# Senior Design 1
## Divide and Conquer Document

*Money Sorting Machine*

University of Central Florida
Department of Electrical and Computer Engineering

**Group 19**

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# Introduction

The financial systems in cities, states, and countries worldwide rely on sophisticated machines to handle their currency efficiently and reliably. These machines play a critical role in reducing human error and maintaining security across various financial operations. From counting bills to identifying counterfeit currency, these tools streamline processes that would otherwise be time-consuming and error-prone. In some countries, the security of paper currency is taken to such extremes that even slightly torn bills are considered invalid and must be exchanged. While this level of scrutiny might seem excessive, it underscores the importance of ensuring the integrity of currency in circulation.

In contrast, the banking system in the United States follows a different set of guidelines. While torn bills may still be acceptable for transactions or deposits, banks enforce several organizational requirements to maintain efficiency and accuracy. One such requirement is the proper orientation of bills during deposits. Bank tellers are trained to ensure that all bills are neatly aligned, facing the same direction and orientation, before being processed. This seemingly minor task can be surprisingly time-consuming, especially for deposits involving large sums of cash, and it often requires meticulous manual effort. Consequently, this process may lead to longer wait times for customers, particularly during busy hours.

To address these challenges, many banks have introduced Automated Teller Machines (ATMs) that allow customers to make cash deposits without waiting for a teller. However, these machines often require customers to pre-orient their bills before inserting them, transferring the organizational burden from the teller to the customer. While this innovation has improved convenience, it still leaves room for inefficiencies and frustrations for users who are unfamiliar with the requirement or struggle with large deposits.

Engineers and financial institutions are continually seeking ways to improve these systems. Their goal is to enhance operational efficiency while also delivering better customer service. Advancements in technology, such as automated currency sorters and deposit machines capable of handling misaligned bills, represent significant steps forward. These innovations not only reduce the workload for bank staff but also improve the overall banking experience for customers by minimizing wait times and simplifying transactions. As these technologies evolve, they promise to revolutionize how financial systems handle currency, balancing the need for security, reliability, and user convenience in an increasingly fast-paced world.

**Goals:**

1. The machine will be capable of orienting and aligning currency bills to ensure uniform direction and orientation, regardless of their initial state.
2. The machine must output bills in a neatly stacked format, ready for further handling, storage, or ATM loading.
3. The machine will operate with minimal user intervention, featuring an intuitive interface for setup and monitoring.

**Stretch Goals:**

1. The machine is capable of accepting mixed denominations and sorting them by value while aligning the orientation.
2. The machine is designed to handle multiple currencies, making it suitable for international use.
3. The machine incorporates an LCD screen that allows users to select the desired bill orientation (e.g., all bills facing up or down, heads or tails) before processing, providing customizable sorting options for different operational needs.

**Objectives:**

1. Determine the optimal mechanism to detect and adjust bill orientation, including sensor types and actuator designs.
2. Design the machine to minimize jams or errors, considering factors such as bill thickness, material, and size variations.
3. Develop a user-friendly interface and system alerts to notify operators of errors, maintenance needs, or completed operations.
4. Test the machine's efficiency and reliability under various conditions, including mixed bill states, to ensure robust performance.

## Features

This high-performance machine is meticulously engineered with nine essential features, each carefully designed to enhance its efficiency, reliability, and ease of use. These features work in harmony to ensure seamless operation, from the moment a bill is inserted to the final stage when neatly stacked bills are ready for collection.

**Input Mechanism**

- The machine is equipped with a specially designed input tray that allows users to load a stack of bills effortlessly. Once placed into the tray, the machine's precision feeding system carefully picks up each bill one at a time, guiding it smoothly into the internal processing system for analysis. This ensures a steady and controlled intake, preventing jams or misfeeds.

**Scanning Mechanism**

- As each bill moves through the machine, it passes through an advanced scanning system that carefully inspects its features. This scanner plays a crucial role in identifying the bill's orientation. By utilizing high-speed optical scanning technology, the system ensures that each bill is processed with accuracy and efficiency.

**Flipping Mechanism**

- If the scanning system detects that a bill is facing the wrong side up, the machine's intelligent flipping mechanism is activated. This automated feature precisely rotates the bill to its correct position before moving it forward for further processing. By eliminating the need for manual adjustments, this mechanism contributes to the overall efficiency and reliability of the machine.

**Orientation Mechanism**

- To maintain uniformity in the final output, the machine is equipped with a sophisticated orientation system. This mechanism ensures that each bill exits the machine in a perfectly aligned manner, with a consistent top-to-bottom and front-to-back configuration. Regardless of how the bills are inserted into the machine initially, they are processed and adjusted so that they emerge in an organized and standardized format.

**Output Mechanism**

- Once the bills have been fully processed, they are neatly delivered to the output tray in a uniform and well-organized stack. This feature allows for easy retrieval and handling, ensuring that the processed bills remain neatly arranged and ready for use. The output mechanism minimizes the need for manual sorting, reducing time and effort for the user.

**Power Source**

- Designed for dependable and continuous operation, this machine is powered using a standard household AC power source. Unlike battery-operated alternatives, which may suffer from inconsistencies or require frequent recharging, this AC-powered system ensures uninterrupted functionality. This reliable power source supports the machine's various automated components, allowing for seamless and efficient operation.

**Automation Features**

- To streamline the entire bill-handling process, this machine is equipped with intelligent automation features. Advanced sensors monitor and control various operations, ensuring smooth transitions between scanning, flipping, orientation, and stacking. These automated processes not only enhance user convenience but also contribute to the overall efficiency and dependability of the machine, reducing the risk of human error.

**Efficiency**

- Engineered for high-speed performance, this machine is capable of processing multiple bills in quick succession, making it an ideal solution for environments that require handling large volumes of cash. By maintaining a consistent processing rate, it maximizes productivity without compromising on accuracy. Whether used in a financial institution, retail setting, or any business that deals with cash transactions, this machine ensures rapid and reliable bill handling.

# Prototype Illustration

The prototype consists of five main components: the **Entry Box**, the **Color Detector and Rejector**, the **Flipper**, the **Rotator**, and the **Output Collection Box**. Each of these components plays a critical role in ensuring that bills are processed efficiently and correctly oriented before they reach the final collection stage.

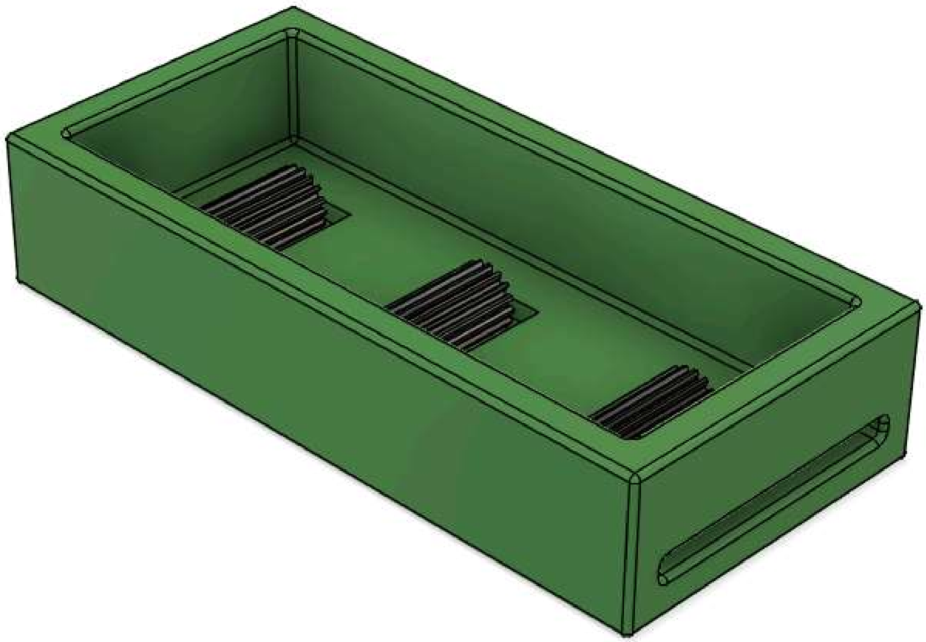
1. **Entry Box**
   The process begins at the entry box, where a stack of bills is placed. This compartment serves as the initial loading point. Beneath the stack, a system of rollers is responsible for feeding the bills into the machine one at a time. These rollers ensure smooth and controlled movement, preventing multiple bills from entering simultaneously and reducing the risk of jams. Initially a single roller with a diamond cross pattern was used to move the bills, however, after some initial testing it was find that the roller lacked the appropriate grip and surface area to move the bills consistently and with speed. The second version of the prototype replaces the single roller with 3 gears, the space between the gears should help grip onto the bills better as well as allow faster intake into the system.
2. **Color Detector and Rejector**
   As a bill moves forward from the entry box, it passes through the color detection and rejection system. This system is responsible for two key tasks:
   - **Orientation Detection:** The color sensor identifies the bill's current orientation to determine whether it needs to be flipped or rotated.
   - **Multiple Bill Detection & Rejection:** If the system detects more than one bill entering at once, it activates a rejection mechanism. The rollers will automatically reverse direction, sending the extra bills back to the entry box, ensuring only one bill proceeds at a time. This is done via detecting the brightness from a led situated below the bills as they pass through. The color sensor detects the brightness, and determines if there is no bills, one bill or more than one bill and determines the correct response.
3. **Flipper**
   If the color detector determines that the bill needs to be flipped, it is directed to the flipping mechanism. This component consists of a guiding pyramid that facilitates the flipping process. The bill moves upward along one side of the pyramid and then rolls back down on the opposite side, effectively flipping it to the correct orientation. If no flipping is required, the guiding pyramid lowers, providing an unobstructed path for the bill to continue forward.
4. **Rotator**
   Once the bill has been properly oriented in terms of front-and-back positioning, it reaches the rotator. This mechanism determines whether the bill needs to be rotated to align correctly. If rotation is required, the bill is held securely in place at the center of the rotator while the machine rotates it to the correct position. If the bill is already properly aligned, it bypasses this stage and continues moving forward via the guiding rollers.
5. **Output Collection Box**
   The final stage of the process is the output collection box, where the correctly oriented bills are gathered. This compartment is slightly angled for ease of access, allowing users

to quickly retrieve the processed bills. A guiding structure at the end of the collection area ensures that the bills remain neatly stacked and easily graspable.

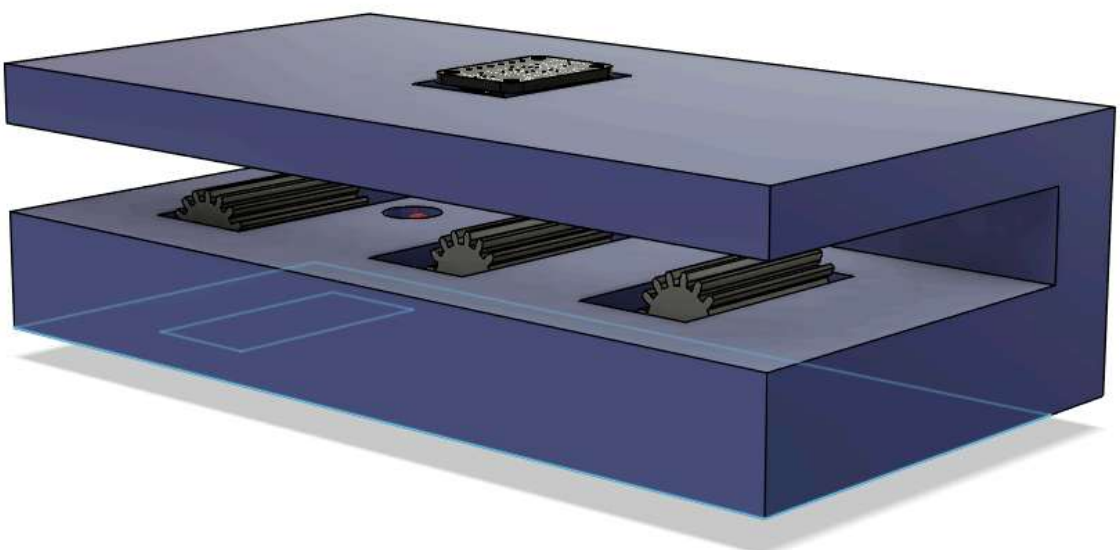
Through this structured sequence of operations, the prototype ensures that all bills are individually processed, properly oriented, and neatly collected, enhancing efficiency and ease of use.

**Entry Box V1:**

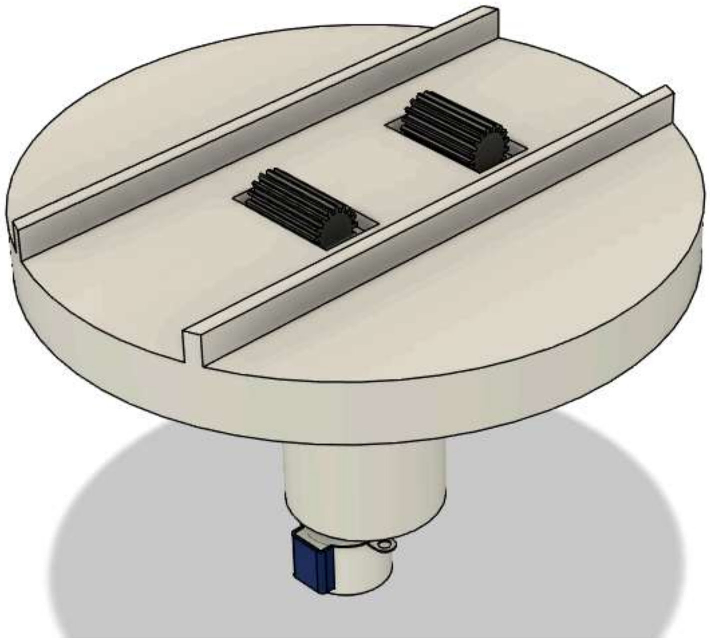
**Entry Box V2:**



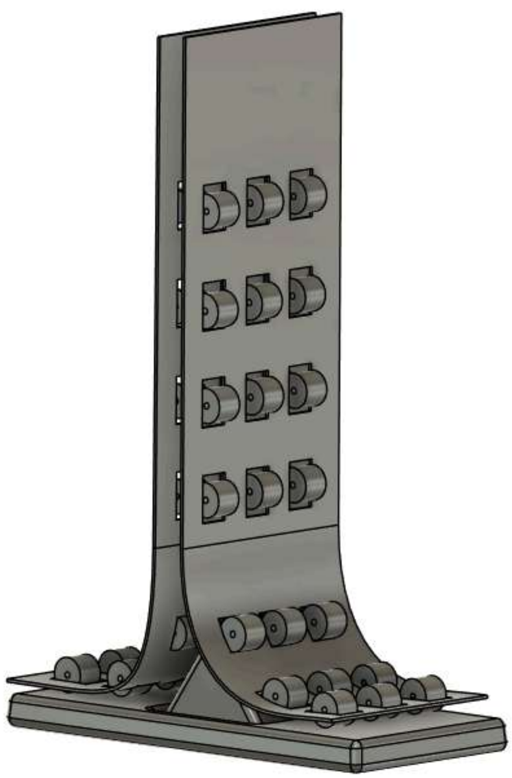
**Color detector and bill rejector:**



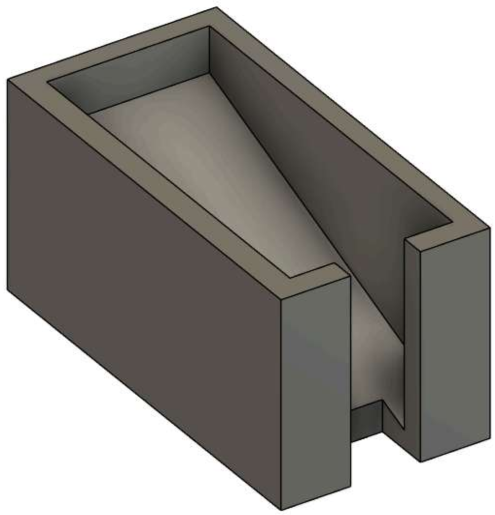
**Rotating Mechanism:**



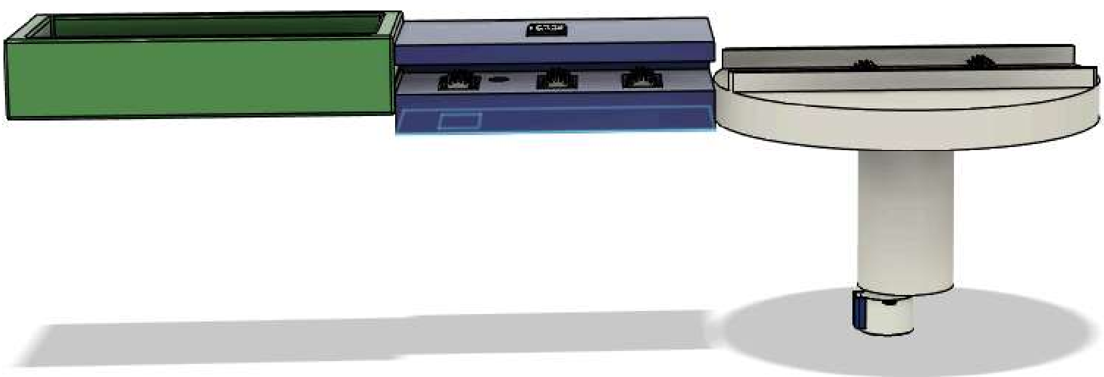
**Flipping Mechanism:**



**Output Collection Box:**



**Final Assembly:**



# Engineering Specifications

The engineering specifications outline the essential design and performance criteria for the Money Sorting Machine, emphasizing speed, accuracy, and compactness. The device must sort bills faster than a human, maintain a 99% accuracy rate, and operate efficiently within standard power supply constraints, all while staying within a competitive budget.

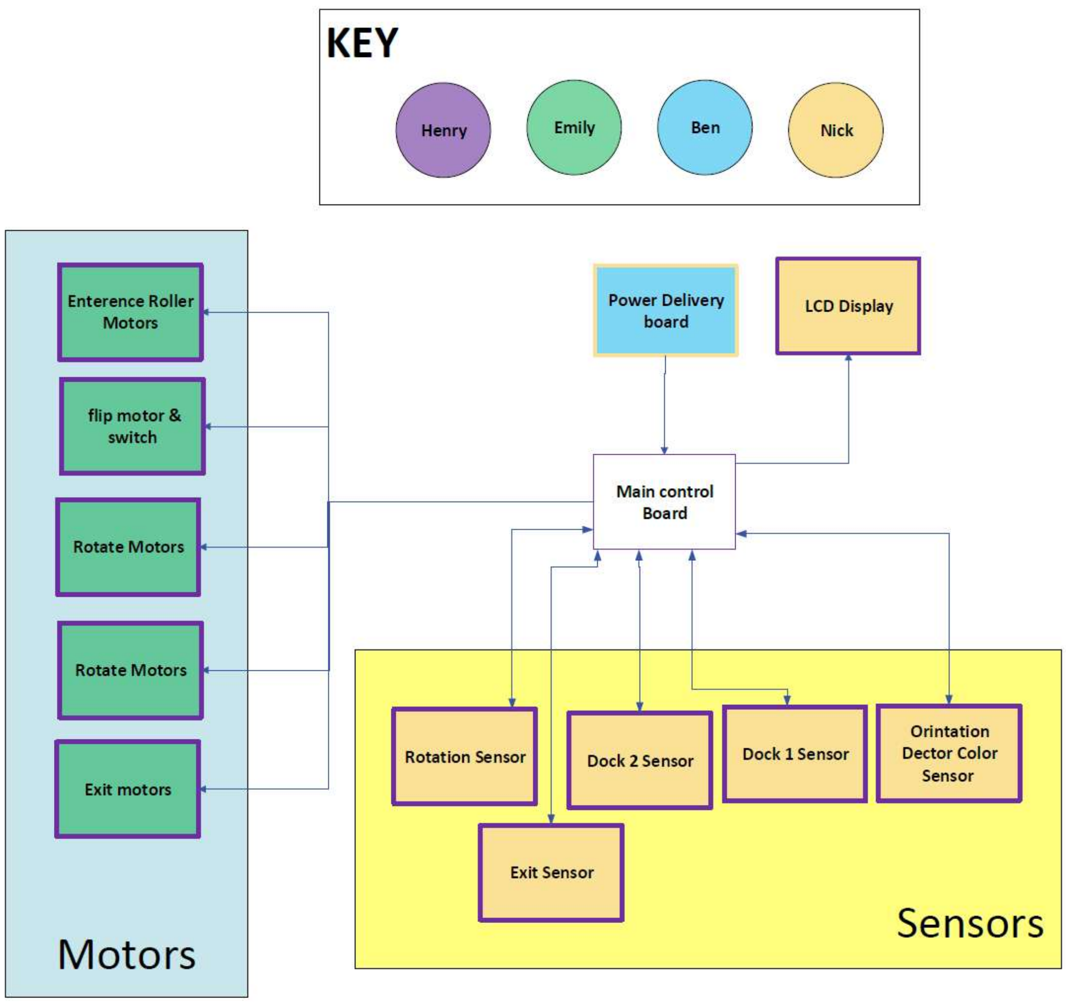
Table 1: Engineering Specifications

| No | Requirement | Description | Priority |
|---|---|---|---|
| 1 | Size | Must fit on a desk, so must not exceed more than 7” x 30” x 3” | Low |
| 2 | Price | In order to be competitive the final product shouldn’t exceed a total BOM of 200$ | High |
| 3 | Speed | It must be faster than a human sorting the stack of bills, through initial testing this implies no more than 2 seconds per bill | High |
| 4 | Power | Must be able to be run off a standard 110V 60HZ AC voltage source standard in all American buildings | High |
| 5 | Accuracy | The machine must be able to correctly detect and orientate bills with a 99% accuracy rate. | High |
| 6 | Resiliency | The Machine must be able to process bills without damaging the bill with an error rate of less than 0.01% | Low |

# Block Diagram

The project is organized into four key areas of focus: Mechanical, Electrical, Coding, and Integration. Each section is color-coded to represent collaboration between two team members, ensuring an even distribution of responsibilities. For example, Ben and Nick will manage the electrical components, while Emily and Henry concentrate on the mechanical components. Each team member contributes to two different areas, fostering balanced teamwork and comprehensive project coverage.

Figure 1: Block Diagram



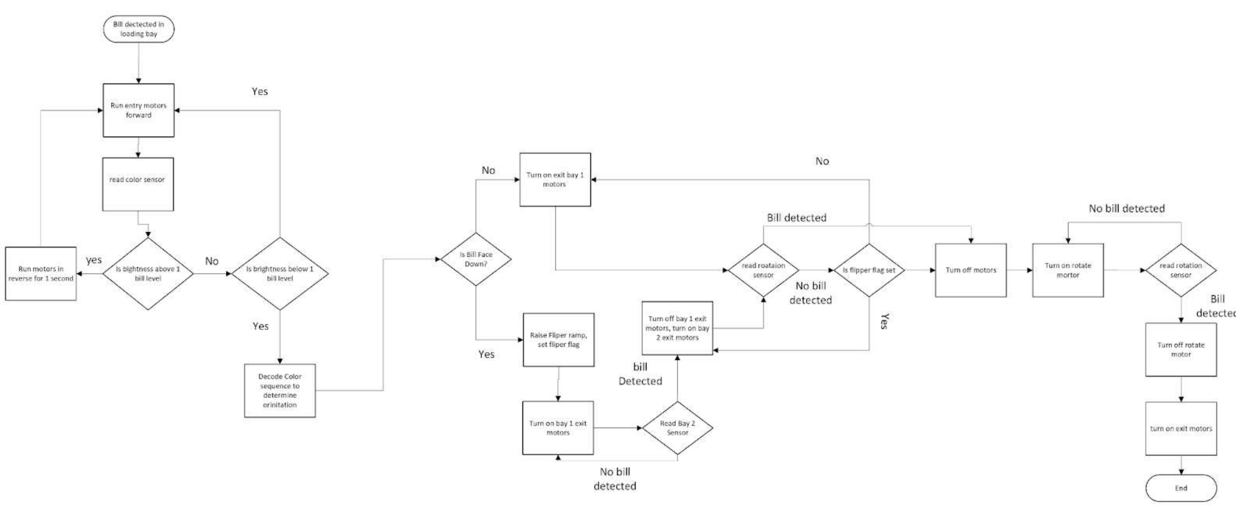
# Software Diagram

The flow chart found below shows the flow of the machine split into each part of sorting the bills, and highlights which parts of the machine must be utilized for each step of the sorting process. Once the machine is turned on, the entry motors are tuned on. The color sensor start detecting brightness and color. When a bill passes over the embedded LED in the color detecting stage, the sensor detects the change in brightness and compares it to the encoded ranges. If the senor reads that the brightness is near the maximum value, then it return to spinning the gears. If the brightness is low enough that one or two bills are believed to have entered at a time, the gears are run in reverse to pull the bills back into the entry phase. If the brightness falls within he acceptable range the color sensor pulls a reading of color as the bill passes through the senior.

Each orientation has a unique color signature, for example, black then white then green then white then black white black white black would be heads up face forward of the 1 dollar bill. Reverse the sequence and you have the reverse orientation. The same applies to the back. No bill is perfectly symmetric so the technique will work for all input bills. Once the color sequence is decoded and the orientation recorded, the senior raises the lifter for the flipping phase if the bill is upside down, and lowers it if no change is necessary.

After the flipping phase, the bill moves to the rotation phase. If the bill is facing the wrong way, then the microcontroller sends a single to a stepper motor to rotate a round plate $180^{O}$ then activates the last motors to move the bill to the final staging area to be picked up by the client.

Figure 2: Software Diagram



## House of Quality Table

The House of Quality table illustrates the relationship between engineering requirements and customer requirements, as well as the interactions among engineering requirements themselves. Positive correlations between engineering requirements are indicated with a plus sign (+), while negative correlations are represented by a minus sign (−).

Each engineering requirement and customer requirement is assigned a polarity. A positive polarity (+) means that increasing the value of the requirement benefits the project, while a negative polarity (−) means that increasing the value of the requirement negatively impacts the project.

Within the table, interactions between engineering and customer requirements are noted. A downward arrow indicates a weak correlation, while a dot represents a strong correlation. Each engineering requirement is assigned a target value.

The selected customer requirements reflect the expectations of an average user, including user-friendliness, portability, affordability, and more. The engineering requirements define our development goals, such as power draw, processing time, and manufacturing cost.

The House of Quality table is a valuable tool for visualizing the relationship between engineering and customer requirements, helping to guide the development process effectively.

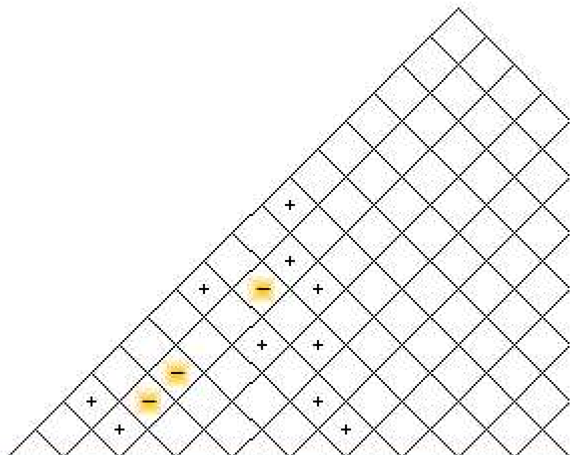
Table 2: HoQ Diagram

QFD: House of Quality
Project: Money Sorter
Revision: 2
Date: 2/3/2025

| Correlations | |
|---|---|
| Positive | + |
| Negative | — |
| No Correlation | |

| Relationships | |
|---|---|
| Strong | ● |
| Weak | ▽ |

| Polarity | |
|---|---|
| Positive | + |
| Negative | - |



| Polarity | Column # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Polarity | - | - | - | + | + | + | - | + | + | - |
| | Customer Requirements / Engineering Requirements | Power Draw | Processing Time | Size | Misalignment Tolerance | Sensor Accuracy | Quality Manufacturing Materials | Manufacturing Cost | Paper Jam Resistance | Capacity | Noise Level |
| + | User-Friendliness | | ▽ | | ● | | | | ● | ● | ▽ |
| + | Safety | ● | | ▽ | | | ▽ | | | | |
| + | Portability | ● | | ● | | | | | | | |
| + | Durability | | | | | | ● | | | | |
| + | Sorting Accuracy | | | | ▽ | ● | | | ▽ | | |
| + | Affordability | | | | | | | ● | | | |
| | Target | <20 Watts | <5 Seconds/Bill | <30x6x6 Inches, 10 lbs | Up to a 15° Misalignment Tolerated | >95% Accurate | >Durability of ABS Plastic | <$500 | >95% Jams Processed | >60 Bills at a Time | <50 dB |

# Budget

Please take note, Table 3 provided below is still in the very early stages of development and will likely evolve as the project progresses. At this point, the cost is based on initial estimates and is subject to change as new information becomes available and the design is refined over the development process. It is important to note that this budget is specifically for the prototype project. As the project transitions out of the prototyping phase into full-scale production, the actual production costs are expected to decrease significantly.

Table 3: Tentative Budget

| Part | Count | Cost | Subtotal |
|---|---|---|---|
| Large Servo Motors | 1 | $30.00 | $30.00 |
| Small Servo Motor | 3 | $2.20 | $6.99 |
| Regular Motor | 30 | $1.50 | $45.00 |
| Large Motor | 2 | $6.50 | $13.00 |
| Plexiglass | 1 | $35.00 | $35.00 |
| Wooden Support | 2 | $5.00 | $10.00 |
| Filament | 2 | $12.50 | $25.00 |
| Tiny Wheels | 30 | $0.74 | $22.00 |
| Regulator Fabrication | 20 | $1.50 | $30.00 |
| PCB Fabrication | 10 | $7.00 | $70.00 |
| Arduino Chip | 1 | $20.00 | $20.00 |
| Arduino Testing Board | 1 | $20.00 | $20.00 |
| AC to DC | 1 | $20.00 | $20.00 |
| Wires | 120 | $0.02 | $7.00 |
| Color Sensor | 8 | $4.00 | $32.00 |
| Miscellaneous Items | ??? | ??? | $100.00 |
| Total Cost | | | $485.99 |

# Project Milestones

Team formation occurred at the beginning of the Spring 2025 semester, marking the official start of the project. To maintain a structured approach, the team develops a detailed timeline, as outlined in Table 4, which highlights several key project deadlines and milestones. Beyond adhering to these deadlines, the team holds regular weekly meetings to ensure steady progress and address any challenges promptly. These meetings foster effective collaboration, allowing members to align on objectives, share updates, and refine strategies. This consistent communication and teamwork are instrumental in driving the project toward success, ensuring that each phase is completed on schedule and to a high standard of quality.

Table 4: Project Milestones

| Task | Start Date | End Date | Duration (Days) | Duration (Weeks) |
|---|---|---|---|---|
| Project Selection | 1/9/2025 | 1/12/2025 | 3 | 3/7 |
| Project Scope | 1/12/2025 | 1/17/2025 | 5 | 5/7 |
| Research | 1/12/2025 | 1/21/2025 | 9 | 1 2/7 |
| Initial D&C Document | 1/12/2025 | 1/24/2025 | 12 | 1 5/7 |
| Final D&C Document | 1/24/2025 | 2/7/2025 | 14 | 2 |
| 30-Page Milestone | 1/12/2025 | 2/7/2025 | 26 | 3 5/7 |
| Individual System Designs | 1/12/2025 | 2/7/2025 | 26 | 3 5/7 |
| 60-Page Milestone | 2/7/2025 | 3/1/2025 | 22 | 3 1/7 |
| Individual System Testing | 2/7/2025 | 3/7/2025 | 28 | 4 |
| 90-Page Milestone | 3/1/2025 | 3/21/2025 | 20 | 2 6/7 |
| PCB Design/Ordering | 3/7/2025 | 4/6/2025 | 30 | 4 2/7 |
| 120-Page Milestone | 3/21/2025 | 4/11/2025 | 21 | 3 |
| Prototyping | 4/6/2025 | 4/22/2025 | 16 | 2 2/7 |
| Final Report | 4/11/2025 | 4/22/2025 | 11 | 1 4/7 |

# Appendix A - References


1) *Electronic money counter with dollar bills*. (2014). iStock. photograph. Retrieved 2025, from https://www.istockphoto.com/photo/electronic-money-counter-with-dollar-bills-gm497143439-41690668.

2) UCF. (2021). Curriculum Alignment. photograph. Retrieved 2025, from https://curriculumalignment.ucf.edu/wp-content/uploads/sites/10/2021/05/cropped-favicon.png.


# Appendix B – Item Examples

1) Large Servo Motor
    a) https://www.amazon.com/ZOSKAY-Coreless-Digital-Stainless-arduino/dp/B07SBYZ4G5
2) Small Servo Motor
    a) https://www.amazon.com/WWZMDiB-SG90-Control-Servos-Arduino/dp/B0BKPL2Y21
3) Regular Motor
    a) [https://www.amazon.com/Topoox-1730RPM-Electric-Turbine-Generator/dp/B07Q44YYKG](https://www.amazon.com/Topoox-1730RPM-Electric-Turbine-Generator/dp/B07Q44YYKG)
4) Large Motor
    a) https://www.amazon.com/AUTOTOOLHOME-Torque-Traxxas-Wheels-Electric/dp/B01M58POHF
5) Plexiglass
    a) https://www.amazon.com/Art3d-Pack-Thick-Plexiglass-Sheets/dp/B0BHQYK6B1
6) Wooden Base
    a) https://www.lowes.com/pd/Interfor-2-in-x-4-in-x-96-in-Spruce-Pine-Fir-Kiln-dried-Stud/5015156647
7) Filament
    a) https://www.amazon.com/Official-Creality-Precision-Toughness-Moistureproof/dp/B0C8NP63GD
8) Wheels
    a) https://www.amazon.com/10PCS-Wheels-Rubber-Accessories-2X20MM/dp/B0DHD2JQH7
9) Wires
    a) https://www.amazon.com/Elegoo-EL-CP-004-Multicolored-Breadboard-arduino/dp/B01EV70C78
10) AC to DC Converter
    a) https://www.amazon.com/Converter-Waterproof-Voltage-Transformer-Adapter/dp/B0D3DPPDY3
11) Arduino Board
    a) https://www.amazon.com/LAFVIN-Board-ATmega328P-Micro-Controller-Arduino/dp/B07G99NNXL
12) PCB Fabrication

    a) https://jlcpcb.com/

13) Color Sensor
    a) https://www.amazon.com/Alinan-TCS34725-Recognition-Development-Communication/dp/B09TR71YRZ

# Appendix C – Copyright Permission