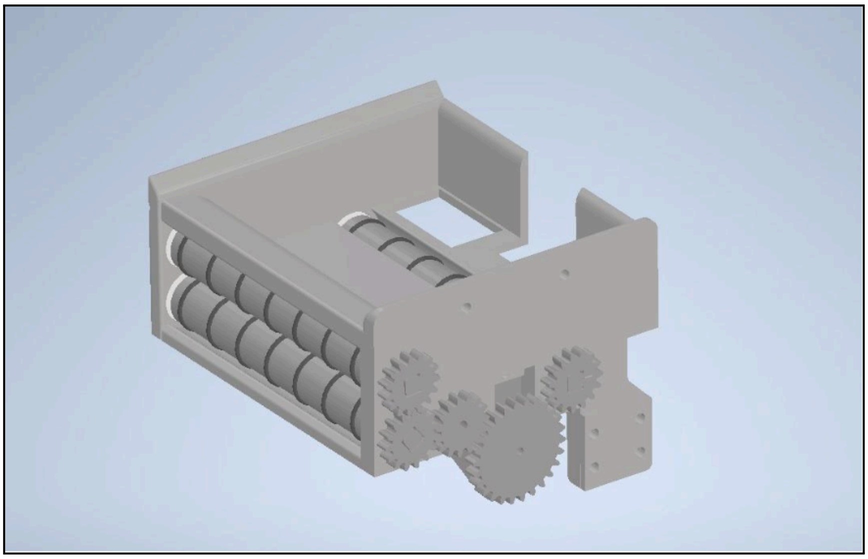


Figure 1

2. Cards Store Mechanism

Design a vertical multi-slot (8 slots) holder with dividers to securely store cards.

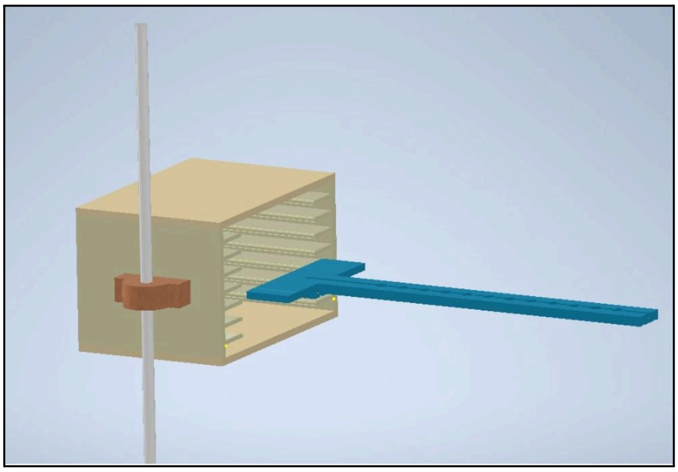


Figure 2

3. Card Recognition System

- Utilizes computer vision with pretrained/fine-tuned models
- Processes images from both internal and external cameras
- Identifies card values and suits with high accuracy

4. Decision Making System

- Custom-trained ML model for card selection
- Select the best card to play in the moment, based on the inputs,
  - Current trump suit
  - Played cards
  - Available cards
  - Game state

5. Cards Deploy Mechanism

- Precise vertical positioning using stepper motor
- Reliable card deployment using DC motor
- Coordinated movement control

3.4 Requirements

Hardware

- ESP32 DevKit V1 Module (30 pin version)
- ESP32 Cam Module OV2640 Camera Bluetooth Wifi Board
- Bipolar Stepper motor
- 2981-A4988 Driver Module
- MG90S 180 Servo motor
- MG90S 360 Servo motor
- DC motor
- L298N Motor Driver
- DM0049 round displays
- MD0582 – DF Player Mini Mp3 Player
- SP0043 - 4 Ohm 5W Speaker 1.5 inch for Portable Amplifiers
- CN0006 - DC Base Barrel Female Socket
- LM2596S 3-40V to 1.5-35V 4A DC to DC Adjustable Step-Down Buck Module (MD0042)
- TCRT5000 IR sensor
- PCF8574 8 bit I/O Expander
- Limit Switch
- Push buttons
- LED flasher

Software

- Arduino IDE
- EasyEDA
- Inventor
- Visual Studio Code
- KAGGLE platform

3.5 Block Diagram

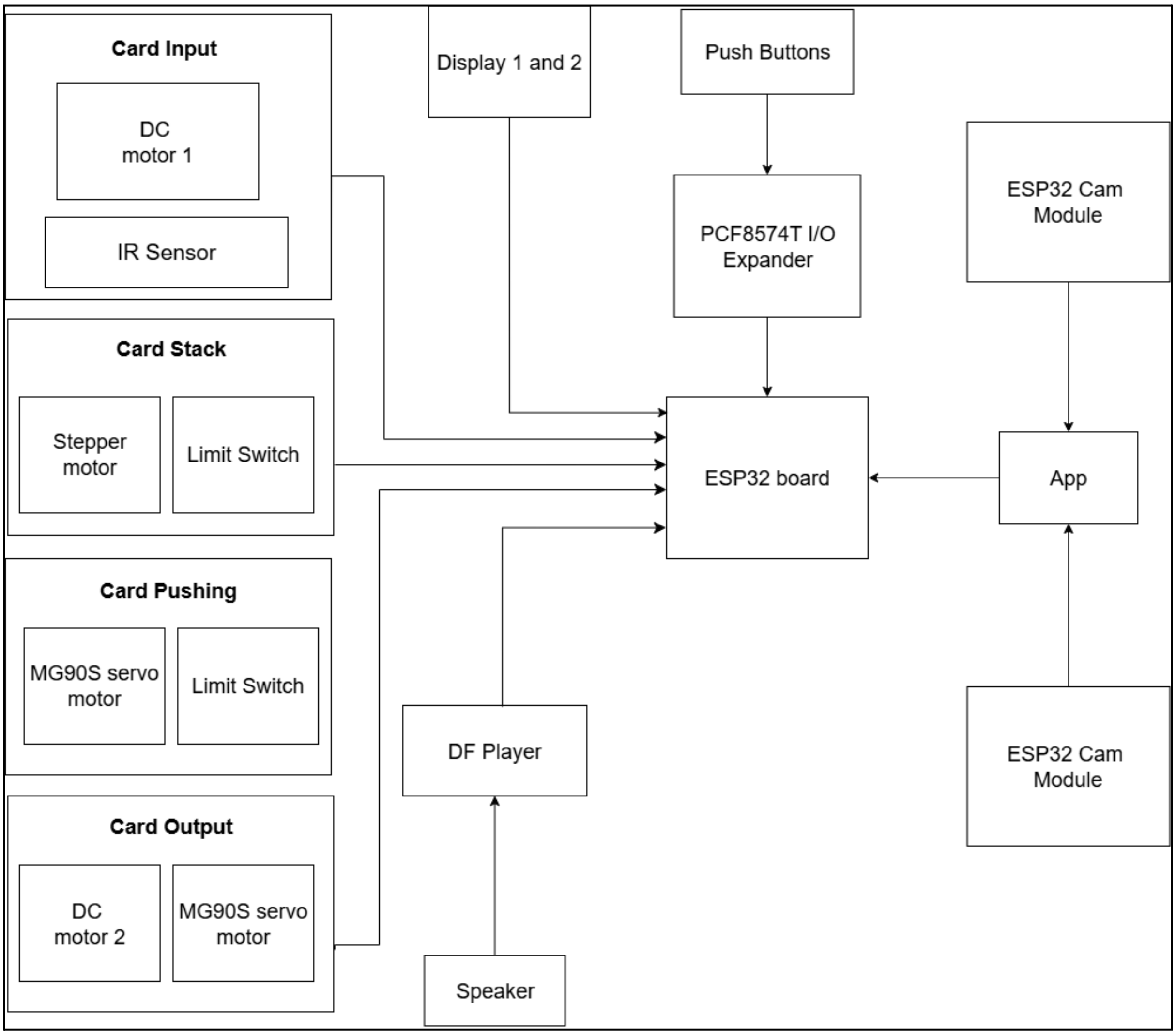


Figure 3: Block Diagram

3.6 Schematic Diagram

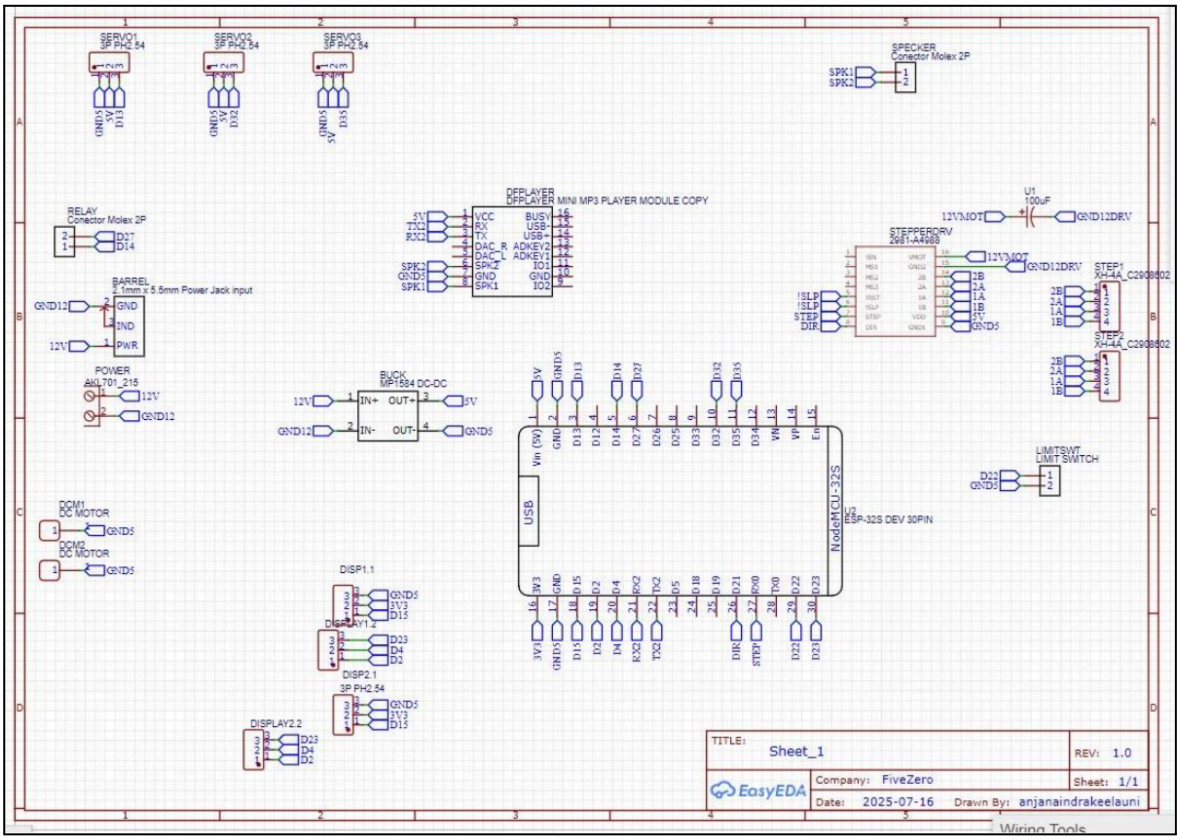
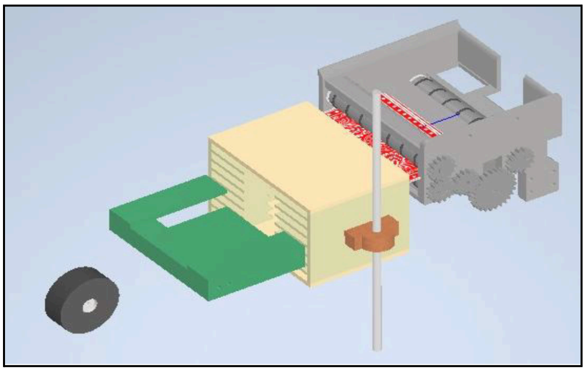


Figure 4: Connection of components

3.7 3D Model



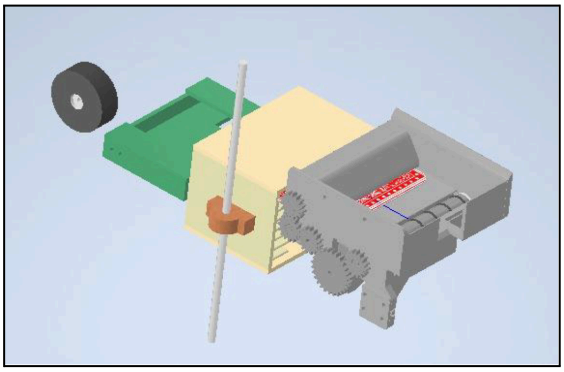
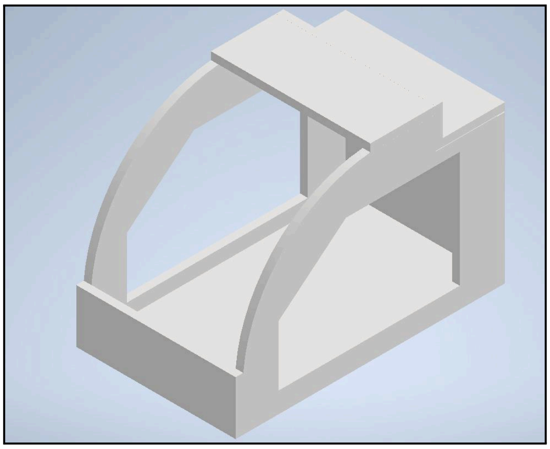


Figure 5 and 6: A graphical or 3D view of the mechanism.



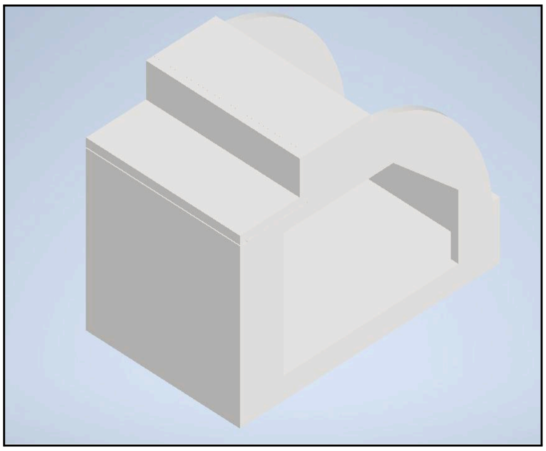


Figure 7 and 8 : A graphical or 3D view of the bot

4.Hardware Integration

ESP32 DEV KIT V1

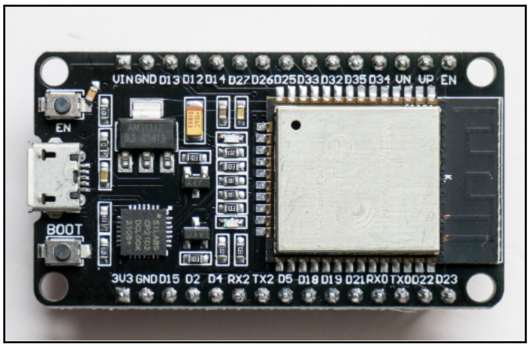


Figure 9

The ESP32 DEV KIT V1 is a popular development board that uses the powerful ESP32 chip. It comes with built-in Wi-Fi and Bluetooth, making it ideal for IoT and wireless projects. Thanks to its dual-core processor, low power use, and many input/output pins, this board is great for creating smart devices, home automation systems, wearables, and other electronic projects quickly and easily.

Feature	Description
Microcontroller	ESP32-D0WDQ6 chip
Processor	Dual-core 32-bit Xtensa LX6 CPU
Clock Speed	Up to 240 MHz
Flash Memory	4 MB (varies by model)
SRAM	520 KB
Connectivity	Wi-Fi 802.11 b/g/n, Bluetooth v4.2 (Classic and BLE)
Operating Voltage	3.3V
Input Voltage (via USB)	5V
GPIO Pins	30
PWM Outputs	16
Communication Protocols	UART, SPI, I2C, I2S, CAN

Use in the system:

In the **Card Master** system, the **ESP32 DEV KIT V1** board serves as the **central controller**, coordinating communication between all hardware components such as the robot's mechanical systems, sensors, display modules, DFPlayer Mini (for sound), and stepper motor drivers and servo motors. It manages **serial communication**, processes game logic using its onboard computing power, and handles **wireless communication** (e.g., for the remote gameplay app) using its built-in **Wi-Fi and Bluetooth** capabilities. This makes the ESP32 essential for real-time control, decision-making, and seamless interaction between human players and the robotic card-playing system.

ESP32 Cam Module OV2640 Camera Bluetooth Wifi Board

Figure 10

The ESP32-CAM is a small-sized, low-cost development board that integrates an ESP32-S chip and a camera module. It is a versatile board that combines Wi-Fi and Bluetooth connectivity with image processing capabilities, making it ideal for various Internet of Things (IoT) applications. Common use cases include surveillance cameras, facial recognition systems, home automation, and remote monitoring.

Feature	Description
Chipset	ESP32-S dual-core processor
RAM	520 KB SRAM
Flash Memory	4MB
Connectivity	Wi-Fi: 802.11b/g/n Bluetooth: v4.2 BR/EDR and BLE
Camera interface	Supports OV2640 and OV7670 cameras
Operating voltage	5V
I/O	GPIO, UART, SPI, I2C

Use in the system:

In the Card Master system, ESP32-CAM modules are used as both internal and external cameras to capture images of the cards. The internal camera reads the robot's own hand of cards, while the external camera monitors cards played by human players. These images are processed to recognize the card values and suits, allowing the robot to make informed decisions during the game. The use of ESP32-CAM enables real-time image capture and wireless transmission, making it a key component for the robot’s visual understanding of the game environment.

MD0582 DF Player Mini Mp3 Player

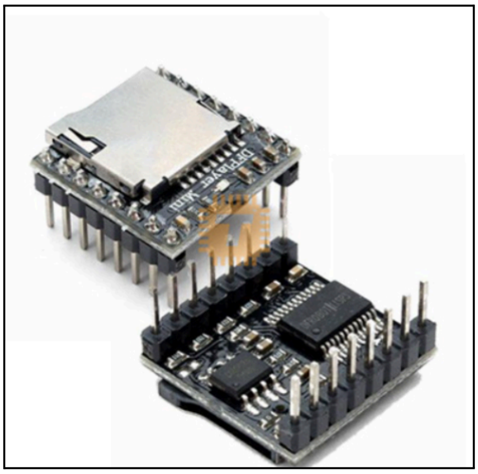


Figure 11

The DF Player Mini is a compact MP3 player module designed to play MP3 (and WAV) audio files stored on a micro-SD card. It’s widely used in embedded systems, DIY electronics, and robotics projects to add sound or music playback capability due to its small size, affordability, and ease of integration. The module supports serial communication.

Feature	Description
Operating Voltage	3.2V – 5V
Operating Current	20mA to 30mA (idle), up to 100mA (playback
Supported formats	MP3, WAV, WMA
Storage support	MicroSD card (up to 32GB)
Audio output	3W (Speaker output) or stereo via AUX
Built-in Amplifier	3W mono class-D power amplifier
Number of pins	16 pins (only 2 are used with esp32)
Communication Protocol	UART (9600 bps default)
Dimensions	22mm x 20mm x 16mm

Use in the system:

The DFPlayer Mini MP3 module is used to provide audio feedback during gameplay, enhancing the interactivity and user experience of the "Card Master" system. The module plays preloaded sound files stored on a microSD card and is controlled via serial communication with the microcontroller esp32. Specific audio clips are triggered based on various game events, such as a system startup sound during initialization, error sounds when a wrong move is made, and cheerful sounds for correct or strategic moves. These sound cues help in guiding players, indicating the system's emotional reactions, and making the interaction more engaging and immersive.

4ohm 5W Speaker 1.5 inch for Portable Amplifiers

Figure 12

The 1.5 inch 4Ω 5W speaker is a compact, high-efficiency audio output device commonly used in portable amplifiers, DIY electronics, and embedded systems. With its small size and decent power handling, it is ideal for applications where space is limited but clear sound output is required. Operating at 4 ohms impedance and handling up to 5 watts of power, it can deliver loud and clear audio when paired with a compatible audio amplifier.

Feature	Description
Size (Diameter)	1.5 inch (approx. 40 mm)
Rated Power Output	5 Watts
Impedance	4 Ω (ohms)

Use in the system:

In the Card Master system, the 1.5-inch 4Ω 5W speaker is used in combination with the DFPlayer Mini MP3 module to output sound effects during gameplay.

1.28 inch 240x240 Round TFT LCD Display Module RGB 3.3VDC (DM0049)

Figure 13

This is a RGB 240X240 dot-matrix TFT LCD module with GC9A01. This module is composed of a TFT LCD Panel, driver ICs, FPC and a Backlight unit. It uses a full-colour LCD screen with a circular appearance and is suitable for making watches, clocks, or measuring instruments. It can also be used with ESP32, Raspberry Pi or Arduino.

Feature	Description
Operating Voltage	3.3 V
Working current	20mA
Display Driver	GC9A01
Display Size	1.28 inches
Resolution	240x240 RGB
Interface	4 SPI (Serial Peripheral Interface)
Number of pins	7 pins
Operating Temperature	–20 °C to +70 °C

Use in the system:

In the Card Master system, two small displays are used to represent the robot's blinking eyes, enhancing its emotional expression and interaction. These displays help simulate human-like behavior, making the robot appear more friendly and engaging to players.

Bipolar Stepper Motor

Figure 14

A bipolar stepper motor generally contains four wires connected to the motor driver output is used for precise position and speed control by energizing coil pairs in sequence to move in discrete steps. It is widely used in 3D printers, CNC machines, and robotics, where accurate movement and repeatable positioning are essential.

Feature	Description
Model	17HS8401 Stepper Motor
Rated Voltage	12-24 V
Rated Current	1.7 A per phase
Step Angle	1.8° per step (200 steps per revolution)
Resistance	Approximately 1.2 Ohms per phase

2981-A4988 Driver

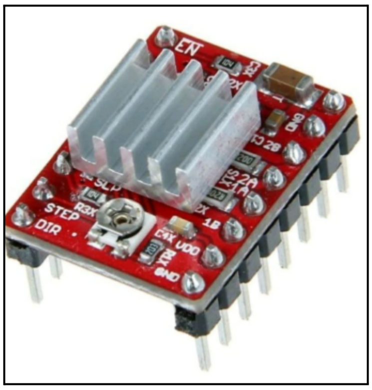


Figure 15

The A4988 Stepper Motor Driver is commonly used to control bipolar stepper motors in applications that require precise and smooth movement. It supports adjustable current control, micro stepping (up to 1/16 step), and thermal protection, making it ideal for use in 3D printers, CNC machines, and robotic systems. The driver allows for accurate positioning and speed control, which is essential for motion-based projects.

Feature	Description
Operating Voltage	8V to 35V
Logic Voltage	3.3V or 5V
Maximum Output Current	2A per coil (with sufficient cooling)
Number of pins	16 pins
Thermal Shutdown	Yes
Overcurrent Protection	Yes

Use in the system:

In the Card Master project, the A4988 stepper motor driver is used to control the stepper motor that moves the card stack containing eight slots up and down. This driver provides precise control over the motor’s position and speed, allowing the robot to accurately align and access specific card slots during gameplay. Its built-in features like microstepping, overcurrent, and thermal protection help ensure smooth and safe motor operation, which is critical for reliable card handling.

Servo Motor MG90S (180 degrees)

Figure 16

The MG90S servo motor is a small, lightweight, and affordable motor commonly used in robotics, hobby electronics, and remote-controlled devices. It is known for its ability to rotate to specific angles (typically from 0° to 180°), making it ideal for applications that require precise movement and positioning, such as robotic arms, camera mounts, and model airplanes. The motor operates using PWM (Pulse Width Modulation) signals and is compatible with most microcontrollers like Arduino and ESP32. Due to its ease of use and compact design, the SG90 is widely favored in both beginner and advanced electronics projects.

Feature	Description
Operating Voltage	4.8V to 6.0V
Operating Speed	0.1 s/60° (at 4.8V)
Control Signal	PWM (Pulse Width Modulation)
PWM Pulse Range	500 µs to 2400 µs
Rotation Angle	0° to 180°
Weight	9 g

Use in the system:

In the Card Master system, the MG90S servo motor is used in the card output mechanism. When a card needs to be delivered, the selected card is first pushed out from its storage slot. Then, the servo motor rotates a part by 180 degrees, which positions a rotating wheel onto the card's surface. As the wheel spins, it makes contact with the card and helps slide or throw the card out towards the players. This process allows smooth and controlled card delivery during gameplay.

MG90S 360 Degree High Quality Servo Motor

Figure 17

The MG90S servo motor is a small and powerful motor commonly used in remote-controlled toys, robots, and DIY electronics projects. It can rotate to specific angles, making it useful for tasks that need precise movement. Because it's affordable and easy to use, it's a popular choice for students, hobbyists, and makers.

Feature	Description
Voltage	4.8V to 6.0V
Current	stall current (when the motor is fully loaded or stuck) can reach up to 700 mA
Operating speed	0.10 sec/60° (4.8V), 0.08 sec/60° (6.0V)
Rotation angle	0 to 360
Control Signal	PWM (Pulse Width Modulation)
Weight	13.4 g

Use in the system:

In the system, the MG90S servo motor is responsible for operating a stick-like mechanism that pushes the selected card from the stack to the card outputting section. When the robot decides which card to play, the card stack—consisting of multiple slots—is first moved up or down using a stepper motor to align the slot containing the required card with the pusher. Once properly aligned, the MG90S servo motor moves the pusher forward to push the selected card toward the output mechanism. After pushing the card, the servo retracts the pusher to its original position. This coordinated action ensures that the correct card is selected and delivered for gameplay accurately and efficiently.

Gear Motor 12V 1000RPM N20 (RB0059)

Figure 18

The Gear Motor 12V 1000RPM N20 is commonly used in small robotic systems, automation projects, and precision mechanisms where both speed and torque are required. Typical applications include mini robots, conveyor mechanisms, card dispensers, door lock systems, and other projects that require reliable and compact motorized movement.

Feature	Description
Code	RB0059
Rated Voltage	12V DC
No Load Current	0.06 mA

Stall Current	0.75 A

Use in the system:

The Gear Motor 12V 1000RPM N20 (RB0059) was used in the card input mechanism of the system to insert cards into the stack. This motor, combined with a geared reduction system, provides sufficient torque and controlled speed to smoothly guide the card into position without causing damage or misalignment. Its compact size and reliable performance make it suitable for continuous operation in the mechanism, ensuring accurate and consistent card insertion during gameplay.

Gear Motor (No Wheel) (RB0012)

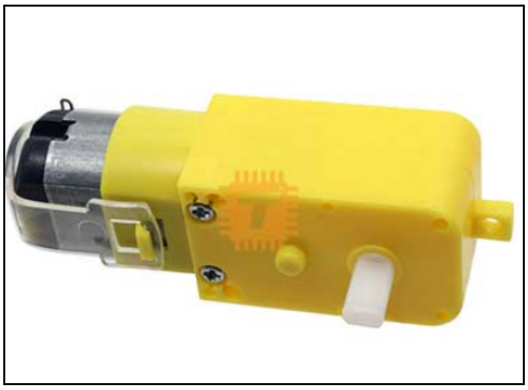


Figure 19

The Gear Motor (No Wheel) (RB0012) is widely used in robotics, automation, and small mechanical projects that require controlled rotational motion with higher torque. It is commonly applied in robotic arms, conveyor systems, and automated mechanisms where precise and consistent motor performance is important.

Feature	Description
Operating voltage	3V~12VDC
The load current	70mA (250mA MAX) (3V)

Use in the system:

In the CardMaster robotic system, the Gear Motor (RB0012) is used in the card output mechanism. It is connected to a wheel that grips and throws the selected card onto the table during gameplay. This setup ensures smooth and accurate delivery of cards, allowing the robot to interact effectively in the card game

L298N DC Motor Driver

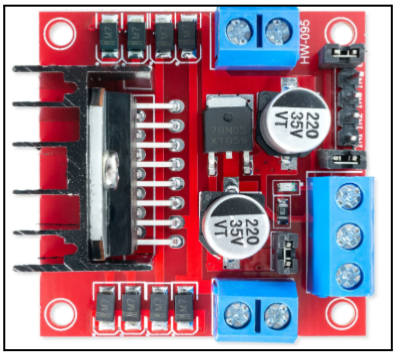


Figure 20

The L298N DC motor driver module is a high-power motor driver perfect for driving DC and stepper motors. It features a dual H-bridge design, allowing for independent control of two DC motors, which means it can control the speed and direction of each one simultaneously. The L298N is widely used in robotics, CNC machines, and other applications where precise motor control is required.

Feature	Description
Operating Voltage	5V to 35V
Logic Voltage	4.5V to 7V
Peak Output Current (per channel)	2A
Continuous Output Current (per channel)	1A
Power Consumption	36W (max)

Use in the system:

In the Card Master system, the L298N motor driver is used to control two DC motors responsible for handling card movement. One motor is used in the card input mechanism, which pulls the cards into the system, while the other is used in the card output mechanism, helping to push the selected card out after gameplay. The L298N driver allows for precise control of the direction and speed of both motors using signals from the microcontroller, ensuring smooth and accurate movement of cards during the game.

PCF8574T 8-bit IO Extension Expander Module

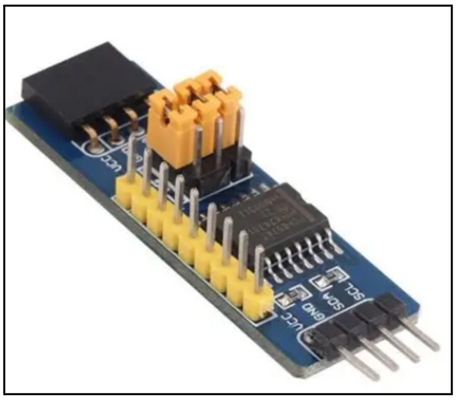


Figure 2

Feature	Description
IC Model	PCF8574T
Operating Voltage (VCC)	2.5V – 6V
Interface	I²C (serial clock SCL, serial data SDA)
I/O Ports	8-bit parallel I/O
Operating Temperature	–40°C to +85°C

In the CardMaster robotic system, the PCF8574 I/O expander module was used to overcome the limitation of insufficient GPIO pins on the ESP32. Since multiple push buttons and the TCRT5000 IR sensor had to be connected, the available pins on the ESP32 were not adequate. After evaluating possible solutions, the PCF8574 was selected as it provides additional I/O pins through the I²C interface while requiring only two pins (SDA and SCL) from the ESP32 for communication. This allowed all push buttons and the IR sensor to be connected efficiently without compromising other system functions. By integrating the I/O expander, the design ensured smooth operation, proper resource utilization, and reliable hardware scalability.

TCRT5000 IR Sensor

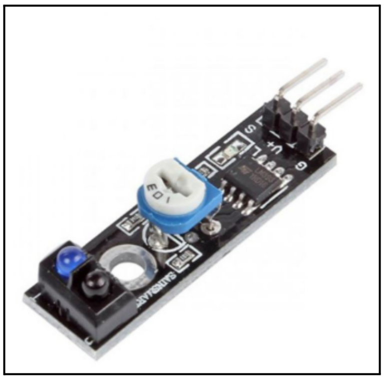


Figure 22

The TCRT5000 IR sensor is mainly used for detecting objects and surface colors by emitting infrared light and measuring the reflection. It is commonly used in line-following robots, object counters, edge detection systems, and proximity sensing. Because it can easily differentiate between light and dark surfaces, it is especially useful in robotics and automation projects.

Feature	Description
Operating voltage	3.3V to 5V
Operating temperature	-25°C to +85°C
Current Consumption	60mA (max)
Range of measuring distance	1mm - 8mm

Use in the system:

In the CardMaster robotic system, the TCRT5000 infrared sensor is used in the card input section to ensure accurate detection of card placement. Before the robot transfers a card to the stack of storage slots, the sensor verifies whether a card has been inserted. This prevents misoperations, such as attempting to move the mechanism without a card or stacking errors. By using reflective infrared sensing, the TCRT5000 provides a reliable and fast response, enabling the robot to synchronize its mechanical movements with the actual presence of a card. This improves the overall efficiency, accuracy, and robustness of the card handling process within the system.

Micro Limit Switch with 15mm Lever 15A 250VAC (BU0033)

Figure 23

A limit switch is an electromechanical device that operates based on the movement or presence of an object. It is designed to detect the presence or absence, passing, positioning, and end of travel of an object. When an object encounters the actuator of the limit switch, it operates the contacts to make or break an electrical connection. Limit switches are commonly used in industrial control systems to control machinery and in various applications such as conveyor systems, elevators, and machine tools to provide precise control and positioning.

Feature	Description
Rating	0.6A, 125VDC; 0.3A, 250VDC
Contact configuration	Normally Open (NO), Normally Closed (NC), or both
Number of pins	03
Current Rating	15A at 125/250 VAC 0.6A at 125 VDC 0.3 at 250 VDC
Operating Temperature	-25C to +80C

Use in the system:

In the Card Master system, the limit switch is used to detect when the card stack has reached the bottom position during its downward movement. Once the switch is pressed, it signals the system that the end has been reached. This triggers the stack to move upward again, ensuring accurate control of the vertical movement and preventing mechanical over-travel. This helps maintain proper alignment and operation of the card handling system.

LM2596 buck converter

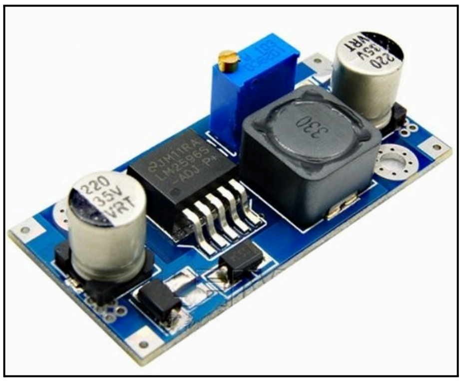


Figure 24

The LM2596 is a high-efficiency step-down (buck) DC/DC voltage regulator designed to convert a higher DC input voltage into a stable, lower DC output voltage. Manufactured by CN China, this component is widely used in applications requiring efficient power conversion with minimal heat generation. Its compact design and integrated features make it ideal for powering microcontrollers, sensors, and other low-voltage devices.

Feature	Description
Input Voltage Range	4.5V to 40V
Output Voltage Range	1.23V to 37V (adjustable)
Output Current	Up to 3A
Efficiency	Up to 92%
Switching Frequency	150kHz

Use in the system:

The LM2596 buck converter was used in the system to efficiently step down the 12 V input from the main power supply to lower voltages (such as 5 V and 3.3 V) required by components like the ESP32, motor drivers, and display modules. Its high efficiency minimized heat generation and energy loss, ensuring stable power delivery for sensitive electronics and protecting them from voltage fluctuations that could cause malfunction or damage.

Push buttons

Figure 25 and 26

Push buttons are small switches used to control devices by pressing them. They are commonly used to turn things on or off, reset systems, or give simple commands to machines. Because they are easy to use, push buttons are found in many devices like toys, remotes, and machines.

Feature	Description
Operating voltage	3V - 12V DC
Rated voltage	50mA - 5A

Use in the system:

In the CardMaster robotic system, a total of seven push buttons are incorporated to support essential game operations and system control. Four of these buttons are dedicated to selecting the trump suit, where the relevant button is pressed by the player at the beginning of the game. Another button is used to output a card from the robot during gameplay. To ensure smooth handling in the card input mechanism, one push button is employed to stop the DC motor once a card has been correctly inserted into the stack. Additionally, a reset button is provided to restart the game or reset the system when necessary. These push buttons serve as simple yet reliable user inputs, ensuring proper interaction between players and the robotic system.

12V 5A SMPS Power Supply Metal Casing (PS0052)

Figure 27

In the CardMaster robotic system, a 12V 5A SMPS power supply (PS0052) with a metal casing was used to provide stable and sufficient power for running the DC motors. The motors require higher current than what the ESP32 or other small power sources can provide, and this SMPS ensures reliable operation by delivering consistent voltage and current. Its metal casing also improves durability and heat dissipation, making it suitable for continuous operation of the robot during gameplay.

Feature	Description
Input Voltage	230VAC
Output Voltage	12VDC
Output Current	5A (max)

5. Testing and Implementation

Card Detection Model

The first step was to develop and train a card detection model. For this, a dataset of **over 400 images captured by our team** was used. These images were taken under different angles and lighting conditions to train the model. However, the trained model could only detect cards when placed at a short distance from the camera. When the cards were positioned farther away, detection accuracy dropped significantly. This indicated that the model's performance was insufficient for real gameplay.

Solution

To overcome this limitation, an existing dataset containing about 10,000 images from the **Roboflow platform** was used to train the model. In this dataset, the card symbols were annotated for precise recognition. This significantly improved the model's accuracy, allowing it to detect cards correctly at both short and long distances. The updated model was then implemented in the robot system, ensuring reliable performance during gameplay.

Card Selection Model

The Omi card game agent was implemented using Python and PyTorch, with training conducted through a self-play mechanism where multiple instances of the agent competed against each other. To validate performance, the trained model was tested against a baseline random-choice bot, achieving an average win rate of approximately 85% after 200,000 episodes and 12 hours of training on an NVIDIA Tesla P100 GPU. The implementation incorporated a custom neural network with a game state encoder and policy network, while reinforcement learning techniques such as REINFORCE with baseline and an experience replay buffer were applied to optimize decision-making. Testing confirmed that the agent was able to independently discover strategies and improve its gameplay over time without the need for human gameplay data.

```
Episode 97500 completed. Mean loss: 0.3106, Mean reward: 0.0075
Episode 97600 completed. Mean loss: -0.2054, Mean reward: 0.0150
Episode 97700 completed. Mean loss: 0.0485, Mean reward: 0.0140
Episode 97800 completed. Mean loss: 0.3925, Mean reward: 0.0140
Episode 97900 completed. Mean loss: 0.2305, Mean reward: 0.0050
Episode 98000 completed. Mean loss: -0.0206, Mean reward: 0.0195
Episode 98100 completed. Mean loss: 0.0017, Mean reward: 0.0110
Episode 98200 completed. Mean loss: 0.0641, Mean reward: 0.0100
Episode 98300 completed. Mean loss: 0.0424, Mean reward: 0.0055
Episode 98400 completed. Mean loss: 0.3497, Mean reward: 0.0115
Episode 98500 completed. Mean loss: 0.1442, Mean reward: 0.0130
Episode 98600 completed. Mean loss: 0.2508, Mean reward: 0.0140
Episode 98700 completed. Mean loss: 0.2329, Mean reward: 0.0080
Episode 98800 completed. Mean loss: 0.3982, Mean reward: 0.0115
Episode 98900 completed. Mean loss: 0.4275, Mean reward: 0.0060
Episode 99000 completed. Mean loss: 0.4751, Mean reward: 0.0075
Episode 99100 completed. Mean loss: 0.4377, Mean reward: 0.0125
Episode 99200 completed. Mean loss: 0.1824, Mean reward: 0.0155
Episode 99300 completed. Mean loss: 0.3515, Mean reward: 0.0195
Episode 99400 completed. Mean loss: 0.4107, Mean reward: 0.0155
Episode 99500 completed. Mean loss: 0.1944, Mean reward: 0.0045
Episode 99600 completed. Mean loss: 0.5823, Mean reward: 0.0175
Episode 99700 completed. Mean loss: 0.3146, Mean reward: 0.0055
Episode 99800 completed. Mean loss: 0.3577, Mean reward: 0.0030
Episode 99900 completed. Mean loss: 0.2185, Mean reward: 0.0080
Training completed in 21228.92 seconds
The agent is ready to play Oomi!
```

Figure 28

3D Printing (Stack part)

During the implementation stage, the first version of the 3D-printed stack was tested but found to be unsuitable for smooth operation. The structure was not strong enough to withstand repeated use, and the gap between the slots was insufficient, causing difficulties when placing and moving cards. Additionally, since the stepper motor was connected only on one side, the movement of the stack became unbalanced, which affected the accuracy and reliability of the mechanism.

Solution

To address these issues, the stack was redesigned and 3D-printed again with several improvements. The strength of the structure was increased, proper spacing between the slots was introduced, and adjustments were made to ensure balanced movement even with the stepper motor connected on one side. These modifications ensured smooth card handling and stable performance of the system.

PCB Implementation Decision

During the PCB design stage, it was initially considered to design a two-layer PCB to accommodate all the required connections in a compact layout. However, after evaluating the increasing cost and additional time required for designing and fabricating a two-layer board, it was decided to proceed with a single-layer PCB instead. To manage the necessary interconnections, additional wires were soldered manually where required. This approach allowed the project to stay within budget and reduced design complexity while still ensuring proper functionality of the circuit.

Setting up DC motors

During the initial stage of motor control testing, a relay module was used to operate the robot's DC motors. The relay functioned as an electrically operated switch, allowing the motors to be turned fully on or off using signals from the microcontroller. While this setup was simple to implement, it presented significant limitations. The motors could only run at a fixed speed and in a single direction without additional complex wiring. Furthermore, when the motors were switched off, they generated a pullback current (back-EMF) that travelled back through the circuit, causing electrical noise and potential risk to the microcontroller and other sensitive components. This lack of back-EMF protection and inability to achieve smooth, controlled movement made the relay-based approach unsuitable for the robot's requirements.

Solution

To address these issues, the relay module was replaced with an L298N dual H-Bridge motor driver. This driver not only allowed control over the motors' direction but also supported variable speed control through PWM signals. The L298N has built-in flyback diodes, which protect the control circuitry from damaging pullback currents generated by the motors. Its electronic switching method provided faster, smoother, and more reliable control compared to the mechanical switching of the relay. With the L298N, both DC motors could be independently controlled from a single module, making the design more compact, efficient, and better suited to the precise motion control required for the robot's operation.

Sound output

During the initial testing phase, a buzzer was used as the primary sound output device for the robot. The buzzer could generate multiple tones by varying the frequency, allowing the output of simple beeps and notes. Although functional, the buzzer's output was limited to monotonous tones that were not meaningful or engaging, making it unsuitable for creating the desired cute and interactive personality of the robot.

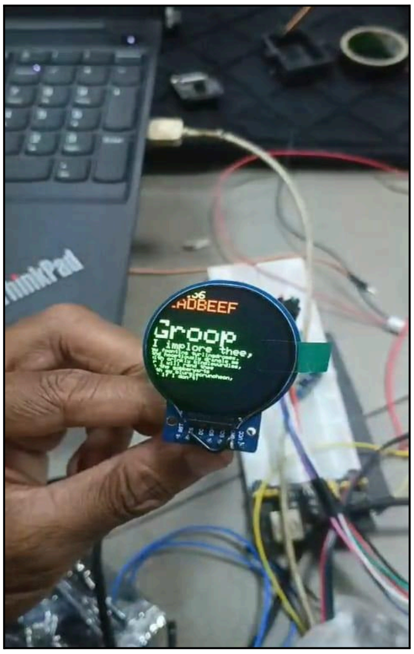
Solution

The limitation of the buzzer in delivering expressive and suitable sounds was identified as a major drawback.To overcome this, the buzzer was replaced with a DFPlayer Mini MP3 module connected to a 4 Ω, 5 W speaker. This setup allowed playback of pre-recorded audio files, enabling a wide range of high-quality sounds and music to be output. As a result, the robot could produce cute, expressive, and contextually appropriate audio responses, significantly enhancing its overall interactivity and appeal.

Display

At the early stage of development, a 1.3" 240×240 RGB TFT IPS LCD module with the ST7789 driver chip was selected to display the robot's animated eyes. The display was visually suitable for the design, offering a square resolution that could easily accommodate expressive graphics. However, during testing, multiple units of the same display failed, with each becoming non-functional after a short period of operation. This consistent failure was attributed to hardware damage, likely caused by electrical stress or voltage compatibility issues. As the displays were repeatedly burning out, it became clear that the ST7789 modules were not reliable for long-term use in this application.

To overcome these issues, the display was replaced with a 1.28" 240×240 round TFT LCD module (DM0049), which operates at 3.3V DC. This module provided similar resolution but with a circular screen, which enhanced the aesthetic appeal of the robot’s eyes. The DM0049 proved to be more robust and compatible with the system’s power and signal requirements, significantly reducing the risk of damage during operation. Its stable performance during extended testing ensured consistent visual output, making it a more reliable choice for the robot’s interactive display needs.



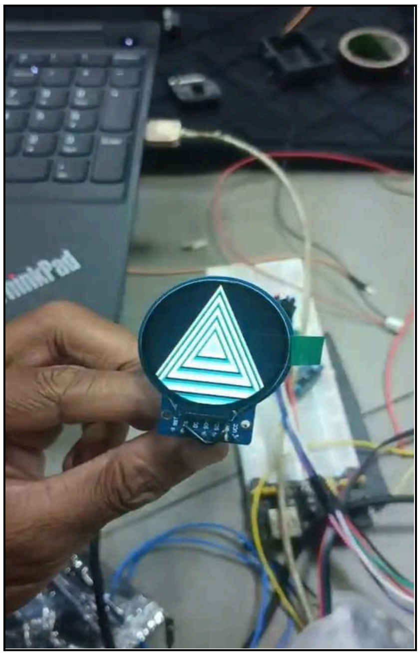


Figure 29 and 30

I/O Expander

During the testing and implementation phase, it was identified that the number of available GPIO pins on the ESP32 was insufficient to connect all required components, particularly the IR sensor and the push buttons. To overcome this limitation, the PCF8574T I/O expander was selected and integrated into the system. This module provided an additional set of I/O pins via the I²C interface, thereby extending the ESP32’s capability to handle multiple input devices simultaneously. With the expander in place, the number of available pins became sufficient for connecting the push buttons and the IR sensor, ensuring smooth operation of the system without hardware constraints.

6. Individual Contribution

235532D - J.V. Ransika

Responsibilities

- **Setting up the displays.**

DM0049 Round Displays for Robot Eyes

1. **Unique Circular Design**
   - The round shape allows for more natural and aesthetically pleasing eye animations, compared to square displays.
2. **High-Resolution Visuals**
   - The 240×240 resolution provides smooth, detailed animations for blinking, gaze movement, and expressions.
3. **Wide Viewing Angle (IPS)**
   - IPS technology ensures the colors and sharpness remain consistent even when viewed from different angles — important for multiplayer interaction.
4. **Compact and Perfect Fit**
   - At 1.28 inches, the display is small enough to fit into the robot's head without crowding other components, while still being clearly visible.
5. **High-Speed SPI Communication**
   - SPI ensures fast data transfer between the ESP32 and the displays, enabling smooth animations without lag.
6. **Low Power Consumption**
   - Ideal for battery-powered operation during long gameplay sessions.
7. **Vibrant Color Output**
   - Supports 65K+ colors, allowing for expressive and eye-catching animations.

Setting Up with the ESP32

1. Pin Connections for Each Display:

The DM0049 round display typically has **VCC**, **GND**, **SCL (Clock)**, **SDA (MOSI)**, **RES (Reset)**, **DC (Data/Command)**, and **CS (Chip Select)** pins.
For two displays, separate **CS** pins are used to control each independently.

- VCC
- GND
- SCL
- SDA
- RES
- DC
- CS

2. Power Considerations:

- Powered from the ESP32's regulated 3.3V output or a dedicated 3.3V supply.
- Backlight is integrated and powered via the VCC pin.

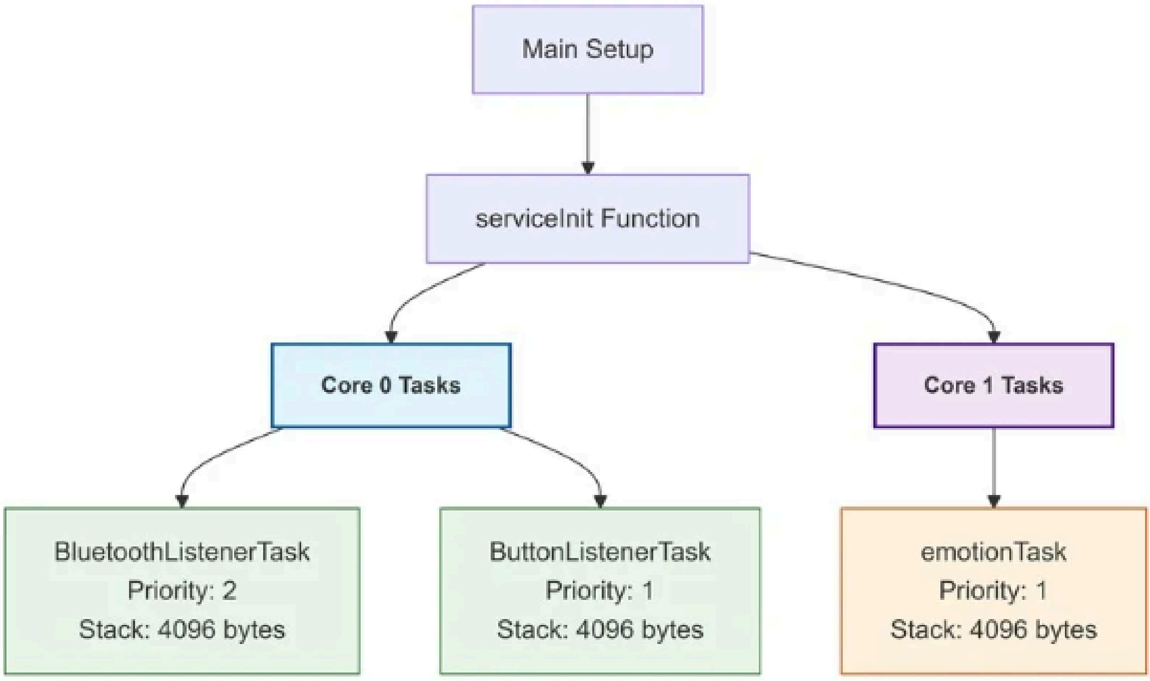
3. Software Setup:

- The **Adafruit_GC9A01A** library (Arduino) supports the round display when configured for 240×240 GC9A01A driver chips.
- The robot's software controls blinking and expression changes based on gameplay events.

4. Mechanical Mounting:

- The displays are mounted inside the robot's head with transparent protective covers.
- Eye spacing is adjusted for a natural and friendly appearance.

- **Setting up the main ESP32 and bluetooth connection with the app**



Figure

- **Card selection model**

One of my main contributions to the project was the design and development of the Card Selection Model, which serves as the decision-making core of the system. The purpose of this model was to enable the robot to make optimal card-playing decisions during the Oomi game rather than relying on fixed rules or random strategies. To achieve this, I implemented a reinforcement learning–based approach where multiple AI agents played simulated Oomi games against each other. Through this self-play mechanism, the agents were able to learn and refine their strategies over time.

The model was trained over 200,000 simulated games, which took approximately 12 hours of training time on an NVIDIA Tesla P100 GPU. The training process was implemented using Python and PyTorch, leveraging their efficiency in deep learning experimentation. The architecture of the model consisted of three fully connected linear layers combined with an LSTM layer, which allowed the system to not only evaluate the immediate game state but also maintain memory of past moves and sequences. This helped the model understand longer-term strategies and context in gameplay.

The outcome of the training process was a model that achieved an ~85% win rate against a random-choice bot, demonstrating its ability to learn effective strategies and make intelligent card selections. By integrating this model into the overall system, the robot was able to perform with a high level of autonomy, adapting its card selection dynamically based on the game state. This contribution was essential to ensuring the interactive and competitive nature of the robot within the game environment.

235543L - L.M.T.Udana

Responsibilities

- **Setting up two cameras**

  As part of my contribution, I was responsible for integrating the ESP32-CAM Module (OV2640 Camera, Bluetooth, WiFi) as both the internal and external vision system of the CardMaster robot. The ESP32-CAM was selected because of its compact size, low power consumption, and ability to capture real-time images while supporting wireless communication.

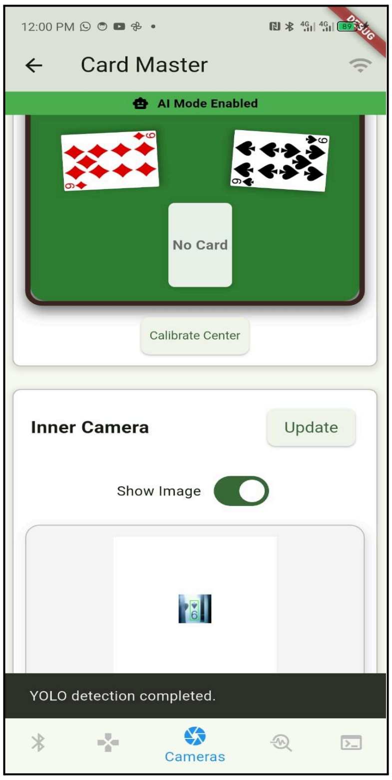
  For the internal camera, the ESP32-CAM was positioned inside the robot to capture images of the robot's own cards. I configured the module to interface with the trained card detection model, ensuring reliable recognition and mapping of each card into its respective slot. Special attention was given to lighting adjustments and positioning so that the images captured were clear enough for the computer vision algorithm to process effectively.

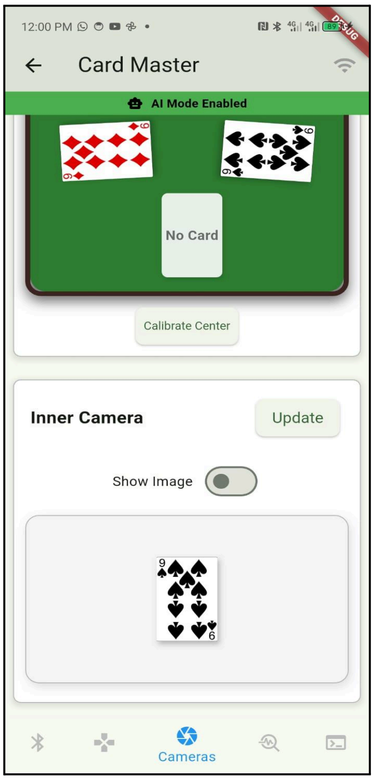
  For the external camera, another ESP32-CAM module was mounted facing the game table to observe the moves of human players. This allowed the robot to monitor the state of the game continuously and provide necessary input for the decision-making algorithm. The challenge here was to achieve a stable video stream under varying lighting conditions and angles, which required multiple calibration tests and adjustments to camera parameters such as resolution and frame rate.

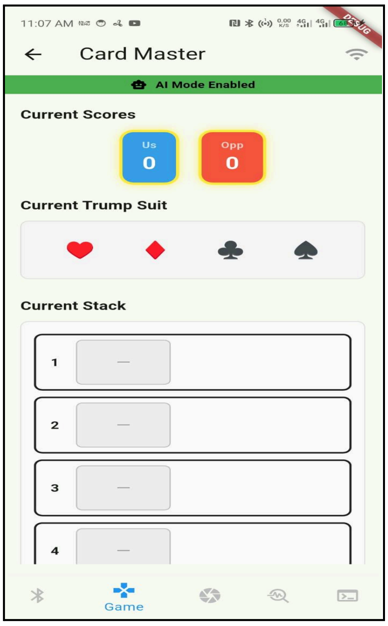
  Additionally, I worked on configuring the ESP32-CAM's WiFi capabilities to communicate captured data efficiently with the main processing unit. This involved setting up the camera as a streaming server and ensuring low latency image transmission to support real-time decision-making by the robot.

Overall, my work on integrating and configuring the ESP32-CAM modules played a critical role in enabling the robot's ability to visually interact with both its own cards and the external gameplay environment, thereby ensuring smooth functionality and reliable performance in the Omi game.

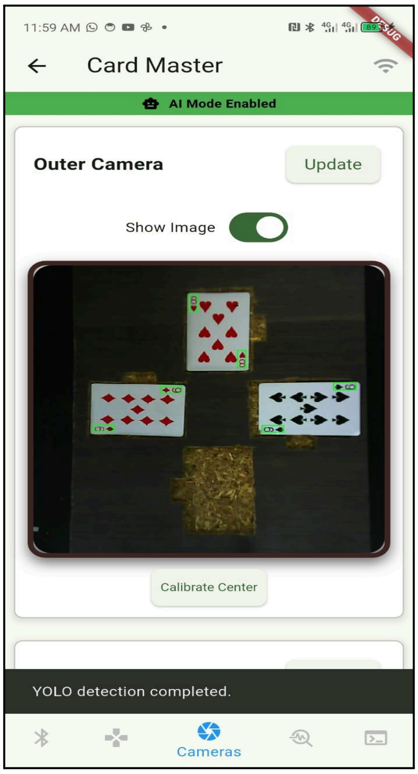
- **Development of the app**

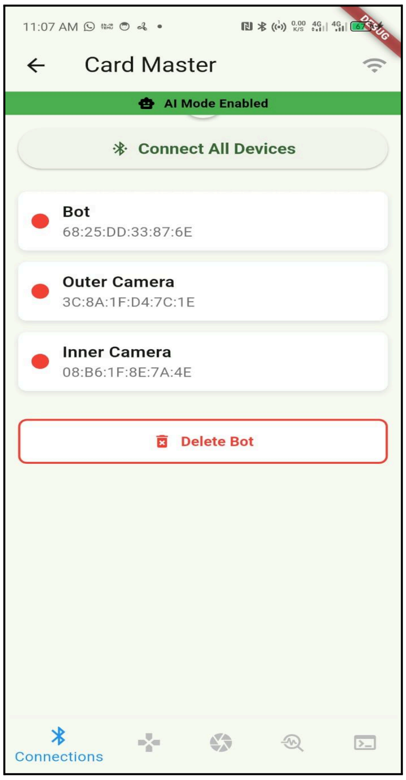





11:07 AM
Card Master
AI Mode Enabled
Current Scores
Us
0
Opp
0
Current Trump Suit
Current Stack
1
2
3
4
Game


11:59 AM
Card Master
AI Mode Enabled
Outer Camera
Update
Show Image
No Card
Calibrate Center
YOLO detection completed.
Cameras


11:59 AM
Card Master
AI Mode Enabled
Outer Camera
Update
Show Image
Calibrate Center
YOLO detection completed.
Cameras


11:07 AM
Card Master
AI Mode Enabled
Connect All Devices
Bot
68:25:DD:33:87:6E
Outer Camera
3C:8A:1F:D4:7C:1E
Inner Camera
08:B6:1F:8E:7A:4E
Delete Bot
Connections

- **Card detection model**

  Another major contribution I made to the project was the design and implementation of the Card Detection Model, which was a critical part of enabling the robot to recognize and manage cards autonomously. The development process began with the creation of a custom dataset of over 400 images, captured using the internal ESP32-CAM module under different lighting conditions and angles to improve robustness. A Convolutional Neural Network (CNN) was trained on this dataset; however, testing revealed a key limitation — the model could only detect cards accurately when placed at a very short distance from the camera. At longer ranges, the detection performance degraded significantly, making it unsuitable for real gameplay scenarios.

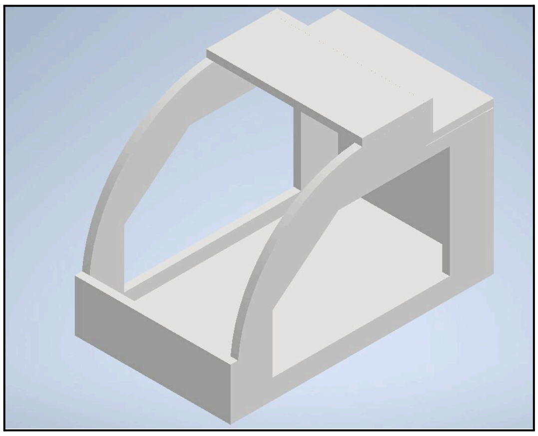
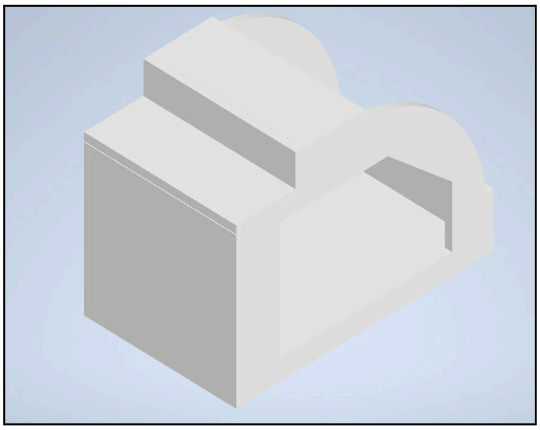
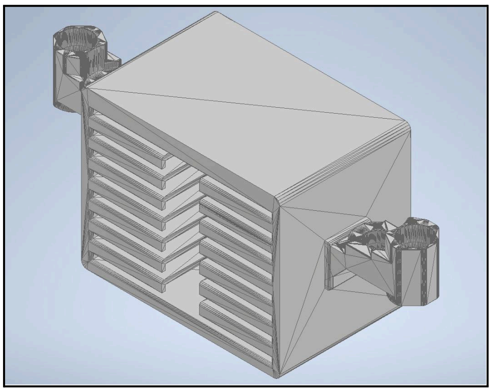
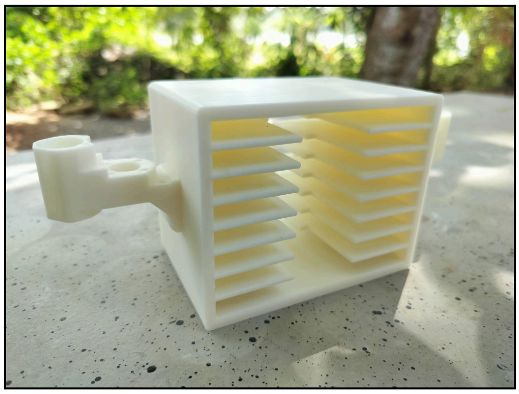
  To overcome this issue, I researched alternative solutions and adopted a larger, pre-annotated dataset from the Roboflow platform, which contained over 10,000 images of playing cards with detailed annotations of ranks and suits. This dataset offered greater diversity, including variations in distance, angle, and lighting, which were necessary for robust real-world detection. Using this expanded dataset, I trained the model on an NVIDIA Tesla P100 GPU, which required about 7 hours of training time. The resulting model, based on Ultralytics YOLO-11s, was capable of processing an image in 2–3 seconds (on mobile devices) and achieved up to 90% detection accuracy across most classes.

  This improved detection system was then integrated into the overall CardMaster robot, enabling accurate recognition of all cards, mapping them to storage slots, and providing the necessary input for the card selection model to make strategic decisions. Through this iterative development process, the card detection model evolved from a limited prototype into a highly reliable recognition system, ultimately becoming one of the core components of the robot's autonomous gameplay.

235533G - R.M.C.S.Rathnayaka

Responsibilities

- **Physical Design and 3D model**

- **Stack movement mechanism**

The stack movement mechanism in the robot is designed to vertically position the card holding stack for optimal card handling during the game. The mechanism is supported by two vertical rods positioned on either side of the stack. On one side, there are two holes: one is a threaded hole through which a threaded rod (lead screw) passes, and the other is a non-threaded hole through which a smooth stainless steel guide rod passes. On the opposite side, there is only one non-threaded hole with another stainless steel guide rod running parallel to the first.

The threaded rod is mechanically coupled to a stepper motor via a shaft coupler. When the stepper motor rotates, the threaded rod also rotates, translating rotational motion into linear vertical movement of the stack through the threaded connection. The stainless steel rods on both sides act as linear guides, ensuring smooth and stable motion while preventing wobbling or tilting.

A limit switch is mounted at the bottom of the structure to mark the end of the downward travel. When the stack moves down and presses the limit switch, the system receives a signal to stop the motor, preventing overtravel and protecting the mechanism from mechanical damage. This arrangement ensures precise, repeatable vertical motion of the stack, which is crucial for accurate card handling during gameplay.

- **Setting up the stepper motor and the limit switch**

The stepper motor used for driving the threaded rod is mounted securely to the base frame of the robot, aligned precisely with the threaded hole of the stack. The motor shaft is connected to the threaded rod using a flexible shaft coupler, which helps accommodate slight misalignments and reduces mechanical stress.

The stepper motor is connected to a stepper motor driver module A4988 that regulates current flow and provides step pulses. The driver is interfaced with the ESP32 microcontroller, which sends precise step and direction signals to control both the speed and position of the stack.

The limit switch is fixed at the lower end of the travel path, positioned so that the stack presses it only at the end of the downward motion. The switch is wired to one of the ESP32's digital input pins, with a pull-up or pull-down resistor configuration as required. In the control program, the limit switch acts as a reference or "home" position, enabling the system to reset the stack position before each game and avoid losing positional accuracy over time.

235524F - M.G.R.S.Nawarathna

Responsibilities

- **Sound output system implementation**

  To make the robot more interactive during gameplay, a sound output system was incorporated. This system produces different audio cues for various events such as startup, idle state, and happy, sad and angry. The objective was to enhance the player experience and make the robot's actions more understandable and engaging.

  DFPlayer Mini MP3 Player Module

  The **DFPlayer Mini** was selected as the primary audio playback module due to the following advantages:

- **Compact Size** – Small form factor allows easy integration within the limited internal space of the robot.

- **Direct MP3 Playback from microSD Card** – Eliminates the need for complex audio streaming or decoding on the ESP32.

- **Onboard Amplification** – The module has a built-in audio amplifier that can directly drive small speakers without requiring an external amplifier circuit.

- **Multiple Control Methods** – Supports UART serial commands, GPIO trigger, and analog control, providing flexibility in integration.

- **Low Power Consumption** – Ideal for battery-powered systems where energy efficiency is crucial.

<u>SP-0043 4Ω 5W Speaker</u>

The **SP-0043** speaker was chosen for its:

- **Power Handling Capacity** – Rated at **5W**, which is sufficient for producing clear and audible sound even in noisy environments.

- **Impedance Compatibility** – 4Ω impedance matches well with the DFPlayer Mini's output specifications, ensuring optimal power transfer.

- **Compact Yet Robust Build** – Small enough to fit inside the robot, yet durable for prolonged operation.

- **Full-Range Frequency Response** – Capable of producing both voice prompts and sound effects with good clarity.

While smaller 0.5W or 1W speakers could have been used, they would have resulted in **lower volume output** and reduced clarity, especially in environments with background noise. The SP-0043 ensures the sounds remain distinct and engaging.

Integration with ESP32 and Other Components

Since the ESP32's **RX0/TX0 pins** were already occupied for communication with the **stepper motor driver**, the DFPlayer Mini was connected to the ESP32's **RX2 and TX2 pins** to avoid conflicts and ensure reliable serial communication.

- DFPlayer Mini → ESP32 Wiring
  - TX (DFPlayer) → RX2 (ESP32)
  - RX (DFPlayer) → TX2 (ESP32)
  - VCC (DFPlayer) → 5V (ESP32)

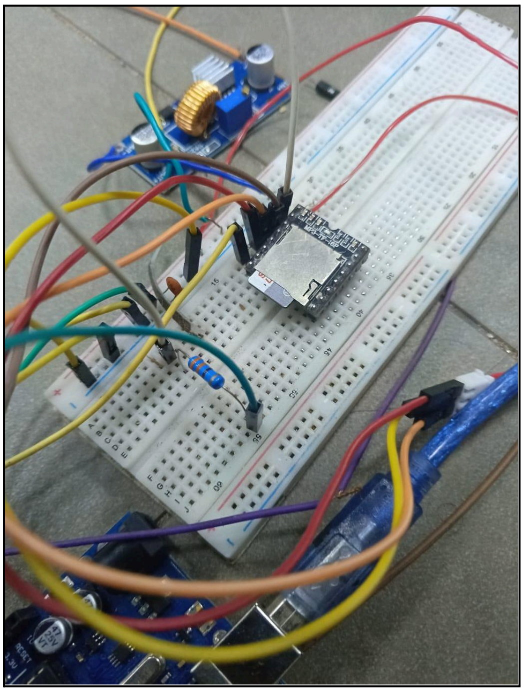
    ○ GND (DFPlayer) → GND (ESP32)

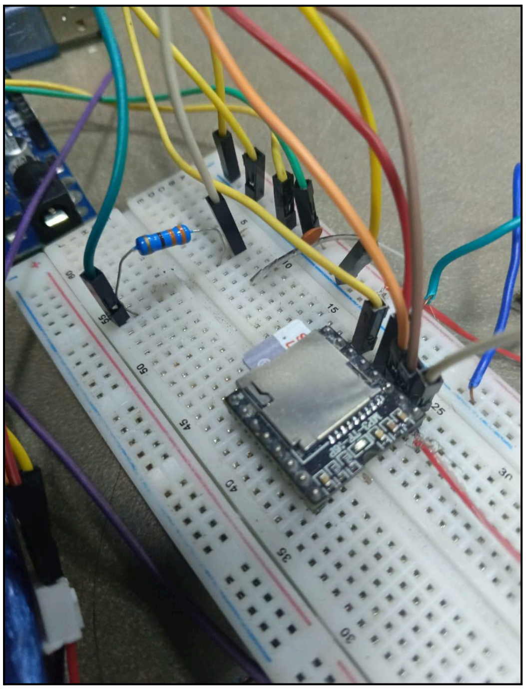
- Speaker Connection

    ○ SPK1 (DFPlayer) → Positive terminal of SP-0043 speaker

    ○ SPK2 (DFPlayer) → Negative terminal of SP-0043 speaker

The DFPlayer Mini directly drives the SP-0043 without any external amplifier, leveraging its built-in 3W audio output capability. Although the speaker is rated for 5W, operating it at a slightly lower wattage increases reliability and extends its lifespan.





- **Setting up servo motors**

1.Setting up the MG90S 180° Servo Motor for Card Output

The MG90S 180° servo motor was selected for the card output mechanism due to its precise angular control, compact size, and compatibility with low-voltage microcontroller systems like the ESP32. This motor's primary function in the system is to align the card slot with the position of the selected card, enabling accurate and smooth card delivery. Its installation began with securely mounting the servo in a fixed position near the card output slot. This ensured that its output arm could rotate without obstruction and align precisely with the slot required for the chosen card.

Electrical connections were then established by linking the MG90's three pins — **signal**, **VCC**, and **GND** — to the corresponding ESP32 pins and a regulated power supply. A **PWM (Pulse Width Modulation)** signal from the ESP32 was used to control the servo's angular position, as the SG90 responds to specific pulse widths to set its output arm at defined angles. The system code was configured to send accurate PWM signals that rotated the servo to predefined positions corresponding to the card delivery path.

Calibration was a critical step in ensuring smooth operation. The servo's neutral position was carefully set so that the arm started from a correct reference point. Fine-tuning was performed to avoid mechanical strain on the servo and to guarantee that the arm rotated only within its safe operational range. This calibration ensured that the mechanism aligned perfectly during each card delivery, resulting in consistent, precise, and reliable operation during gameplay.

2.Setting up the MG90S 360° Servo Motor for Card Pushing mechanism

The MG90S 360° continuous rotation servo motor was chosen for the card pushing mechanism because of its ability to rotate indefinitely in either direction, making it ideal for linear pushing and retracting motions. Its role in the system is to move a stick-like arm that pushes the selected card out of the stack and into the output slot. The motor was mounted in a stable position close to the card stack, ensuring the pushing arm could move freely in and out without interference from surrounding components.

Wiring connections followed the same principle as the SG90, with the motor's **signal**, **VCC**, and **GND** pins connected to the ESP32. However, the MG90S differs from a standard servo in that its control is based on rotation speed and direction rather than specific angles. The PWM signal from the ESP32 was programmed to set the motor's speed and rotation direction, allowing the arm to move forward to push a card or backward to return to the starting position.

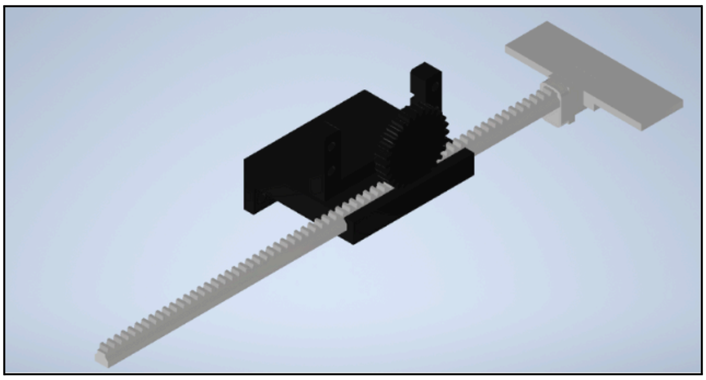
Calibration for this motor involved adjusting the PWM duty cycle and timing in the control code. Since the MG90S is a continuous rotation servo, precise control of position relies on controlling how long the motor rotates, not the angle. This timing was tested and refined so that the pushing arm extended just enough to eject a single card without pushing too far and causing a jam. It was also ensured that the retraction was smooth and complete, resetting the arm for the next card delivery. This careful setup and tuning guaranteed **smooth, accurate, and efficient card pushing** during the robot's gameplay operations.

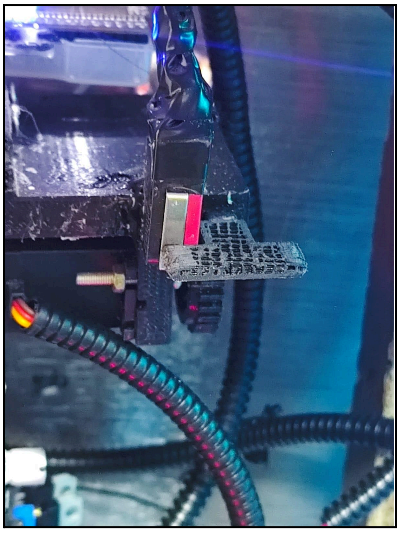
- **Setting up the card pushing mechanism**

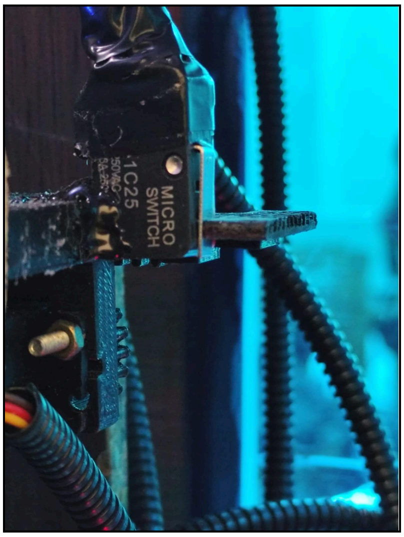
The card-pushing mechanism of the robot was designed to accurately move the selected card from the aligned stack into the outputting part of the system. This mechanism was built around the MG90S 360° servo motor and attached to the servo's output shaft was a custom-fabricated stick-like pushing arm, dimensioned and shaped to make smooth contact with the card's surface without bending or damaging it. The pushing arm was aligned precisely with the slot leading to the outputting part, so the motion path would be consistent for every card.

To achieve controlled and reliable operation, a pull-up limit switch was integrated into the mechanism to detect the completion of the backward movement of the pushing arm. This allowed the system to know exactly when the pusher was in its home position and ready for the next card. The servo motor was programmed to rotate forward for a calibrated duration, driving the pushing arm forward just far enough to fully insert the card into the output slot. Once the push was complete, the servo reversed its rotation, retracting the arm until the limit switch was triggered. This ensured that the arm always returned to the exact same starting point, preventing mechanical drift over multiple operations.

The servo mount had to hold the motor at the correct height and orientation so that the pushing arm would travel parallel to the card surface. The limit switch was placed where it could be reliably pressed by the retracting arm without obstructing its movement. All moving parts were tested for clearance to avoid jamming, and the servo's rotation speed was tuned to provide a balance between smooth operation and quick response. This combination of precise mechanical alignment, well-chosen components, and position feedback resulted in a highly dependable card-pushing mechanism that operated seamlessly with the rest of the robot's systems.







- **PCF8574 I/O Expander**

  During the implementation stage, one of my main contributions was identifying and integrating the PCF8574 I/O expander module into the system. While connecting the components, it was realized that the number of GPIO pins available on the ESP32 board was insufficient to handle all the inputs and outputs required. Specifically, the design required the integration of one IR sensor and seven push buttons to enable proper interaction and control of the robot. However, the ESP32's available pins were already occupied with other peripherals, creating a limitation in terms of expandability.

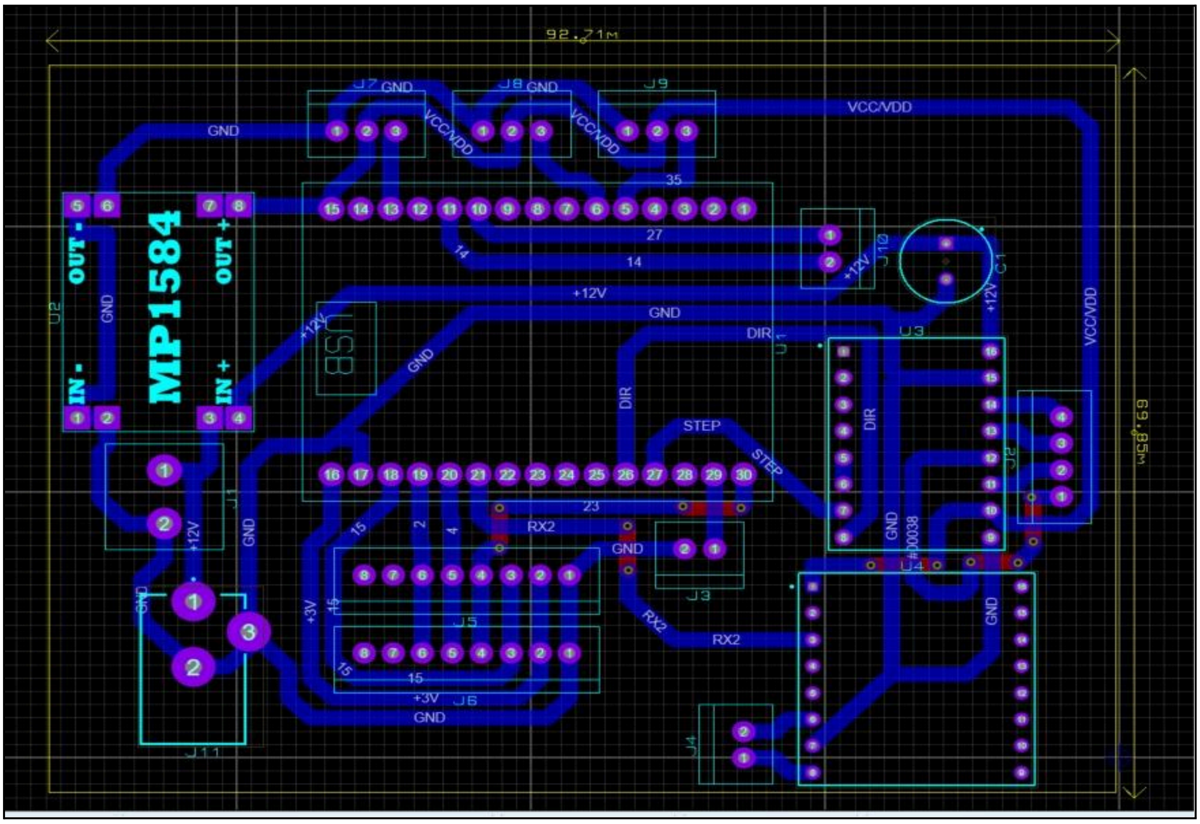
  To overcome this challenge, I researched possible solutions and proposed the use of the PCF8574T I/O expander, which is an I^2C-based 8-bit parallel I/O extension module. This module was selected because it communicates over the I^2C bus, meaning that only two pins of the ESP32 (SDA and SCL) are needed, while it provides eight additional I/O pins. These extra pins were sufficient to connect both the IR sensor and the seven push buttons, ensuring that the system design requirements were met without compromising other connections.

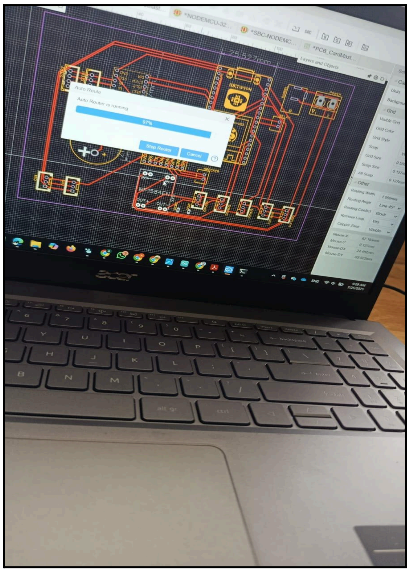
  I was responsible for integrating the PCF8574 into the circuit, configuring its I^2C communication with the ESP32, and verifying the inputs from the push buttons and the IR sensor. By choosing and implementing this module, I ensured that the system could be expanded effectively without increasing hardware complexity or requiring a second microcontroller. This decision not only solved the GPIO shortage problem but also kept the design more cost-effective and efficient.

235513V - D.M.A.I.Dissanayaka

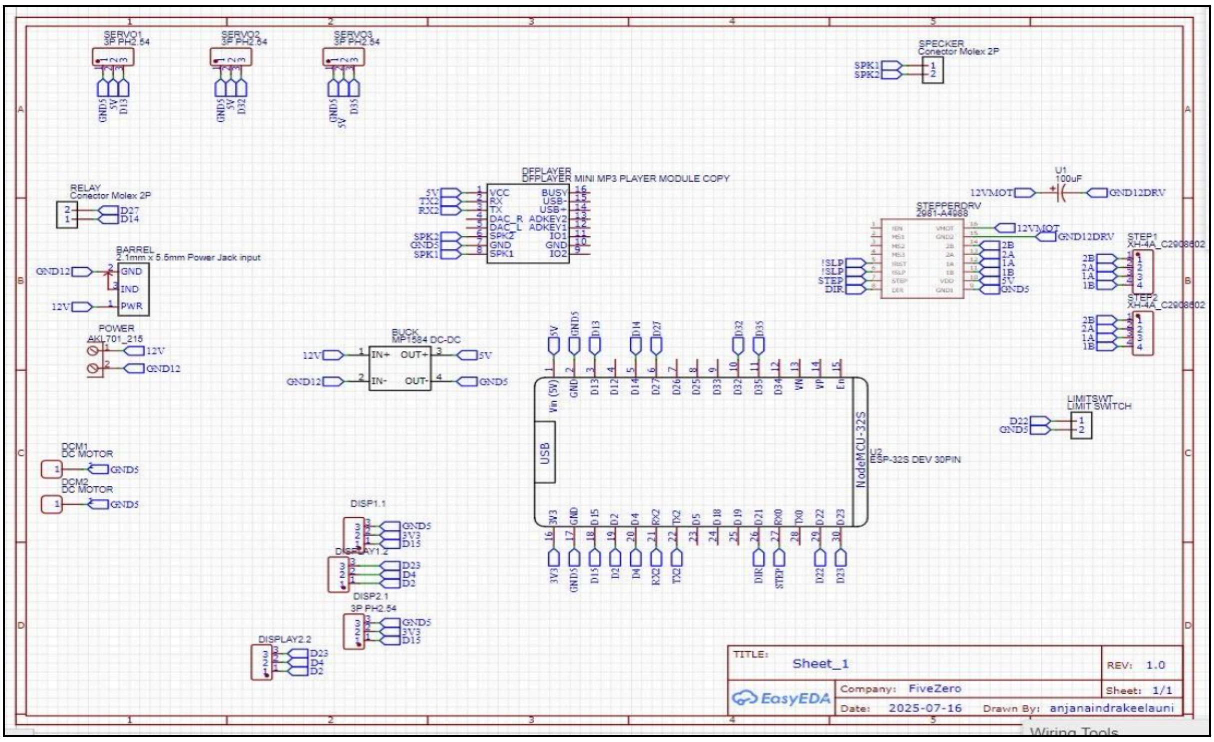
Responsibilities

PCB Design





- **Schematic Design**



- **Setting up DC motors**

1.Setting up of the Card Ejection DC Motor

The brushed DC motor in the OMI card game robot is responsible for the final ejection of the card onto the table. This motor is connected to a rubber-coated wheel positioned in direct contact with the card once it is inserted into the outputting section by the pushing mechanism. When activated, the motor spins the wheel at a sufficient speed to generate the necessary friction to grip the card's surface and propel it forward, ensuring the card is thrown smoothly and accurately onto the playing area.

During assembly, the motor was securely mounted on a custom-designed bracket to maintain proper alignment between the wheel and the card path. The wheel was firmly attached to the motor shaft using a set screw to prevent slippage during high-speed operation. The distance between the wheel and the guiding surface was adjusted to apply optimal contact pressure on the card—enough to grip it effectively without bending or damaging it. Electrical connections from the motor terminals were soldered and insulated, then connected to a motor driver module, which allows precise control over its rotation speed and duration through the microcontroller.

To ensure consistent operation, the motor was tested with different card thicknesses, adjusting the wheel position and motor speed until the cards were reliably ejected. Rubber padding was added to the wheel's surface to increase friction and minimize wear on the cards. The final setup ensures that the DC motor activates only after the pushing mechanism has placed the card into the ejection zone, providing smooth, controlled, and accurate card delivery during gameplay.

2.Setting up of the Card Inserting DC Motor

The brushed DC motor used for the card inserting mechanism plays a crucial role in smoothly guiding the card into the designated slot once it has been partially pushed by the servo-based mechanism. The motor is mechanically connected to a set of rollers via a geared transmission system, as shown in the CAD model. These rollers make direct contact with the card, gripping it through friction and feeding it forward into the slot at a controlled speed. The gearing arrangement not only transmits motion from the motor to the rollers but also optimizes torque to ensure consistent card movement without slippage or damage to the card’s surface.

For the setup, the DC motor was mounted securely on the mechanism’s side frame, with its shaft coupled to the gear train using a rigid coupling to avoid misalignment. The rollers were installed in parallel pairs to ensure uniform contact across the card’s surface, preventing skew during insertion. A rubber coating was applied to the rollers to maximize grip while minimizing wear. Electrical wiring from the motor to the motor driver was soldered, insulated, and secured along the frame to prevent interference with moving parts. The motor driver was configured to provide smooth acceleration and deceleration, avoiding sudden starts that could bend or jam the card.

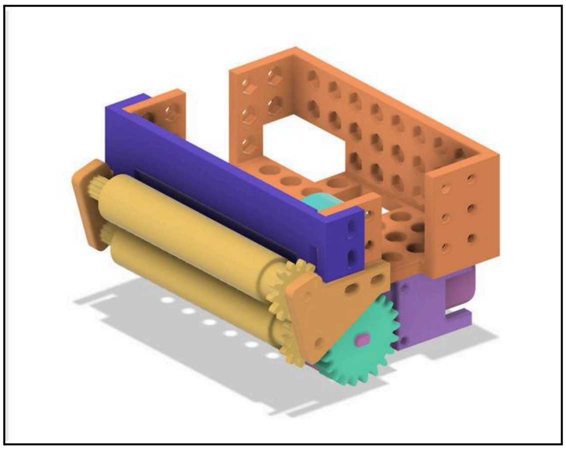
The mechanism was tested with different card materials and thicknesses to calibrate motor speed and roller spacing. Fine adjustments were made to roller alignment so that the card would pass centrally into the slot without deviation. Once tuned, the motor provided reliable and repeatable insertion, ensuring the card was positioned accurately in the outputting section, ready for the next stage of the game.

- **Card input mechanism**

The card input mechanism combines a TCRT5000 IR sensor and a brushed DC motor to ensure proper detection and insertion of cards into the storage slots. A small opening is provided in the card input path, through which the IR sensor detects whether a card has been placed by the player. This detection is essential to confirm card availability before activating the insertion process.

Once the IR sensor confirms the presence of a card, the DC motor drives the rollers to pull the card smoothly into the stack. The motor provides the necessary force for insertion, but its operation is strictly dependent on the sensor signal. This prevents unnecessary motor running, reduces wear, and avoids jams when no card is present.

By integrating the IR sensor into the mechanism, the system ensures that only valid card placements trigger the motor, making the process both reliable and efficient. The sensor–motor coordination guarantees accurate positioning of each card in the slot, preparing it for the next stage of gameplay.



7. Future Development

For further advancement of the project, it has been decided to integrate a Raspberry Pi into the robotic system to enhance both processing power and interactivity. While the current implementation with ESP32 modules provides reliable control and communication for the game-playing functionalities, the Raspberry Pi will enable more advanced features such as image processing, decision-making with machine learning models, and smoother coordination among system components.

With the Raspberry Pi, the system can be extended to incorporate real-time computer vision for more accurate card recognition using a camera module, eliminating possible limitations of simpler recognition methods. Additionally, the Raspberry Pi's higher computational capability will allow the integration of voice-based interaction, enabling players to interact with the robot through speech commands, thereby increasing the robot's interactivity and making the gameplay more engaging.

Another area of improvement includes the addition of network connectivity features, where the Raspberry Pi can facilitate remote monitoring and online gameplay, allowing users to connect and compete with others virtually. Furthermore, advanced data logging and analytics could be implemented, recording game statistics and strategies that can later be analyzed to improve the robot's decision-making algorithms.

Overall, by integrating a Raspberry Pi, the project can evolve from a primarily hardware-controlled prototype into a more intelligent, interactive, and user-friendly system with broader applications beyond the current card game setup.

8. Total Cost

Component	Qty	Price	Total
ESP 32	1	1100	1100
Display	2	1650	3300
ESP32 Cam Modules	2	2140	4280
Stepper Motor	1	4700	4700
Stepper Motor Drive	1	320	320
Power Supply	1	1000	1000
Buck Converter	1	130	130
Servo Motor MG90S 360	1	920	920
Servo Motor MG90S 180	1	540	540
DF Player Mini MP3	1	350	350
Speaker	1	980	980
Limit Switch	2	80	160
Gear Motor	1	650	650
Puch Buttons		300	300
PCB		500	500
IR Sensor	1	720	720
3D Printing		7000	7000
Wire Casing		800	800
Casing		3200	3200
Nuts & L Clips		1225	1225
Wires		540	540
PCB Mount Wire Clips		530	530
Capasitor	1	8	8
Aluminium Flexible Coupling	1	230	230
Paints		1280	1280
Card Pack	2	200	400
Others		2980	2980
Stickers		280	280
Shipping & Transport		4220	4220
Total			**42643**

9. References

Playing Cards Dataset:

https://universe.roboflow.com/joshuas-workspace/playing-cards-9gfac

Ultralytics YOLO11: https://docs.ultralytics.com/models/yolo11/

Kaggle Platform: https://kaggle.com

Tkinter: https://docs.python.org/3/library/tkinter.html/

Matplotlib:**Matplotlib — Visualization with Python** **US20050040594A1 - Pre-shuffler for a playing card shuffling machine - Google Patents**

US6254096B1 - Device and method for continuously shuffling cards - Google Patents

US20120267851A1 - Card shuffler with gravity feed system for playing cards - Google Patents

https://universe.roboflow.com/