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.

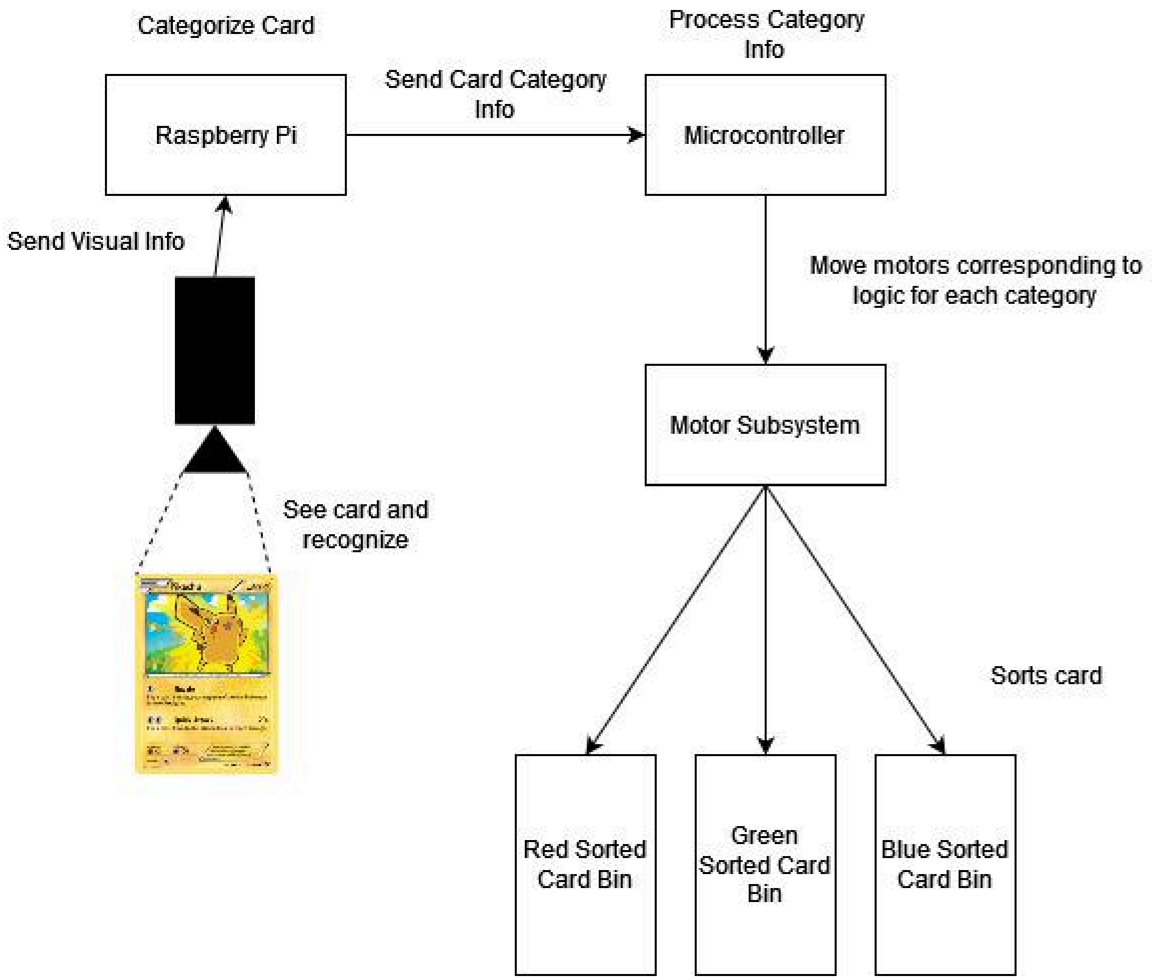
Solution

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.

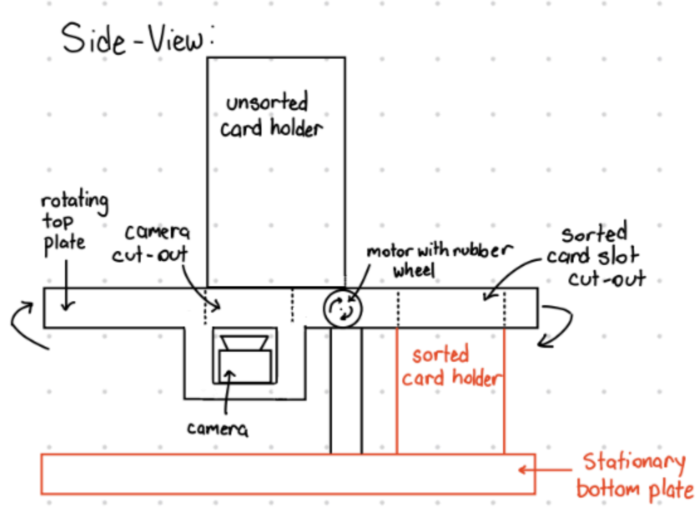
To implement the Automatic Trading Card Sorter(ATCS), we will aim for simplicity first. Based on the machine shop's input, it was found that it will be better to use a feeder that will dispense one card to be read by a camera, be assigned a classifier value, and then moved to the appropriate sorted pile. 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 camera 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. The way cards will be sorted is 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.

Visuals

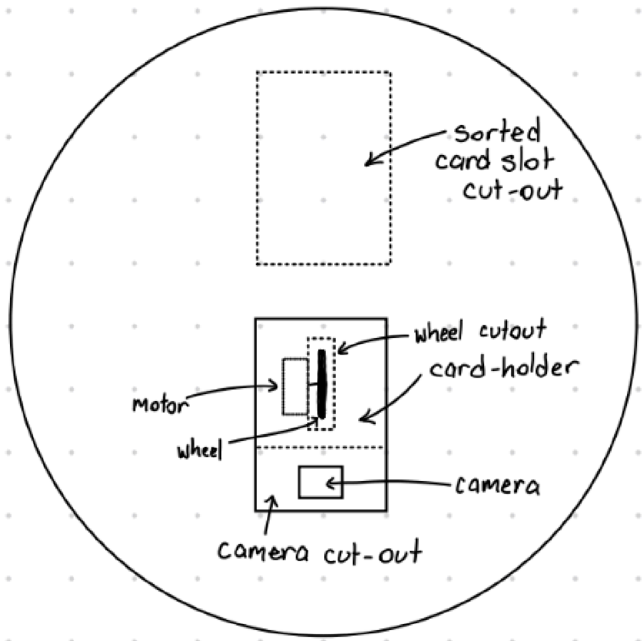


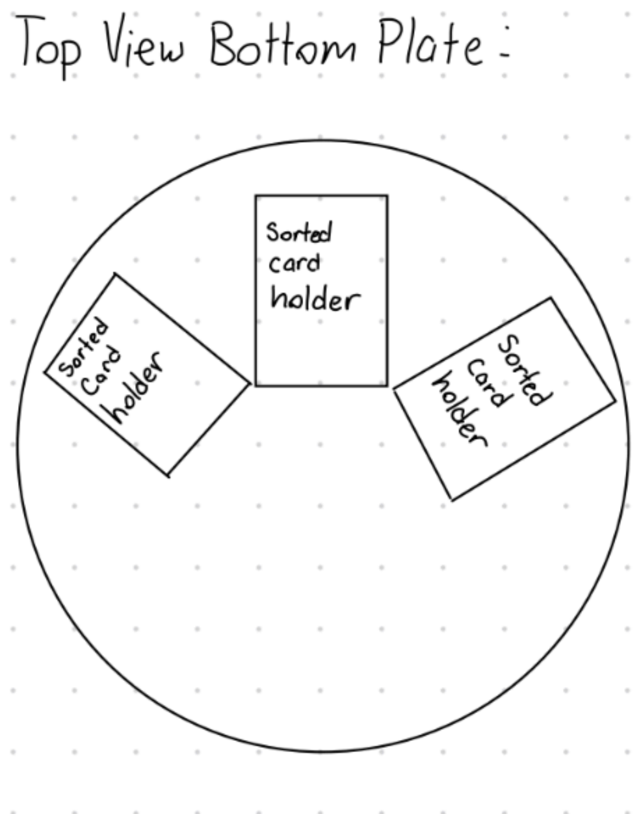
Categorize Card
Raspberry Pi
Send Card Category Info
Process Category Info
Microcontroller
Send Visual Info
Move motors corresponding to logic for each category
Motor Subsystem
See card and recognize
Sorts card
Red Sorted Card Bin
Green Sorted Card Bin
Blue Sorted Card Bin



Side-View:
unsorted card holder
rotating top plate
camera cut-out
motor with rubber wheel
sorted card slot cut-out
sorted card holder
camera
Stationary bottom plate

Top View Top Plate:



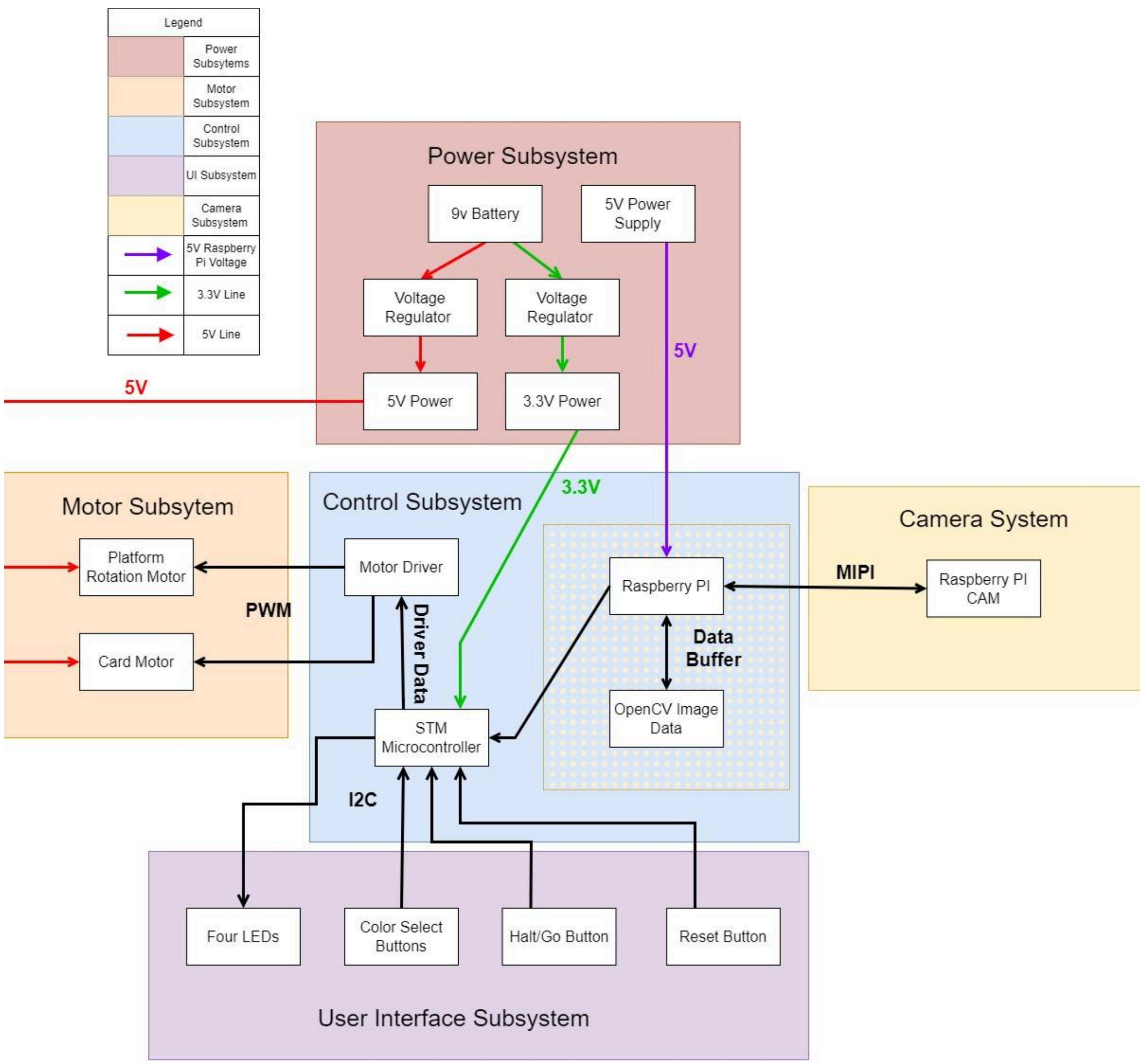


High level Requirements

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



Subsystem Overview

Power Subsystem

- The system will incorporate a dual source power supply configuration.The Raspberry Pi will be powered by outlet, 5V DC power supply that will be dedicated exclusively to energizing the Raspberry Pi and Pi Cam. 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 Pi having voltage fluctuations if not handled correctly. To avoid this, a separate 9V battery will be dialed down to 3.3V for the motors to use and another 3.3V 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.

Motor Subsystem

- 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 transport a card from a hold and move it along to be read so that it then be dropped onto a pile. The motors will be controlled through Pulse Width Modulation(PWM) communication from the Control system which handles both motors.

User Interface Subsystem

- 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. Whether the user only wants reds sorted or perhaps all three at the same time. The user will be free to choose. 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.

Camera System

- 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.

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 9V battery that will have a stepped down 3.3V. 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. Meaning 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.

Subsystem Requirements

Power Subsystem

- Use 9V battery to supply voltage regulator
- Supply 3.3V to the microcontroller of the Control Subsystem
- Supply 6v to the Motor Subsystem
- Supply 5V to Raspberry Pi
- Maintain a consistent and regulated voltage level throughout with the use of voltage regulators

Motor Subsystem

- The motor used to pick which sorted card holder has a rotation range of 180 degrees
- The motor used to move cards must be able to rotate in one direction without a rotation range
- This means that this motor must be either a DC motor or a stepper motor
- The voltages of the motors must operate at a voltage provided by the AZ1117 voltage regulator
    - The AZ1117 has pre-configured output voltages of 3.3V and 5V

User Interface Subsystem

- Must inform user of which category the device is sorting for using LEDs
- Must be able to take user input from buttons to change the sorting logic of the microcontroller
- Must halt immediately when halt button is pressed
- Be able to to reset to a default position that will leave device ready to continue operation

Camera Subsystem

- Must have a level of color separation and color accuracy to be able to distinguish between different pokemon card basic colors
- In particular at least between the red (fire-type), green (grass-type), blue (water-type) used in the border of different types of pokemon cards. The other option will be reserved for shiny’s or other non-RGB cards
-

Control Subsystem

- STM must connect with Raspberry through i2c and GPIO pins with no direct voltage connections.
- Must be able to correctly categorize categorize cards by their border color based on the singular color/other
- Controls the motor subsystem based on card categorization and user interface subsystem.
- The microcontroller will use some programmed logic to decide which direction the sorting motor will point to based on the buttons pressed and the colors read.

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)	200 mA	Motor states max draw is 200mA. We will allocate 600mA 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, 600 mA	

Vin	**9 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	9 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	

Calculating Tj = 98.8036°C (MCU), 73°C (Stepper Motor), 121°C(Servo Motor) < 125°C.

2xAZ117 is sufficient for our components.

Risks:

1. Card slot thickness
    a. Talking with the machine shop, a big problem we would need to address is creating a slot for the machine to only accept one card at a time. If the slot is too big, multiple cards will be sent to the organized pile without being organized. If the slot is too small we risk damaging the card. Pokemon cards in specific are printed on 12pt card stock. This means that each card is 0.012 inches thick. So in order to only accept one card, we would need the slot to be in between 0.012 and 0.024 inches tall, since anything larger than .024 inches would allow for two cards to pass through at once.
2. Speed and efficient throughput
    a. In order for this project to be considered successful, the speed and accuracy of the machine must be significantly better than that of a human. This means that motors in our machine must be running quickly. Speed leads to two possible issues: increased thermals and the design of the top plate must be both light and robust enough to handle spinning at a high speed. This means that we would need to tune both the speed and power draw of the platform rotation motor.
3. Effect on the card
    a. The goal of the machine is to make it easier for collectors to organize their cards. Because of this, it is essential that the machine itself doesn't apply enough pressure to the card so that it'll cause a dent or launch it at a speed that would damage an edge. In order to deal with this issue we would need to test different ways to tension the card against the wheel connected to the card motor.

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

Works Cited

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