Design Document

TA: Nikul Arora
Professor: Arne Fliflet

Project #32: Andrejun Agsalud, David Medina, Steve Guzman

Introduction

Problem

With the collection of trading cards expanding, collectors and sellers face a significant logistical challenge; sorting through thousands of cards efficiently to identify and categorize them for storage or sale. According to business research insights, the trading card marker was valued at $956 million in 2021 with projection seeing it rise more and more per year ("Trading Card Market Size, Share, Growth | Forecast - 2031"). With individual cards being worth thousands of dollars nowadays, the stakes and accuracy of sorting through many packs of cards is critical. Reselling websites such as Ebay have witnessed a 142% boost in card sales in 2020 (Lindner). There are currently many ways to store and organize cards through booklets and trays; there are even playing card sorters you can buy. However, there is a clear lack of a tool that can help people go through trading cards. The current manual sorting process is time-consuming and prone to error, leading to missed opportunities or damages to the cards. Not only this, but the use of fingers can possibly damage and smudge the cards, lowering the value of the trading card.

Solution

This team proposes a solution that aims to address the lack of a trading card sorting by building a device that will allow its user to efficiently sort through a pack of Pokemon cards without fail. This Automatic Trading Card Sorter will leverage existing technologies and combine them into a single package that will be easily fabricated. We aim to reduce the time and effort required to sort trading cards while also maintaining the card's condition.

To implement the Automatic Trading Card Sorter (ATCS), we will aim for simplicity first. Based on the machine shop's input, it was found that it will be better to use a feeder that will dispense one card to be read by a camera, be assigned a classifier value, and then moved to the appropriate sorted pile. The mechanism for dispensing one card will involve a clever design for the feeder and servo motor that will hold one end of the card, while the camera scans the other. For this solution, we aim to sort by 3 to 4 colors. Since most trading cards of color have the borders colored, only a small section of the card will be analyzed by the camera that will be using computer vision to tell the colors apart. Once a color has been identified, the onboard microcontroller will handle the logic of what to do with that color and decide what direction the platform motor should rotate. Cards are sorted by having the platform where they are being analyzed rotate and place the card into a bin of the appropriate color. There will be buttons available to pause the machine so the user can empty a bin and place it back and buttons for which colors are enabled to be analyzed. LEDs will accompany the color buttons so that the user is aware of which colors are currently being sorted.

Our solution will decrease the time and effort trading care enthusiasts go through when going through a new pack of cards, allowing them more time to organize their collections for storage or sale, and becoming a staple in the card collectors home.

Visual Aid

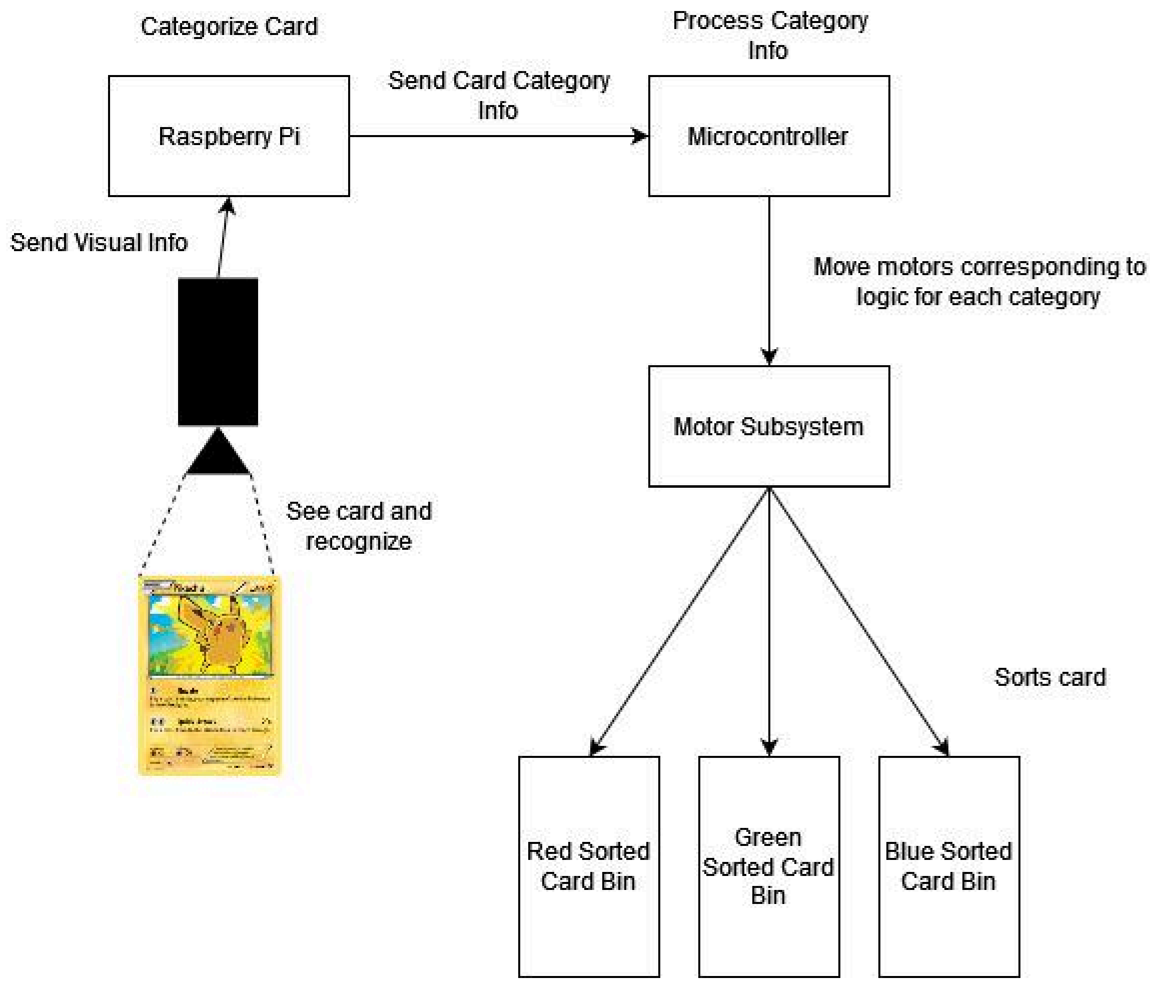

Figure 1: Visual Aid

High-level requirements list:

1. Two packs of Pokemon cards (22 cards) will be sorted by primary color with one extra bin for non-RGB cards. Maximum of 2 mis-colored cards with the goal of achieving at least 80% accuracy in sorting. It is a **success** if 16 out of the 20 actual pokemon cards are sorted in the correct spaces.
2. A single pack (12 cards) should be able to be sorted in 30 sec + or - 2 seconds.
3. Will identify RGB (primary colors) with 90% accuracy. Computer vision will recognize if color doesn't match.

Design

Block Diagram:

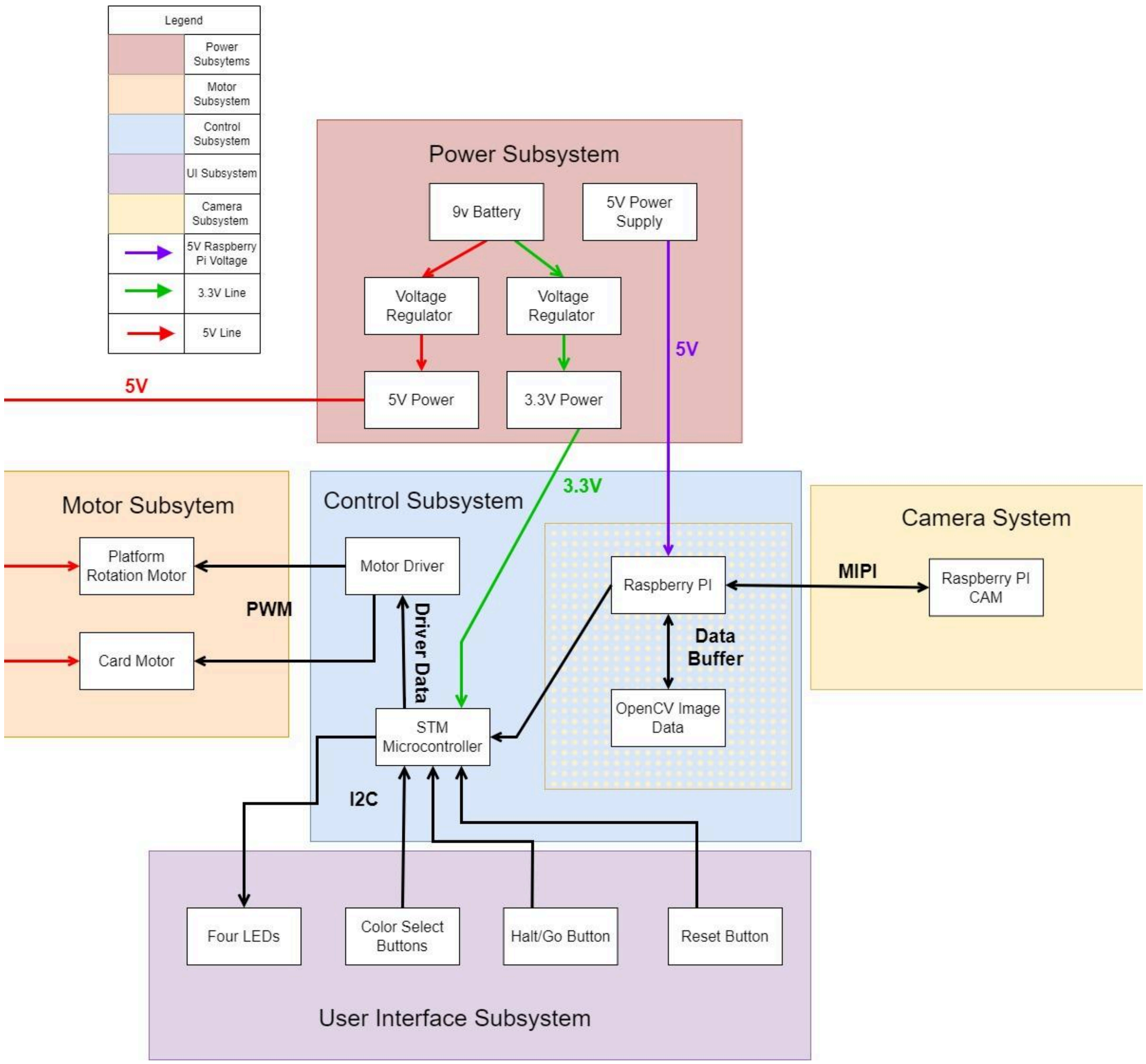

Figure 2: Block Diagram

The high level block diagram features all the subsystems and main components that will be part of our design. The system will run on two power sources. The first source will be dedicated to the Raspberry Pi 4 and comes included with it. It will provide the Pi with 5V independent of all other components. A 7.4V LiPo battery will provide power to all other components through voltage regulators that will step down the voltage. The 5V step down voltage will go to the servo motor, the stepper motor and its driver.

By having the LiPo battery be at 2.6Ah, we can ensure high performance without the need to worry about the rapid drain that comes with other batteries like Alkaline. This early investment will ensure that the motors will run without worry of rapid discharge.

The other 3.3V voltage regulator will power the Espressif(ESP) 32 WROOM which in turn will power other components in the User Interface(UI) subsystem. The ESP will be designed to go on a Pi-hat PCB of our design. This will let the ESP serve as the control logic of the device, taking data from the Raspberry Pi and Camera system to control the motors based on the UI.

The UI subsystem will allow the user to choose which colors to sort and provide system options of halt and reset. In tandem with the ESP, the Motor Subsystem will smoothly position the card for Camera system analysis. Once the analysis is complete, the stepper motor will transfer the card to a designated drop area, where the servo motor will have already aligned it.

Physical Design:

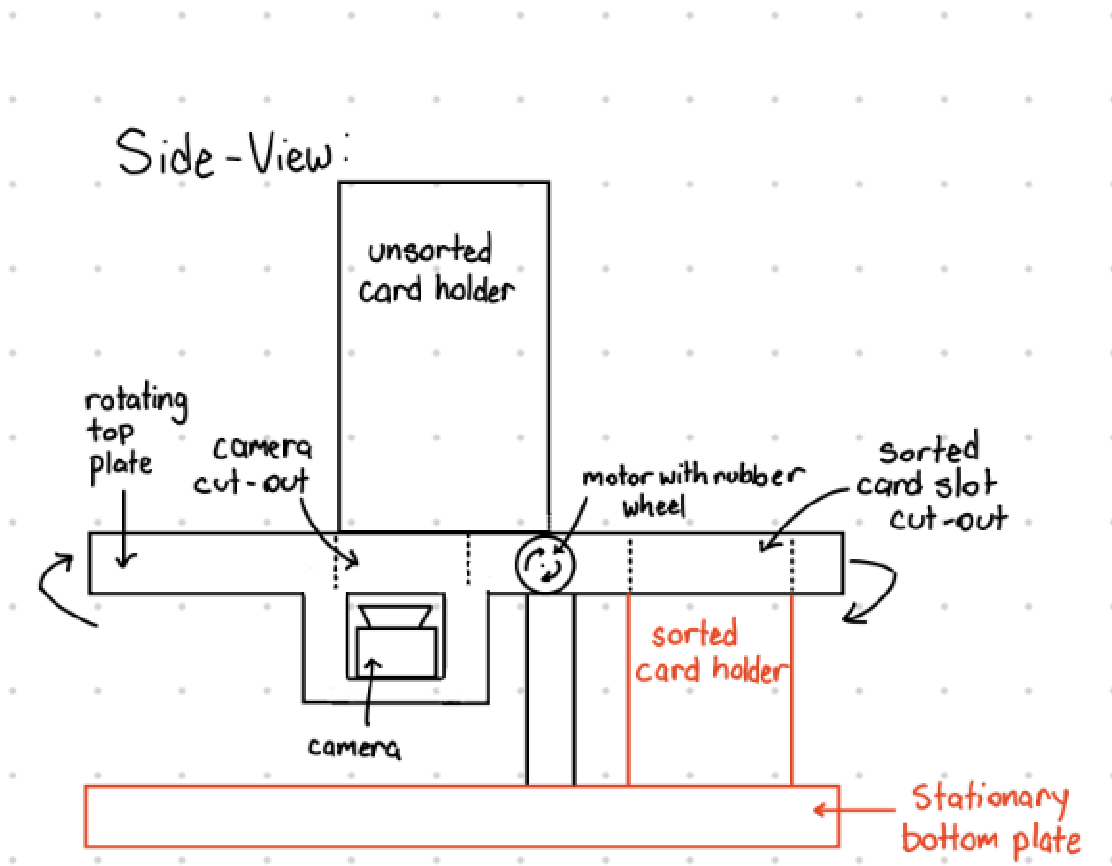

Figure 3: Physical Side view of Design

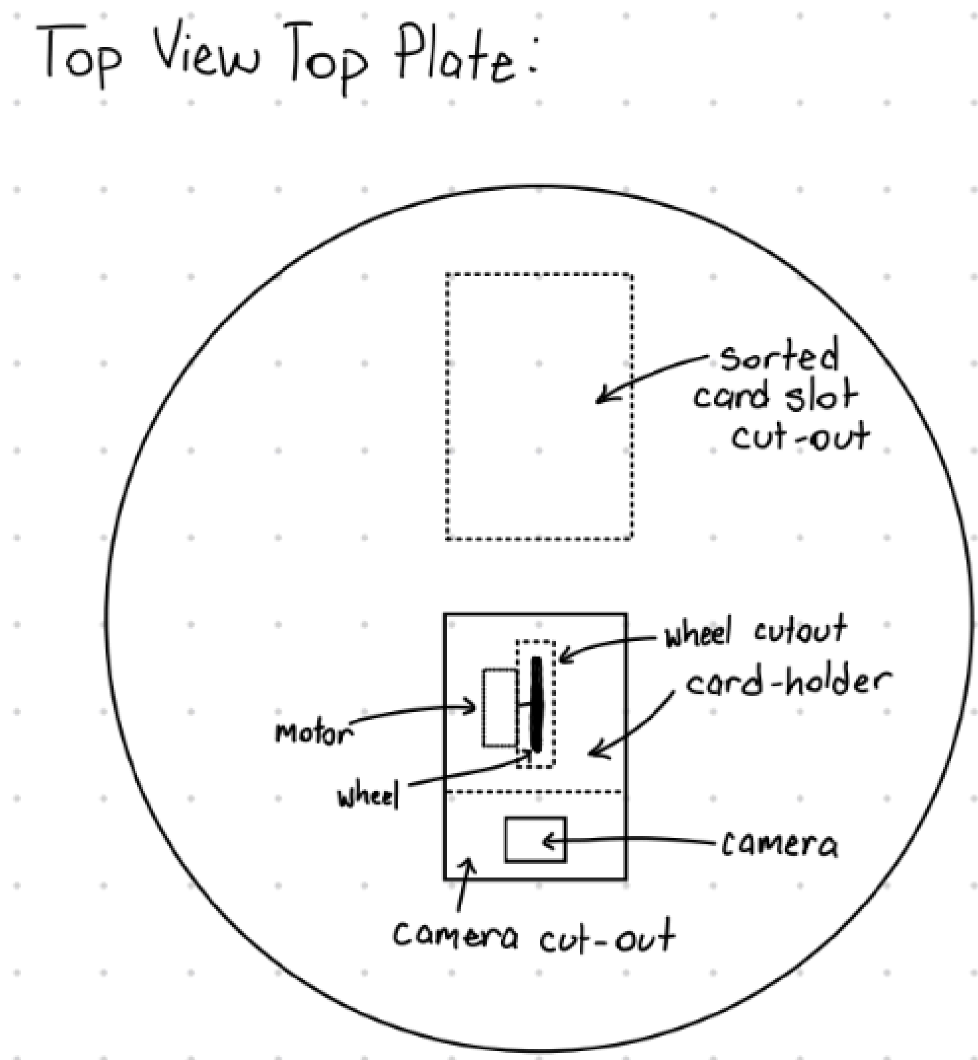

Figure 4: Physical Top view of Top Plate

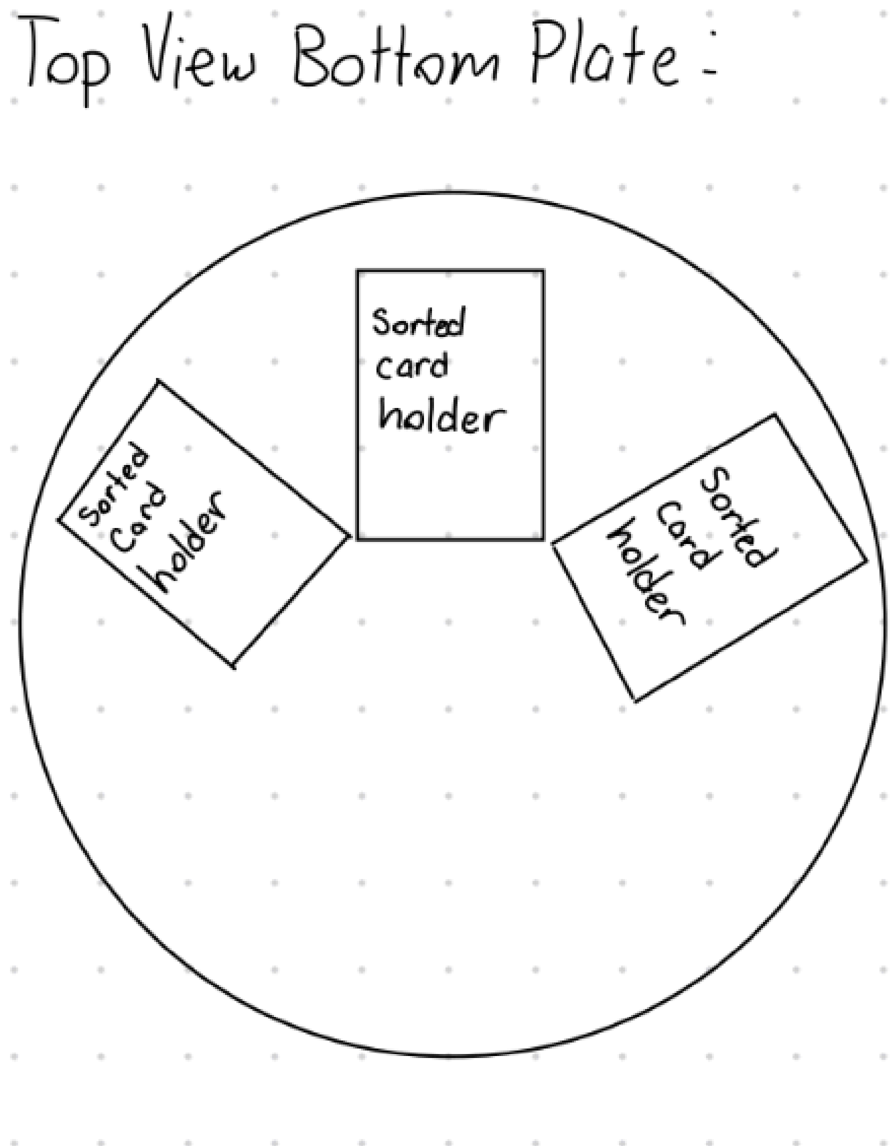

Figure 5: Physical Top view of Bottom Plate

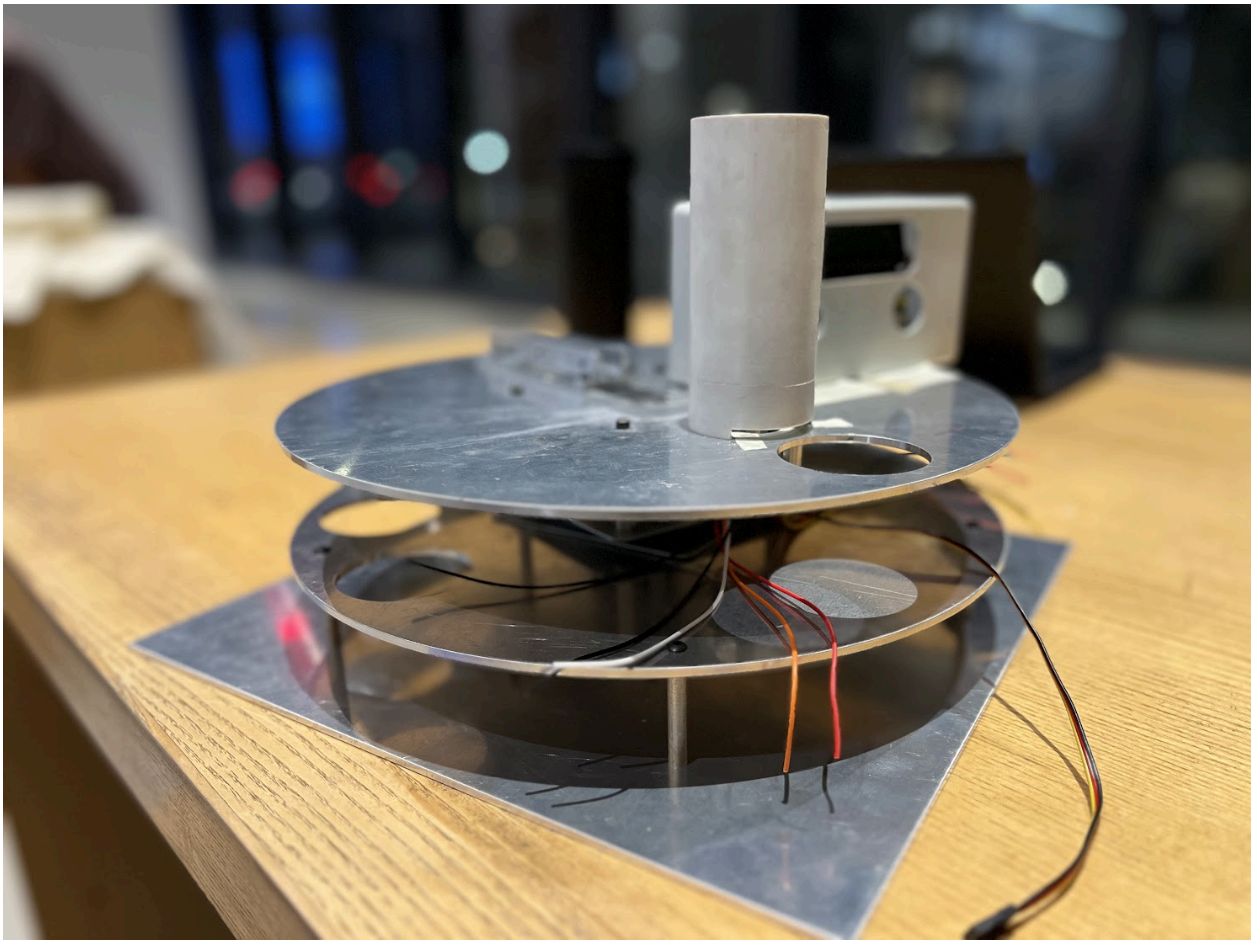

Figure 6: Given Base Design by Machine Shop

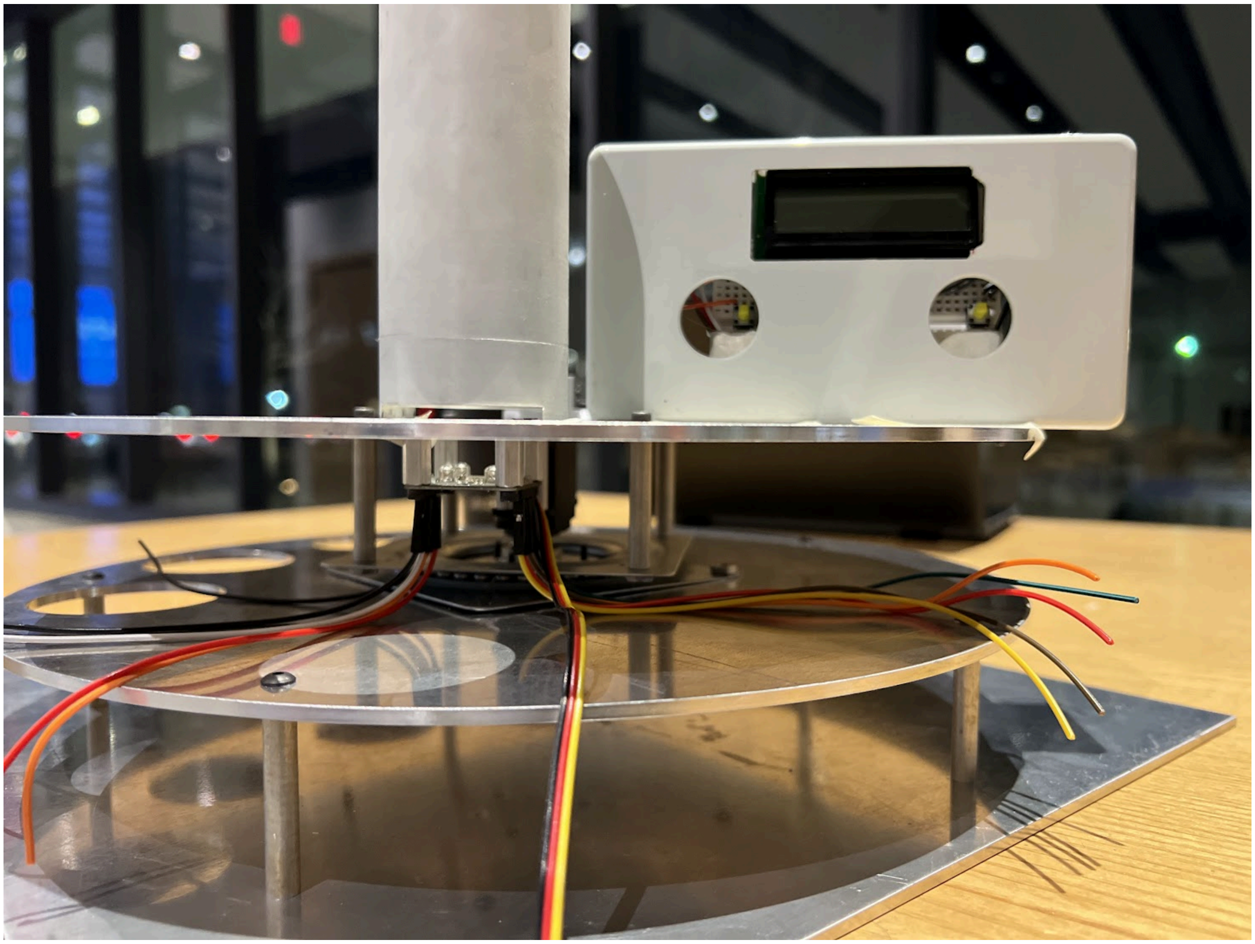

Figure 7: Side of View of Base Design

The device will be made of CNC cut metal plates with the help of the machine shop. The rotating base design seen in figures three and seven will be retrofitted once again from a previous semesters project. The card bin cutout will be a minimum of 2.5 inches by 3.5 inches to fit a standard pokemon card. A Pi-hat PCB with the ESP32 microcontroller will house connectors and necessary components. This will all be housed in an enclosure with a slit for the Pi Cam to come out and read the cards. Current testing with OpenCv does not see the light level being an issue at the moment. The Pokemon cards will sit in a container waiting to be analyzed by the pi. From here, the servo motor will point the card in the direction of the corresponding slot. Finally, the stepper motor will dispense the card into the correct pile.

Subsystem Overview

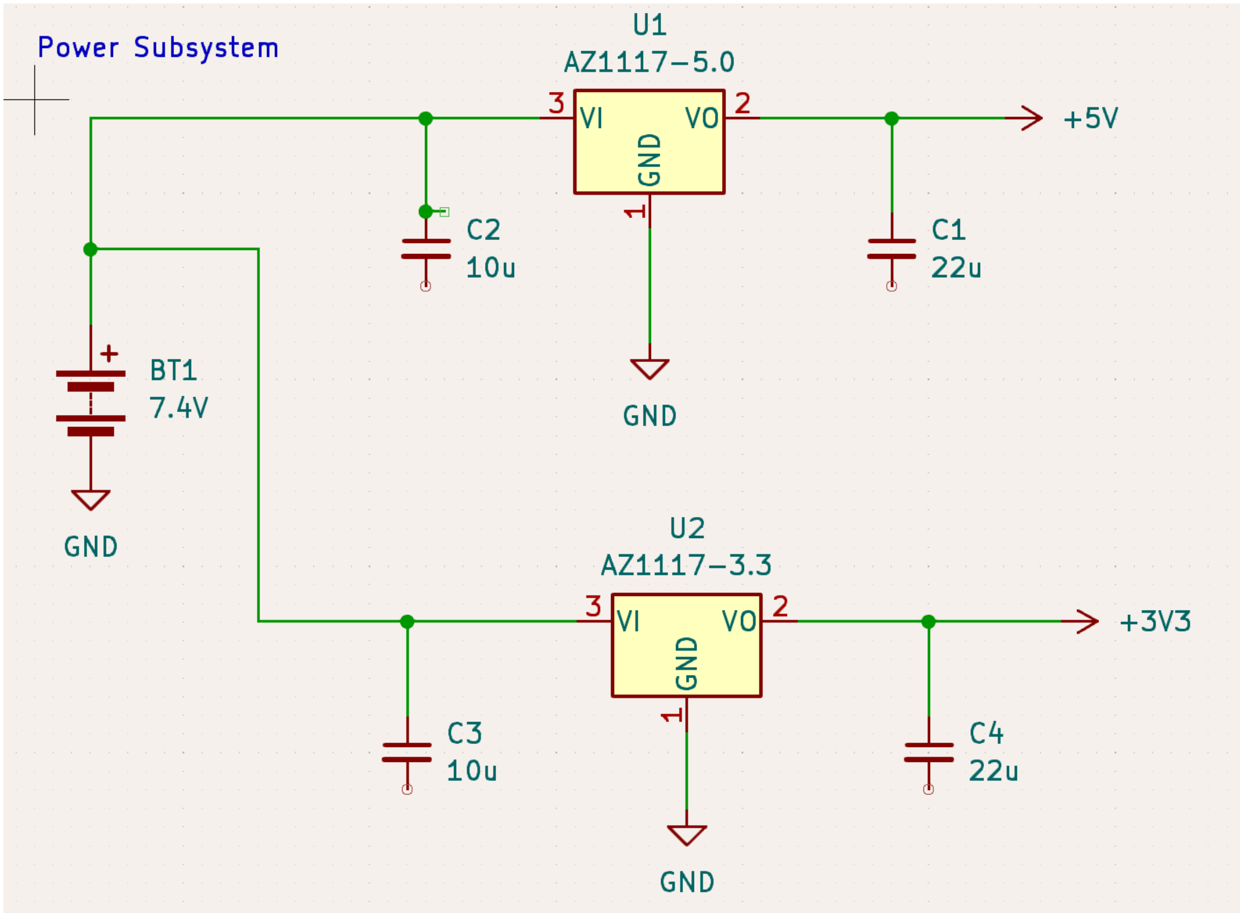

Figure 8: Prototype KiCad Power System Sketch

Power Subsystem

- The system will incorporate a dual source power supply configuration. The Raspberry Pi and Pi Cam will be powered with a 5V DC power supply, dedicated exclusively to energizing. This was chosen to sidestep potential power hiccups that could occur when both the Pi and motors share a power source. This could lead to the Pi having voltage fluctuations if not handled correctly. To avoid this, a separate 7.4V battery will be dialed down to 3.3V for the motors to use and 5V for the microcontroller to use. In the future, a consumer version of this system should all run off one outline that is regulated down to all three key components.

Requirements:	Verification:
The AZ1117 voltage regulator must receive voltage from a 7.4V battery and provide output voltages of 3.3±0.5% V and 5±0.5% V.	1. Use a multimeter and measure the voltage at both output nodes from the voltage regulator to verify it supplies a voltage within 0.5% of 3.3 V and 5 V. 2. Use the multimeter and measure the input voltage for both regulators to make sure the correct voltage is being given and confirm a stable connection between the regulator and their respective device. 3. Record voltage values in a table for both the voltages being given out from the regulator and the voltages being supplied to both motors and microcontroller..
The AZ1117 voltage regulator has a minimum of 1 A.	1. Use a multimeter to measure the output current at the output nodes from the voltage regulator.
The AZ1117 voltage regulator must stay under the 125°C maximum junction temperature.	1. Use an infrared thermometer to measure the surface temperature of each voltage regulator. Verify that the temperature values are below 125°C.

Motor Subsystem

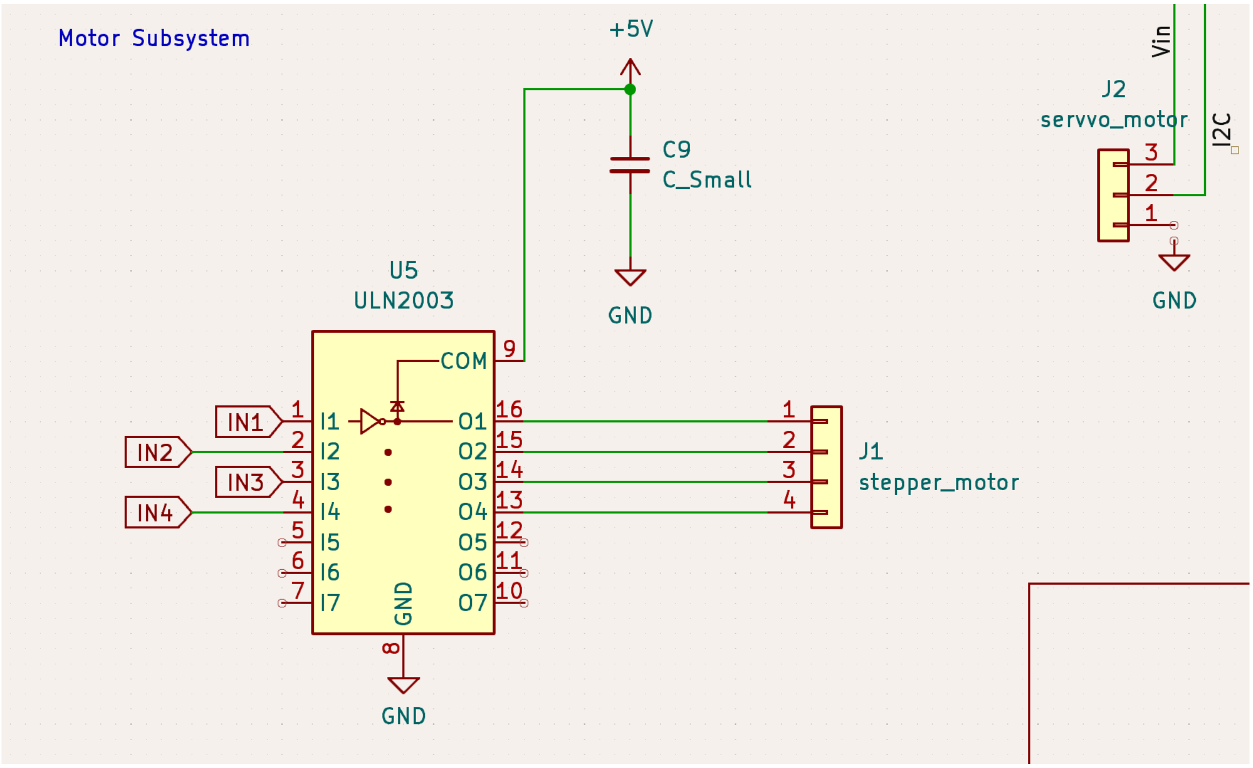

Figure 9: Prototype Motor Subsystem Sketch

- Many options for actuation exist that could help with the success of this project, but at the suggestion of the machine shop, the use of a Servo motor for the base was recommended. For the cards to move into place to be analyzed by the Pi Cam, a stepper motor will be used. It is the only accurate way of getting a card to consistently move into place without having to do a gear system for a normal rpm motor. The goal of this system is to read the card on top of the camera to then be dropped into a corresponding bin. The motors will be controlled through Pulse Width Modulation (PWM) communication from the Control system which handles both motors.

Requirements:	Verification:
The stepper motor must be rotated a specific amount to dispense exactly one card.	1. Place 2 cards to be sorted by the machine.

	2. After turning it on, ensure the first card is ejected properly into a bin. 3. Make sure the second card does not stick out of the machine.
Both motors must be supplied with 5±0.5% V from the power subsystem.	1. Place 4 cards into the machine. Make sure 1 card is placed face down, another is placed face down rotated at 180 degrees, a third is placed face up, and a fourth face up rotated 180 degrees. 2. Apply a voltmeter to both motor connections and record the values of all card ejections on a table.

User Interface Subsystem

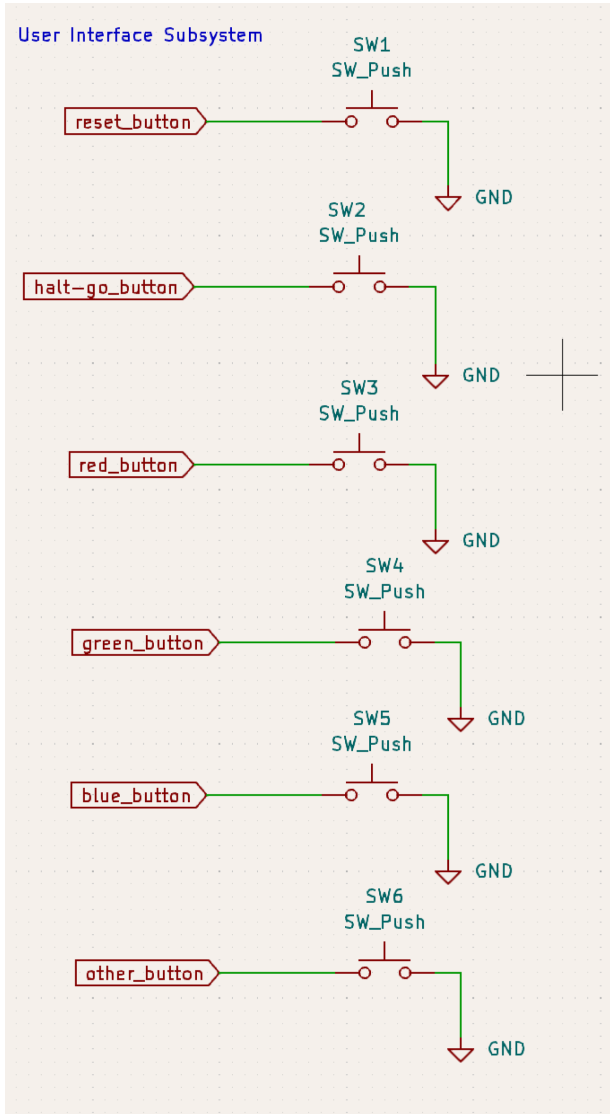

Figure 10: Incorrect User Interface

- The User Interface will consist of six buttons that will interact with the device through Digital Input Signals (DIS). The buttons were preferred due to them being simple and practical to use for the current color sorting options. There will be four buttons to decide which colors are on the sorting list. This allows the user to choose to sort only red cards, or to sort between red, green, and blue cards at the same time. The fourth button will be for non-RGB colored colors. There will also be function buttons such as a Halt button and a Reset button. The Halt button will pause the current operation while the reset button will move the motors back into a starting position.

Requirements:	Verification:
Buttons should send digital inputs to the ESP32 which changes its logical configuration. LED's should receive digital outputs from the ESP32 which signal the microcontroller's current configuration.	Each Button got its respective section
Make sure the Reset button works	1. Use a serial debugger to record the value being sent to the ESP32 when the Reset button is not being pressed 2. Press and hold the Reset button. Record the value being sent to the ESP32 with the serial debugger and ensure it's a different value than when the Reset button was not pressed. 3. Release the Reset button. Record the value being sent to the ESP32 with the serial debugger and ensure the value is the same as the value recorded from step (1). *Running a serial debugger involves connecting the ESP32 to a computer with the corresponding hardware pins and running any emulation software such as PuTTY to read what values are being sent/received by the ESP32.*
Make sure the Reset button stops the motor, returns it back to its original position, and turns off the LED lights	1. Place a stack of cards and select an option to sort the cards. 2. After starting the sorting, press and release the reset button. 3. Verify that the machine stops sorting any other cards, moves the motor back to the original position in between the two middle binns, and that all LED lights are turned off.
Make sure the Halt/Go button works	1. Use a serial debugger to record the value being sent to the ESP32 when the Halt button is not being pressed 2. Press and hold the Halt button. Record the value being sent to the ESP32 with the serial debugger and

	ensure it's a different value than when the Halt button was not pressed. 3. Release the Halt button. Record the value being sent to the ESP32 with the serial debugger and ensure the value is the same as the value recorded from step (1).
Make sure the Halt/Go button stops the machine if it's sorting cards, and starts it again if it's in an idle state.	1. Place a pile of cards to be sorted onto the machine. 2. After selecting a color to sort, verify that when the button is pressed, the machine begins sorting colors. 3. After the button is released and the machine has begun sorting cards, press and release the button as well. 4. Verify that the machine stops both motors.
Make sure the Red/GreenBlue/Other button works	1. Use a serial debugger to record the value being sent to the ESP32 when the Red button is not being pressed 2. Press and hold the Red button. Record the value being sent to the ESP32 with the serial debugger and ensure it's a different value than when the Red button was not pressed. 3. Release the Red button. Record the value being sent to the ESP32 with the serial debugger and ensure the value is the same as the value recorded from step (1). 4. Repeat steps 1-3 for the Green, Blue, and Other buttons.
Make sure the Red/GreenBlue/Other lights up the respective LED, and that no more than 3 LEDs are lit up at the same time.	1. Make sure the machine is not sorting any cards at the moment and that all LEDs are turned off. 2. Verify that choosing the Red option by pressing its respective color turns on the LED. 3. Make sure that pressing the button again turns off the LED. 4. Repeat steps 1-3 for the rest of the color option buttons. 5. Make sure that if three options are selected, pressing the final button does not turn on its respective LED.

Camera System

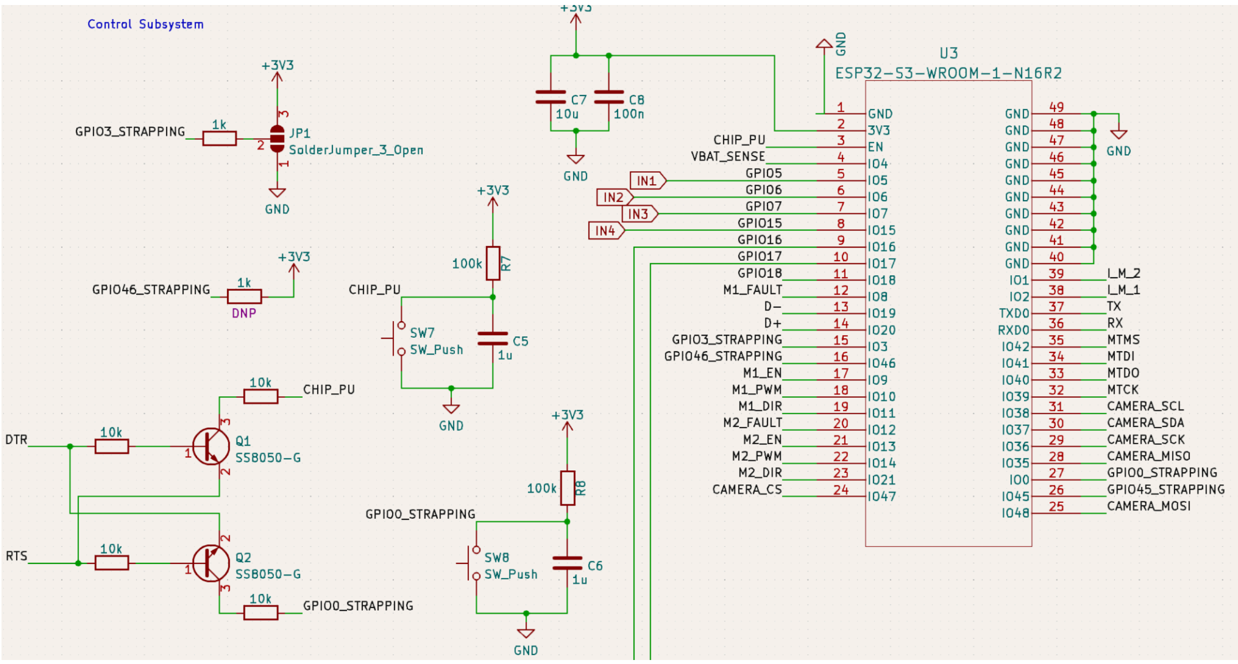

Figure 11: Prototype Control System for ESP32

- For this device, the camera system will be the main way for trading cards to be identified.The camera will be a PI cam since its caballities with the PI will simplify the process and avoid having to match another camera's standards to the Raspberry PI. The camera will be slotted in a space where it can look up at a part of the card. From here, the card is then moved based on what the Raspberry determines the color to be.

Requirements:	Verification:
The camera subsystem must have a high color accuracy. This means that the ESP32 must receive correct categorization data from the pi.	1. Insert 20 cards with varying colors in the machine. 2. With a serial debugger, record the color values that the camera senses, ensuring that the color matches what is visually seen as close as possible with the selected options, 3. Repeat steps 1-2 for a total of three trials, ensuring that the sensor can distinguish cards based on the

	selected RGB options.

Control Subsystem

- This system will consist of a Raspberry Pi 4 with a daughter board PCB that will fit an STM chip as the microcontroller. The power pins will not be connected as by requirements, the microcontroller will be powered by a 7.4 V battery that will be stepped down to 3.3 V. The Raspberry Pi will take the Pi cam data and use OpenCV, a computer vision extension, to determine the primary color of the card on a range. This means that if a color is orange, it will get rounded to red for example. The logic of handling what to do with the color and which motor to spin will be determined by the STM. The microcontroller will also handle responses from the buttons that the user presses and light up the appropriate LEDs.

Requirements:	Verification:
The ESP32 must be able to parse information received from the raspberry pi and user interface. Using this information, it must be able to: 1. Rotate the base servo motor to the correct card bank 2. Rotate the card stepper motor to dispense a single card	1. Once the ESP32 gets the info for the color the card is, confirm that the motors correctly sort the card. This occurs in the following steps: a. The base servo motor rotates to point to the correct bin location. b. The stepper motor rotates to move the card out and have it drop on the correct bin.
The ESP must receive 3.3±0.5% V.	1. Use a voltmeter at the input voltage pin, and make sure there's 3.3 V being supplied to the chip. Place a set of 5 cards to have the machine sort, and confirm 3.3 V are being supplied throughout the sorting.

Tolerance Analysis:

Our project requires the use of multiple voltage regulators due to the different power requirements of different components. In order to avoid thermal damage we need to ensure that we correctly group different components to an appropriate voltage regulator. Since we are using set voltages that match with the preconfigured voltages of the AZ1117 voltage regulator, we will use two AZ1117's set at 3.3V and 5V.

The AZ117 has a typical current draw of 1.35A

Part (Operating at 5V)	**Max Current Draw**	**Comments**
Stepper Motor (Card Motor)	100 mA	Calculated through I = V/R, where V is operating voltage and R is winding resistance at 25°C. We calculated 41mA, but will allocate 100mA.
Servo Motor (Platform Motor)	300 mA	Motor states max draw is 200mA. We will allocate 300mA just to be safe.
Total Max Current Drawn	700mA < 1.35A	

Variable	**Value**	**Comment**
Tj	125° C	Based on the voltage regulator
Iout	100 mA, 300 mA	Current draw of each motor
Vin	7.4 V	Battery Voltage
Vout	5 V	Component Voltage
Θjc	30° C/W	Thermal resistance of voltage regulator
Θca	90 C/W	Ambient thermal resistance
Ta	+25°C	

Part (Operating at 3.3V)	Max Current Draw	Comments
ESP32-S3-WROOM-1	107.9 mA	Peak current draw of the MCU in modem-sleep mode. Since we don't need wireless, this is the highest the MCU will draw.
Total Max Current Drawn	107.9 mA < 1.35A	

Variable	Value	Comment
Tj	125° C	Based on the voltage regulator
Iout	107.9 mA	MCU current draw
Vin	7.4 V	Battery Voltage
Vout	3.3 V	Component Voltage
Θjc	30° C/W	Thermal resistance of voltage regulator
Θca	90 C/W	Ambient thermal resistance
Ta	+25°C	

Tj=iout(vin−vout)(Θjc+Θca)+Ta

Calculating Tj = 78.0868°C (MCU), 53.8°C (Stepper Motor), 111.4°C(Servo Motor) < 125°C.

2xAZ117 is sufficient for our components.

Cost Analysis:

Labor:

Assuming the average salary provided by the University of Illinois for computer engineering graduates of $109,176. We can assume an hourly wage of $50 an hour. With this, we can calculate the total labor for all partners to be:

($50/hour) x 2.5 x 84 hours x 3 members = $31,500

Based on estimates from the machine shop's quoted hours of 45 to complete the project with an hourly rate of $56 an hour, we can calculate the cost of the machine shop's labor:

($56/hour) x 45 hours = $2,520

Parts:

Description	Manufacturer	Quantity	Price	Link
Continuous Rotation DC Motor Servomotor	Parallax Inc.	1x	$19.95	https://www.digikey.com/en/products/detail/parallax-inc/900-00008/1774454
Unipolar Stepper Motor Permanent Magnet Gear Motor Frame Size 4096 Step 5VDC	MikroElektronika	1x	$8.00	https://www.digikey.com/en/products/detail/mikroelektronika/MIKROE-1530/5724295?s=N4IgTCBcDa4BwCMCeArAtAFjgAgM4BcBTAB2wFsB7fCgJxAF0BfIA
Raspberry Pi 4 Model B 8GB		1x	$75.00	https://www.pishop.us/product/raspberry-pi-4-model-b-8gb/?src=raspberrypi
Raspberry Pi Camera Module 3		1x	$25.00	https://www.pishop.us/product/raspberry-pi-camera-module-3/
RF TXRX MODULE BT PCB TRACE SMD	Espressif Systems	1x	$3.35	https://www.digikey.com/en/products/detail/espressif-systems/esp32-s3-wroom-1-n4r8/16162637
IC REG LINEAR 3.3V 1A TO252-2	Diodes Incorporated	1x	$0.44	https://www.digikey.com/en/products/detail/diodes-incorporated/AZ1117CD-3-3TRG1/4470979
IC REG LINEAR 5V 1A TO252-2	Diodes Incorporated	1x	$0.47	https://www.digikey.com/en/products/detail/diodes-incorporated/AZ

				[1117CD-5-0TRG1/4570580]
LED GREEN DIFFUSED 3MM ROUND T/H	Würth Elektronik	4x	$0.17	[https://www.digikey.com/en/products/detail/w%C3%BCrth-elektronik/151031VS06000/4489988]
SWITCH PUSH SPST-NO 3A 120V	E-Switch	7x	$2.39	[https://www.digikey.com/en/products/detail/e-switch/RP3502ARED/280448]
TRANS 7NPN DARL 50V 0.5A 16DIP	Texas Instruments	1x	$0.47	[https://www.digikey.com/en/products/detail/texas-instruments/ULN2003AN/277624]
RES 510 OHM 5% 1/4W AXIAL	YAGEO	4x	$0.10	[https://www.digikey.com/en/products/detail/yageo/CFR-25JB-52-510R/2306]
CAP CER 10UF 16V X5R 0805	Samsung Electro-Mechanics	1x	$0.10	[https://www.digikey.com/en/products/detail/samsung-electro-mechanics/CL21A106KOQNNNE/3886754]
BATTERY PACK LI-ION 7.4V 18650	Dantona Industries	1x	$17.87	[https://www.digikey.com/en/products/detail/dantona-industries/L74A26-2-1-2W/13692635]
		Total Material Costs:	$168.46	

Adding together labor and material costs, the total cost of the project adds up to **$34,188.46.**

Schedule:

We are assigning tasks based on the preferences and prior experience of each member.

Week of	Andrejun	Steve	David
2/12	Finalize Design Document, Order Parts, Rough ESP32 Breadboarding	Finalize Design Document, Order Parts, Set up Pi OpenCV	Finalize Design Document, Order Parts, Rough KiCad Design
2/19 (Design Review)	Design Review, Revise design and talk with Machine Shop, Breadboard rough design (focus on pi-to-MCU and MCU-to-motor)	Design Review, Revise design and talk with Machine Shop, Basic OpenCV functionality	Design Review, Revise design and talk with Machine Shop, Finalize initial PCB design based on breadboard
2/26 (PCB review)	Get basic OpenCV functionality, get output from pi to microcontroller	Get basic OpenCV functionality, Get MCU logic with UI-subsystem	Talk to machine shop based on PCB review, get output from pi to microcontroller
3/4 (First Round PCB, Final Machine Shop Revision, Team Evaluation)	Receive PCB, basic assembling and testing, Check OpenCV/UI-logic functionality	Receive PCB, basic assembling and testing, Check OpenCV/UI-logic functionality	Receive PCB, basic assembling and testing, test circuit
3/11	Further develop OpenCV, help PCB redesign	Further develop OpenCV, help PCB redesign	Further calibrate on breadboard, PCB redesign
3/18 (Second Round PCB)	Receive second order of PCB, test for faults with UI microcontroller connection and OpenCV	Receive second order of PCB, test for faults with UI microcontroller connection and OpenCV	Receive second order of PCB, breadboard for redesign
3/25 (Third Round PCB, Individual Prog. Report)	Receive third order of PCB, Breadboard for final design	Receive third order of PCB, Further test OpenCV	Receive third order of PCB, Breadboard for final design
4/1 (Fifth Round PCB)	Finish adjustments and assembly of design	Finish adjustments and assembly of design	Finish adjustments and assembly of design

4/8	Mock Demo, Prepare Presentation	Mock Demo, Prepare Presentation	Mock Demo, Prepare Presentation
4/15	Final Demo	Final Demo	Final Demo
4/29	Final Presentation	Final Presentation	Final Presentation

Discussion of Ethics and Safety:

When considering the ethics of and Safety of the Automatic Trading Card Sorter(ATCS), it is crucial to adhere to the established codes of ethics provided by the Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery(ACM). By adhering to these codes below, the ATCS will be able to address potential misuse of the device and safety concerns.

Ethical Considerations

IEEE Code of Ethics: By incorporating these rules into our project, we can clearly articulate the team's commitment to ethical principles and professional conduct. This will not only guide the team's decision making, but ensure to the project staff and our users that we are serious about developing our device.

- Rule 1: Emphasizing the importance of safety, health, and welfare of the public. Through the use of the halt/pause button, emergency stops in case of emergency are possible. Testing of the design will ensure proper mechanical and electrical safety measures that may be added along the way.
- Rule 5: Seeking, accepting, and offering honest criticism of technical work is critical to any design which ultimately leads to improvements and innovation. Acknowledging and correcting errors, being transparent about the capabilities of and limitations of the design , and creating detailed documentation will foster an environment of integrity and collaboration.
- Rule 7: Treating all the team members and users of the device with fairness and respect is fundamental. We encourage new ideas within the team at every step of the process by staying in constant contact with each other and ensuring that group members agree with major decisions.

- Rule 8: Committing to a harassment-free environment, including the prohibition of bullying behavior, ensures a safe and positive atmosphere for all team members and stakeholders involved in the project. If needed, a TA can be called to mediate a discussion if serious enough.

Code of Ethics:

In general, we aim to focus on honesty, fairness and the protection of confidential information. To the best of our ability we will strive to achieve high quality in both the process and products of professional work.

- 1.1- Contribute to society and to human well-being, acknowledging that all people are stakeholders in computing. We hope to have the ATCS impact the trading card market and ease the user experience.
- 1.2 Avoid harm: Design the device to minimize risks to users, including physical harm from mechanical parts or psychological. In particular, ensuring that the removing parts such as the motors don’t injure anyone or damage the cards is a priority.

Safety Concerns

To ensure the safety of our device, we will separate it into mechanical and electrical components. With the development and operation of a physical device comes an inherent safety risk, including both electrical hazards and mechanical malfunctions that could lead to injury or property damage. To mitigate these risks, the project will:

1. Rigorous Testing and Enclose of Components:
    a. Implement rigorous testing phases to ensure all moving parts and electrical components are securely enclosed, significantly reducing the risk of accidents.
    b. Design the device with integrated fail-safes, such as using a servo motor with 90 degrees of mobility. Including a pause button will also allow the user to pause the device in case of an emergency.
2. Responsive Mechanism for Malfunctions
    a. Equip the device with mechanisms that allow moving parts to halt immediately in case of a card jam or any malfunction, ensuring quick response to potential hazards.
    b. Inclusion of a pause button is crucial as it provides the user with the ability to stop the device instantly. Also, measures to prevent the over rotation of servo motors to prevent uncontrollable movements.
3. Optimization of Motor Strength
    a. Carefully calibrate the motor strength to ensure cards are handled gently without being dented or damaged, preserving the integrity of trading cards during sorting.
4. Adherence to Electronic Tolerances
    a. Determine the electronic tolerances to prevent overheating, short-circuiting or any electrical failures.

Avoiding Ethical Breaches & Safety Issues

To effectively avoid any breaches in ethics and safety, a 2 step plan will be followed to avoid these issues:

1. Risk Assessment
    - ISO 12100: “Safety of machinery…”. This standard will provide guidelines for identifying hazards, assessing risks, and implementing measures to mitigate these risks. It will serve as a foundation for which through risk assessments will be conducted on mechanical and electrical components of the device
    - Unknown (nobelcert.com)
        - See page 19 for the Strategy Guidelines
2. Continuous Review and Testing
    - IEEE 29119-1: Software and Systems Engineering testing. Provides a framework for which testing practices and validation processes that ensure software components of the project meet safety and regulatory requirements.
    - ISO/IEC/IEEE 29119-1, Software and systems engineering—Software testing—Part 1: Concepts and definitions (wildart.github.io)
        - See Figure no. 5 in page 19 for dynamic test process and Figure no. 4 in page 17 for a general approach in prioritizing testing procedures

Citations:

ISO/IEC/IEEE 29119-1, Software and systems engineering—Software testing—Part 1: Concepts and definitions, 1 September 2013, https://wildart.github.io/MISG5020/standards/ISO-IEC-IEEE-29119-1.pdf. Accessed 8 February 2024.

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