March 17th, 2023

Dr. Mike Hegedus
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Subject: ENSC 405W Design Specification for CashGrab

Dear Dr. Hegedus,

This document will outline the design specifications for CashGrab, an automated Point of Sale (PoS) designed by Payment Peers.

This project aims to tackle the challenges associated with cash transactions, including employee theft, human errors, counterfeit currency, and cross-contamination. To overcome these issues, the project proposes the development of a PoS device that can automate the processing of cash transactions. By limiting the possibility of human error, this device will improve the accuracy and efficiency of the payment process. The device will also incorporate a software application and image processing technology to verify and track inserted bank notes, reducing the risk of counterfeit currency.

The various design specifications will be described in detail in this document and will be justified accordingly. These decisions in regards to the design will be made with the requirements prescribed in the requirement specification document in mind. The explanation of the design specifications will also help in the description of the various components and constraints that comprise our project.

On behalf of Payment Peers, thank you for taking the time to review the design specifications relating to our product. Please feel free to contact our Chief Communications Officer, Dakota Crozier at dakotac@sfu.ca regarding any questions or concerns.

Sincerely,
Jacob Forrest
CEO
Payment Peers

Design Specification Document and Appendices

Company 07

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Abstract

This design specification document serves to describe the implementation details regarding how the requirements for the CashGrab point-of-sale system will be satisfied. CashGrab consists of three major subsystems, the cash transport system, the image processing system, and the user facing software applications. This document also provides development stages for each requirement, a testing plan, and a list of possible design alternatives. Design specification tracing conventions are employed to identify the stage of development that a specification needs to be met. The test plan addresses how the subsystems and components will be verified. The design alternatives will become useful if the primary implementation plan for a specific feature fails.

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Glossary

Term	Definition
ABS	Acrylonitrile butadiene styrene (ABS) is a temperature and flame resistant plastic commonly used in 3D printing.
CSI	Camera Serial Port (CSI) is a hardware interface used to connect cameras to processors or other devices in embedded systems.
FLANN	Fast Library for Approximate Nearest Neighbors (FLANN) is an open-source library for performing fast approximate nearest neighbor searches in high-dimensional spaces [2].
Hasp	A slotted hinged metal plate that forms part of a fastening for a door or lid and is fitted over a staple.
LCD	Liquid Crystal Display (LCD) is a form of flat panel display that primarily uses liquid crystals to activate pixels
OpenCV	An open source computer vision and machine learning library.
PLA	Polylactic Acid (PLA) filament is a recyclable, natural thermoplastic polyester that is derived from renewable resources such as corn starch or sugar cane
Plexiglass	A transparent thermoplastic material often used as a lightweight and shatter-resistant alternative to glass.
PoS	A Point of sale (PoS) system is a computerized network used to process transactions and record sales in retail stores and other commercial establishments.
Raspberry Pi	A small, affordable, and versatile computer that can be used for a wide range of projects and applications.

SIFT	Scale-Invariant Feature Transform is a feature detection algorithm that is robust with respect to scale, illumination, and rotation [1].
Staple	A tough, steel loop that's firmly bolted or screwed in place. The staple mates with a slot in the hinged hasp that fits over it. A padlock is then typically used to secure the hasp in position.

Parts List

Part ID	**Description**
Mech-001	Cylindrical roller and servo motor housing
Mech-002	Cash insertion slot
Mech-003	Conveyor belt system
Mech-004	DS04 servo motor
Mech-005	Feetech servo motor
Mech-006	Plexiglass holder
Mech-007	Cash deposit box
CV-001	ASUS Webcam C3
CV-002	Acrylic Sheet Clear Plexiglass
CV-003	Raspberry Pi Model 3 B

Version History

Document Version History	**Date**
1	March, 7, 2023
2	March, 17, 2023

Approval

This design document has been received and approved by Payment Peers for the purpose of the initial design specification of the CashGrab touchless cash payment system.

1.0 Introduction

Every year, Canadian businesses lose a collective $1.4 billion dollars in revenue due to employee theft, with the average employee stealing $2,500 before getting caught [3]. Food trucks are no exception to this statistic; one of our team members, a former food truck employee, recounts that it was common for hundreds of dollars of cash to be missing from the register at the end of a work day, likely due to employee theft. Concerns regarding employee theft are not the extent of a business' problems with employees handling cash as employee handling of cash can lead to cross-contamination [4]. Our team at Payment Peers have developed CashGrab, a device which alleviates the aforementioned issues while complying to the unique constraints of food trucks.

1.1 Scope

CashGrab is a point-of-sale (PoS) system which facilitates cash transactions without employees physically contacting any cash, and is specifically designed to meet the needs of food truck businesses. CashGrab is affordable, compact, secure, and allows for cash transactions without introducing potential for employee theft, and cash-based cross-contamination.

CashGrab facilitates touchless cash transactions by providing a medium for cash handling. Employees input the owed value into the device. Customers insert cash into the device, at which point the cash value is detected and subtracted from the owed value.

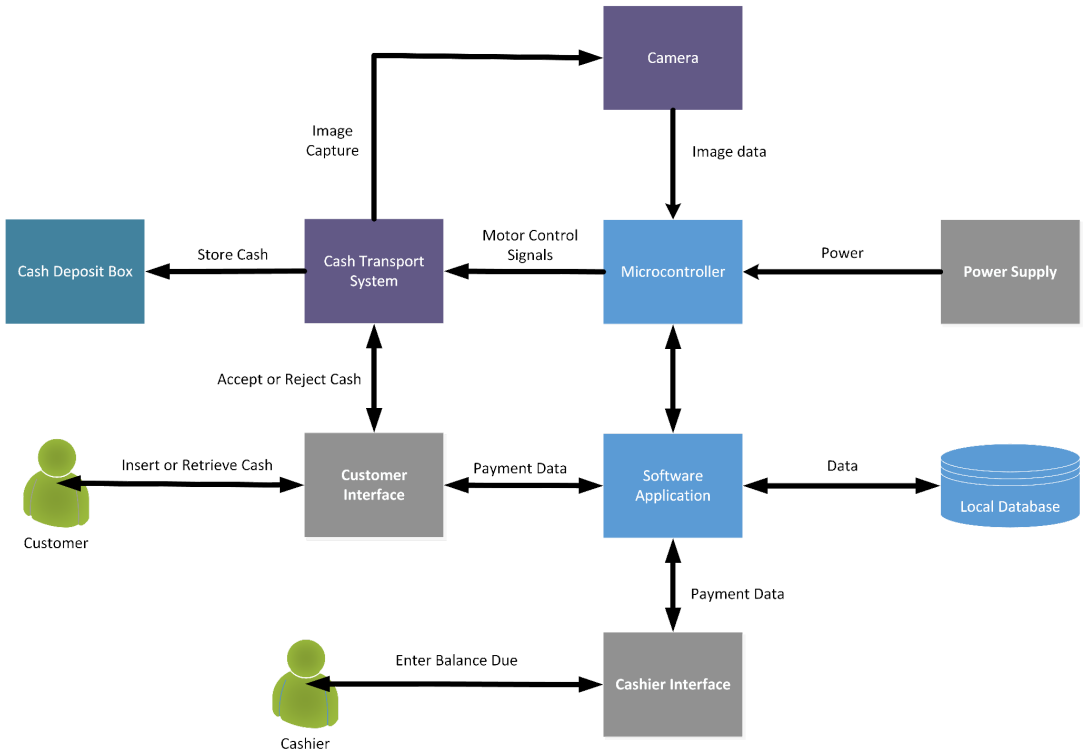

Figure 1 - CashGrab System Block Diagram

1.2 Expected Challenges

The expected challenges in developing CashGrab are mainly, but not exclusively, results of the system's requirements. Key expected challenges include the following:

- Designing the mechanical portion of the device within the size constraints
- Performing low-latency currency detection on inexpensive and low-performance hardware
- Transporting cash through the system reliably and efficiently with minimal instances of currency being stuck.

1.3 Response to Feedback

In response to feedback given in previous progress meetings we have considered the suggestions of the administrative staff and have used the feedback the guide our implementation in the following ways:

- The currency detection subsystem will employ use of computer vision to preprocess image data to be in a more desirable form for feature detection and matching.

1.4 Product Stage Classifications

The requirements in this document are organized according to the following convention:

Des {Section}.{Requirement Number} {Stage of Development}

Encoding	Development Stages
A	Proof-of-concept
B	Engineering Prototype
C	Production Version

Table 1 - Development Stage Encoding

2.0 Design Specification

2.1 Design Specification Overview

Design ID	Requirement ID	Description
Des 2.1.1 A	Req 3.1.1 A Req 3.1.3 B Req 3.1.8 B	The Administrative Web Interface will be displayed on an external LCD monitor that is connected to the Raspberry Pi via an HDMI connection. The monitor will sit on top of a swiveling stand so that the cashier can turn the monitor to face the customer when appropriate.
Justification		To begin a transaction, the cashier will navigate to the 'new transaction' page on the web application and enter a total value to be paid by the customer and then swivel the monitor towards the customer so they can easily view the remaining balance.
Des 2.1.2 A	Req 3.1.4 B	The cashier will interface with the CashGrab machine a keypad and mouse that will be connected to the Raspberry Pi via a USB connection.
Justification		The cashier will utilize the mouse to navigate the web application and the keypad to enter payments during the transaction.
Des 2.1.3	Req 3.1.5 B	Items and sales prices will be displayed through the cashier facing display.
Justification		The cashier facing display will allow the cashier to see and input customer items for sale.
Des 2.1.4 C	Req 3.1.10 C Req 3.1.12 C	The device's components will be manufactured using ABS.
Justification		ABS material is flame retardant and has operating temperatures from -20C to 80C [5].
Des 2.1.5 C	Req 3.1.11 C	The device's casing will be made using ABS, and will be manufactured such that the device's walls are adequately thick where appropriate. Device internals will be secured to the casing.
Justification		The thickness of the device's casing will prevent damage during daily use. Device internals will be secured to ensure that components do not become disconnected in the case of the device being dropped.

Des 2.1.7 C	Req 3.1.13 C	The system will contain external USB ports.
Justification		External USB ports will allow for connectivity with other PoS and non-PoS devices.

Table 2 - Overall System Design Specification

The CashGrab system is composed of three main systems, consisting of a user interface, currency insertion mechanism and currency detection . currency insertion, currency image detection and the menu driven interface. The user interface will be the web interface displayed on a Liquid Crystal Display (LCD) placed upon a swivel pad as shown below in figure 2. The administrative web interface software that will facilitate all essential operations such as creating transactions. The cashier will have a USB connected number pad and mouse to use and navigate the interface. A single LCD screen will be used rather then two dedicated LCD screens for customers and cashiers. This will reduce cost and have minimal impact upon the customer because the cashier can rotate the display towards the customer whenever needed. The currency insertion system has been designed for efficient and safe insertion of bills sequentially. The currency detection system will identify the value of the bill and verify whether or not it is counterfeit. If the bill is inserted incorrectly or deemed to be counterfeit it will be rejected and returned to the customer via the insertion hole.

Figure 2: Monitor Swiveling Stand [6]

2.2 Mechanical Design Specification

2.2.1 Currency Insertion Mechanism Specification

Design ID	Requirement ID	Description
Des 2.2.1.1 A	Req 3.1.7 B, Req 3.2.1.4 B	The cash insertion point will have chamfered sides. The insertion point will have a height similar to that of a single Canadian bank note.
Justification		Chamfered sides and an insertion point with a minimal height will prevent users from inserting multiple bills into the system.
Des 2.2.1.2 A	Req 3.1.7 B, Req 3.2.1.4 B	Two rotating cylindrical rollers with minimal separation will be used to propel bank notes into the system after they have been inserted
Justification		The minimal separation between the rollers will prevent multiple bills from being further inserted into the system.
Des 2.2.1.3 A	Req 3.1.7 B	Each cylindrical roller will be rotated by a servo motor.
Justification		Servo motors are inexpensive and deliver sufficient torque to rotate the rollers.

Table 3 - Design Specification of the Currency Insertion Mechanism

On the customer facing side of the device, we 3D printed a cash insertion slot with a width slightly larger than a Canadian bank note. The height of the insertion slot is just slightly over 5 mm. This minimal height was used to prevent the user from inserting multiple bank notes or other, non-currency related objects. Cylindrical rollers were the chosen mechanism for propelling inserted bank notes into the system. The cylindrical shape grips the bank notes sufficiently and rotates well with the servo motor. In addition, ribbing was added to the surface of the roller to add friction and minimize the likelihood of bills getting stuck or slipping inside the system after they have been inserted. The width of the roller is a key dimension and was made to be 69.85 mm which is equal to the width of a Canadian bank note.

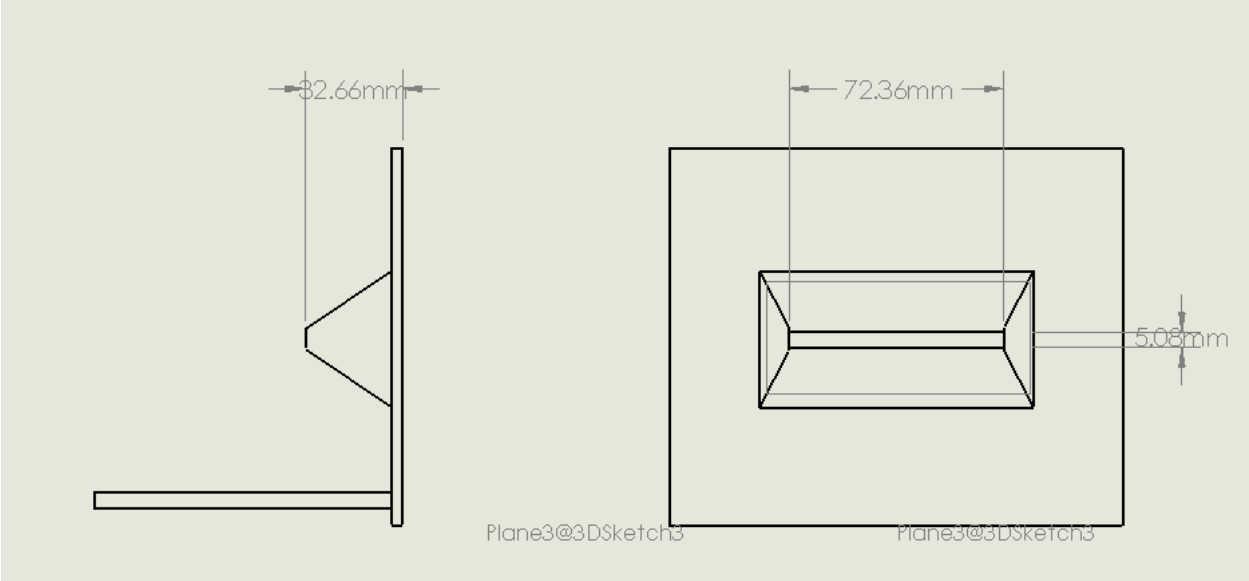

Figure 3 - Cash Insertion Slot

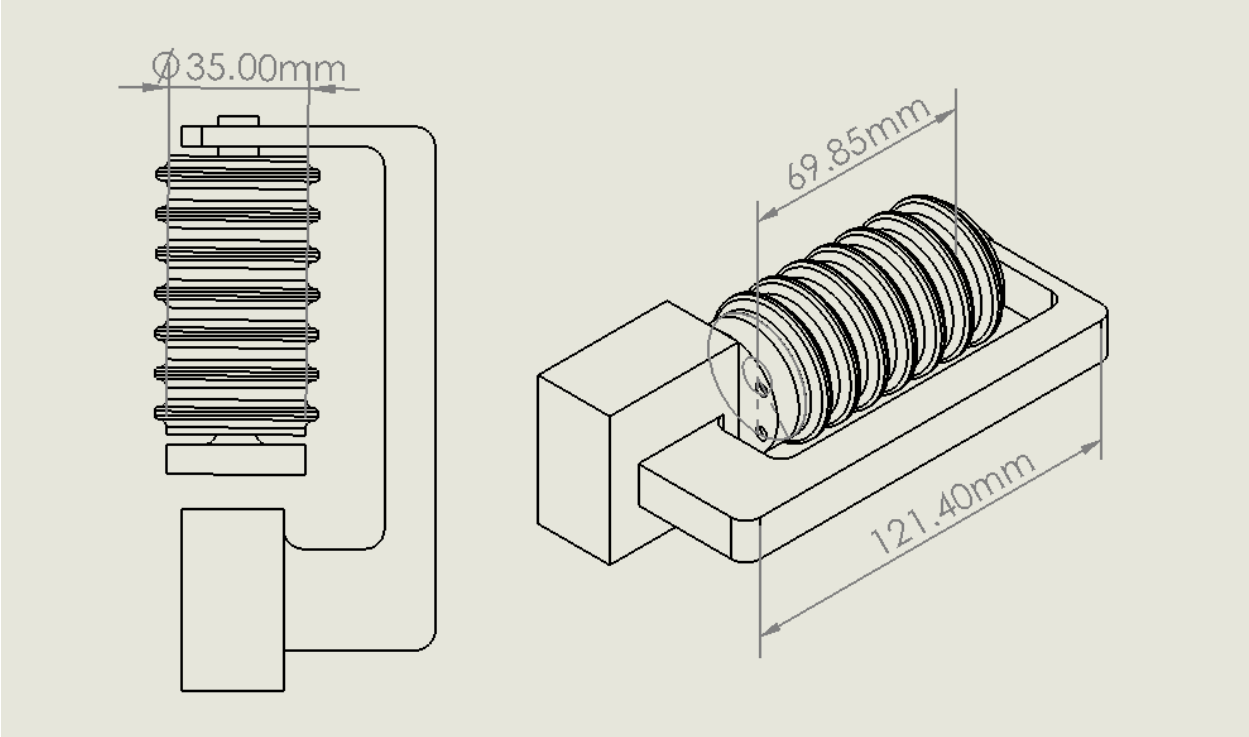

Figure 4 - Cylindrical roller

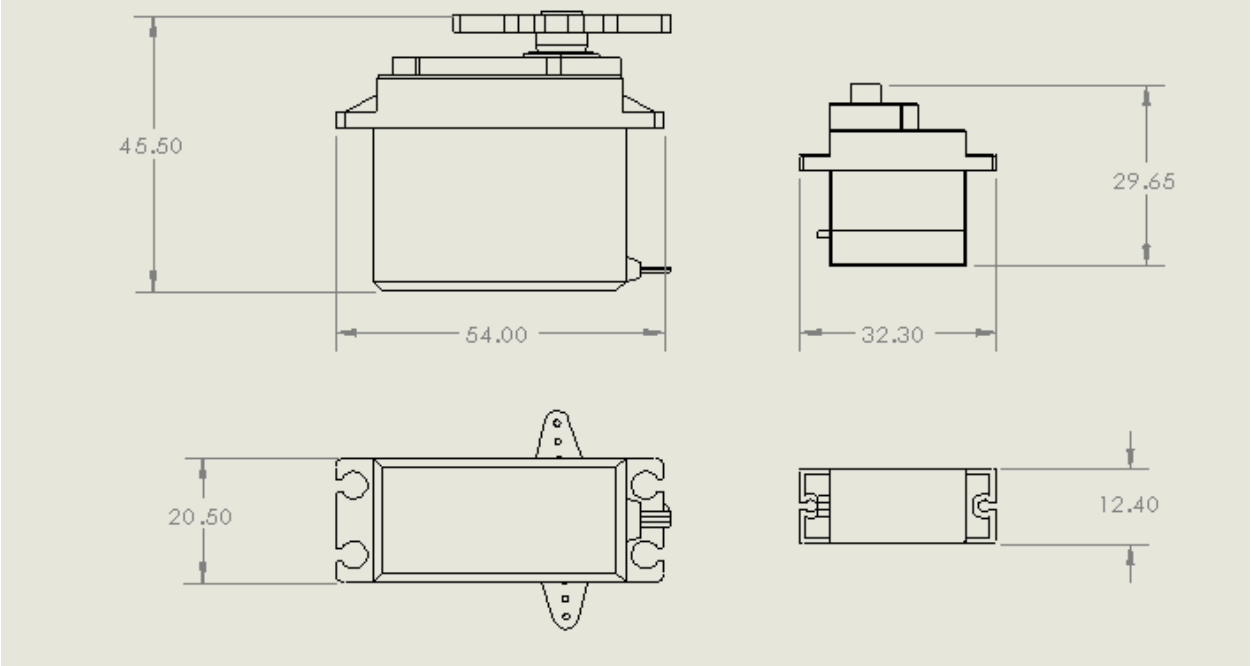

Figure 5 - Servo Motors

2.2.2 Currency Transportation Mechanism Specification

Design ID	Requirement ID	Description
Des 2.2.2.1 A	Req 3.2.1.1 A, Req 3.5.2 A	Edges along the cash transportation path will be fileted and motors will halt only when a bill is stuck.
Justification		Rounded edges will prevent tears or cuts from occurring. Halting the motors when a bill is stuck will prevent bills from being excessively stretched.
Des 2.2.2.2 B	Req 3.2.1.2 B	Motors will be continuously rotating to keep banknotes continuously in motion
Justification		Motors will always be rotating the conveyor belts to prevent bank notes from stalling, unless power is cut off to the system.
Des 2.2.2.3 B	Req 3.2.1.3 B	The conveyor belt will have a width of 71 mm, a height of 2 mm, and a length of 300 mm.
Justification		The length and width dimensions were created so that it will fit all Canadian banknotes (152.4 mm x 69.85 mm).

Table 4 - Design Specification of the Currency Transportation Mechanism

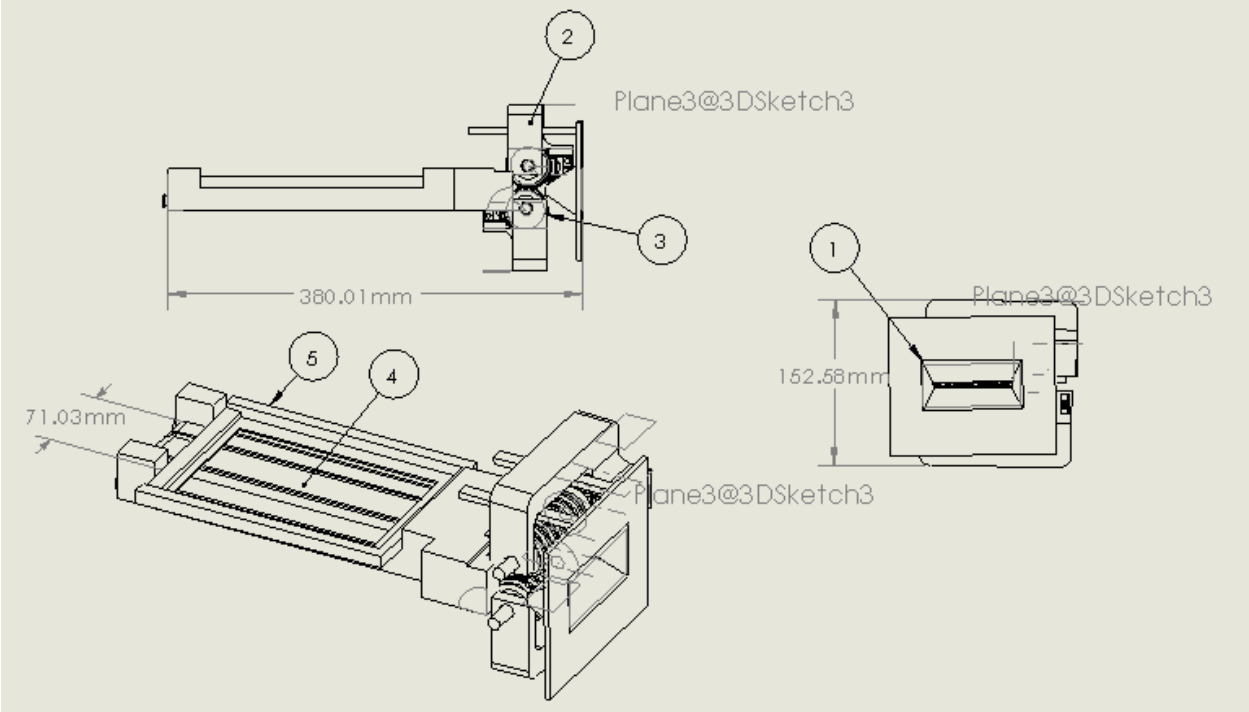

Figure 6 - Complete Assembly

Part Number	Description
1	Cash insertion slot
2	Cylindrical roller and servo motor housing
3	Cylindrical roller
4	Conveyor belt system
5	Plexiglass holder

Table 5 - Currency Transport System Parts

2.2.3 Currency Returning Mechanism Specification

Design ID	Requirement ID	Description
Des 2.2.3.1 B	Req 3.4.2.3 A, Req 3.4.2.5 C, Req 3.5.3 B	The same motors used to propel banknotes into the system will operate in reverse to return rejected bank notes to the user through the cash insertion slot.
Justification		Reversing the rotation direction of the current motors allows us to reduce the device's parts costs. Additionally, the

	implementation for reversing the direction of rotation is fairly simple.

Table 6 - Design Specification of the Currency Returning Mechanism

The mechanism for returning rejected bank notes to the customer follows the same mechanism in section 2.2.2. If the inserted bank note is determined to be counterfeit, damaged, or undetectable, the conveyor belt system and the cylindrical roller will rotate in the opposite direction to return the bank note to the user.

2.2.4 Currency Image Capture Mechanism Specification

Design ID	Requirement ID	Description
Des 2.2.4.1 A	Con 3.7.1 A	The Asus Webcam C3 will be used to capture images for the image processing algorithm.
Justification		The camera captures 1080p (2 Megapixels) resolution frames which should provide enough data without overwhelming the Raspberry Pi's computational power.
Des 2.2.4.2 A	Con 3.7.2	The Asus Webcam C3 will use one of the USB ports provided by the Raspberry Pi.
Justification		The Raspberry Pi has four available USB 2.0 connectors. The only other device that will require a USB connector will be the keypad, therefore using one of the USB ports for the camera will not violate the constraint.
Des 2.2.4.3 B	Con 3.7.3 B	An LED strip will be installed into the device enclosure to provide sufficient lighting for the camera
Justification		To ensure that the camera is able to capture clear images within the enclosed device, we will need a light source of some kind. LED lights are low power devices compared to incandescent bulbs so we will use a simple LED strip.

Table 7 - Design Specification of the Currency Image Capture Mechanism

The camera chosen for the image capturing system is the ASUS Webcam C3. The camera will connect to the Raspberry Pi through one of its USB-A connectors. This camera features a fixed focus 1080p (2 Megapixels) video resolution which should be enough for the image processing algorithm to function while not overwhelming the Raspberry Pi's computation power. Using a webcam with a long cable will allow us to reposition the camera as necessary during construction and maintenance of the system. To ensure that the bank notes remain flat while still being able to capture images for processing, a small sheet of plexiglass will be placed above the cash transport mechanism. Figure 9 shows a simple part designed to hold the plexiglass sheet.

Figure 7 - ASUS Webcam C3 [7]

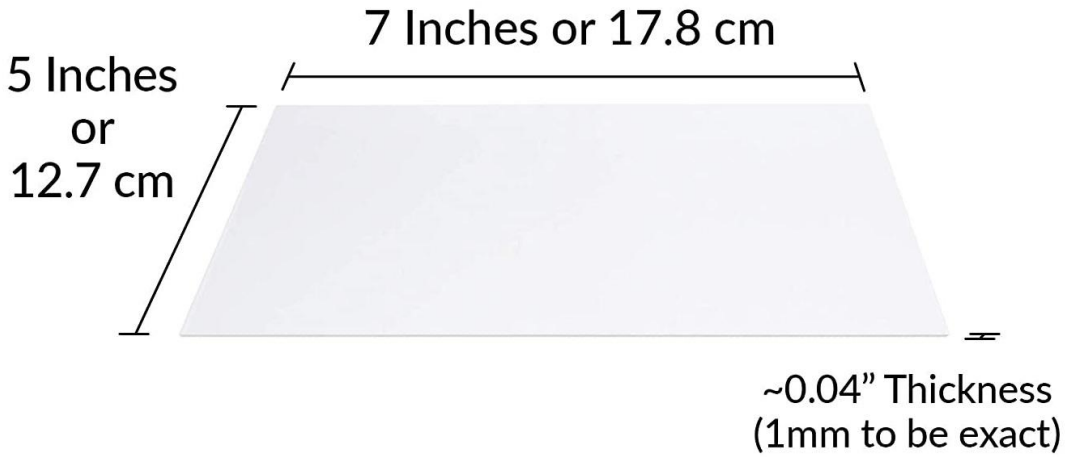

Figure 8 - Acrylic Sheet Clear Plexiglass [8]

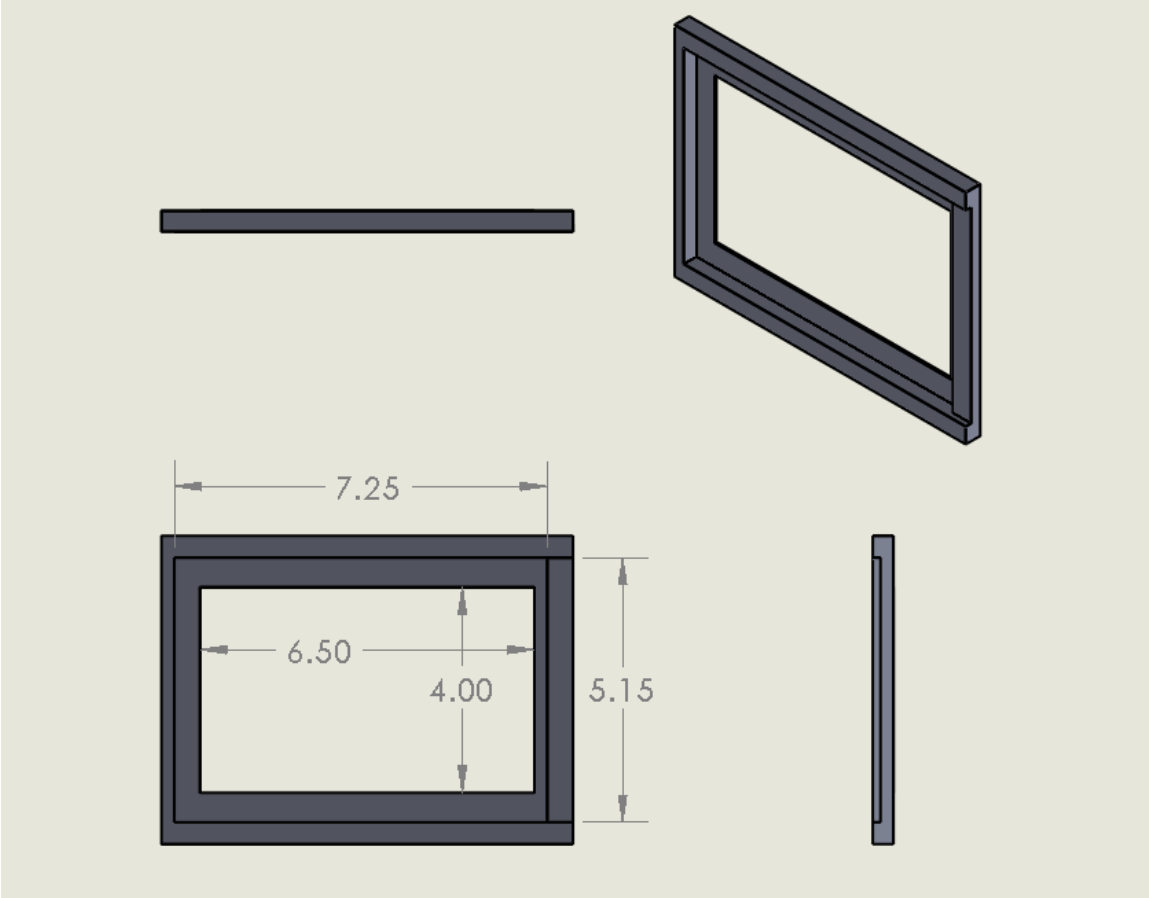

Figure 9: Plexiglass Holder (Inches)

2.2.5 Cash Deposit Box Specification

Design ID	Requirement ID	Description
Des 2.2.5.1 A	Req 3.1.6 A	The cash deposit box will be a small rectangular box that can be removed from the CashGrab machine.
Justification		A removable cash deposit box provides the ability for the owner to access the stored cash
Des 2.2.5.2 A	Req 3.1.6 A Req 3.2.2.3 B Req 3.2.2.4 B	The cash deposit will utilize a hasp & staple locking mechanism that will be secured by padlock.
Justification		A hasp & staple locking mechanism allows the owner to select their own padlock to meet their individual security requirements. For example, some owners might prefer to use a key while others might prefer a combination padlock. With a purely mechanical lock mechanism, the cash deposit

		box will not become unlocked when the power supply cuts out..
Des 2.2.5.3 A	Req 3.2.2.1 B	The locking mechanism for the cash deposit box is made out of 304 stainless steel.
Justification		304 Stainless Steel is a durable material that will likely survive most drops. [9]
Des 2.2.5.4 B	Req 3.2.2.2 B	The cash deposit box will be 3D printed with PLA filament. The external facing side of the deposit box will have a depth of 2.5 inches.
Justification		From internal testing the 3D printed PLA parts are cut resistance to non-powered tools.
Des 2.2.5.6 C	Req 3.2.2.6 C	A limit switch will be used to determine when the cash deposit box is removed from the CashGrab device and an alarm notification will be sent to the web application.
Justification		A limit switch is a switch operated by the motion or presence of an object. In this case the switch will be operated by the motion and presence of the cash deposit box.

Table 8 - Design Specification of the Cash Deposit Box

The cash deposit box is the ultimate destination for accepted banknotes traversing through the currency transportation system. The deposit box is designed for secure storage of the customer payments. The deposit box can be removed from the CashGrab machine by sliding it out of its slot on the cashier facing side of the machine. To prevent unauthorized access to the cash deposit box, a hasp & staple locking mechanism will be installed. The staple will be screwed into the cash deposit box and the hasp into the outside of the CashGrab machine. The hasp will then be secured to the cash deposit box via a padlock. The staple on the cash deposit box will also be used as a handle to assist in removing the deposit box from its slot.

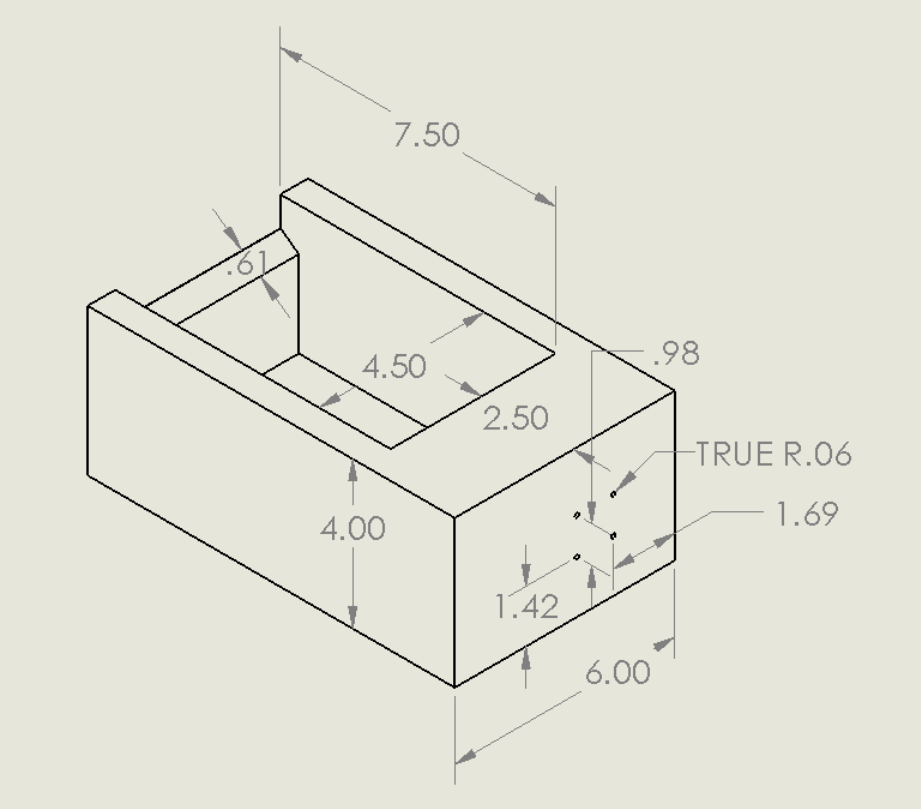

Figure 10: Cash Deposit Box (Inches)

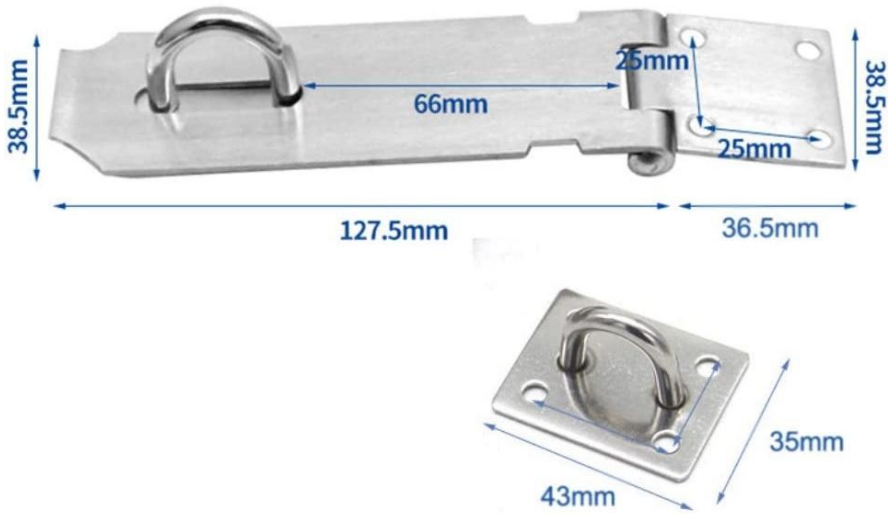

Figure 11: Hasp & Staple Locking Mechanism for the Cash Deposit Box [9]

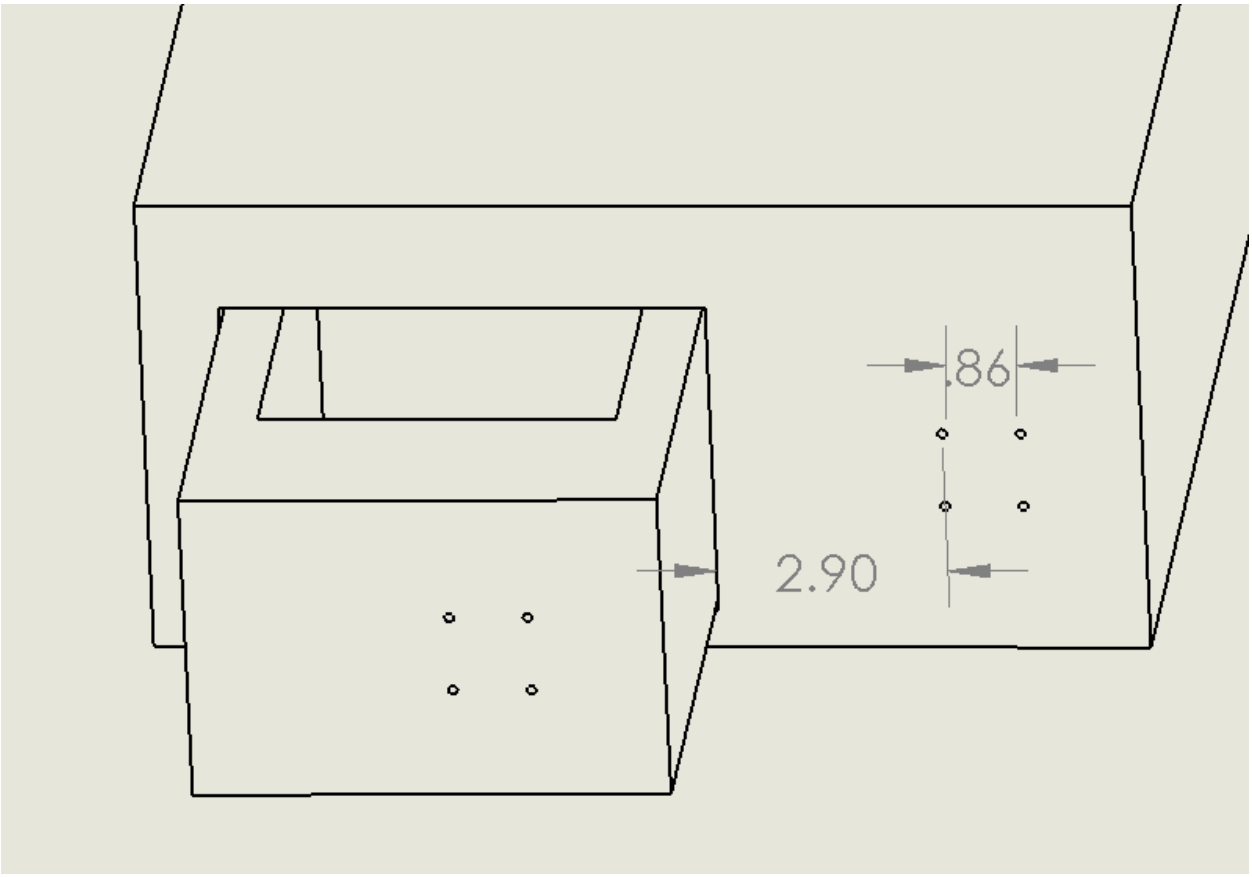

Figure 12: The Cash Deposit Box Inside the Slot on the CashGrab Machine (Inches)

2.3 Software Design Specification

The software portion of CashGrab is divided into three subsystems: currency image capture, currency detection, and the administrative web interface. The currency image capture subsystem takes an image of the inserted bank note. The currency detection subsystem identifies the denomination of the inserted bill, updates the customer's amount owed, and instructs the mechanical subsystems to store or return the bill. The administrative web interface provides an interface for managers and other administrative users to obtain transactional and sales information from the CashGrab device.

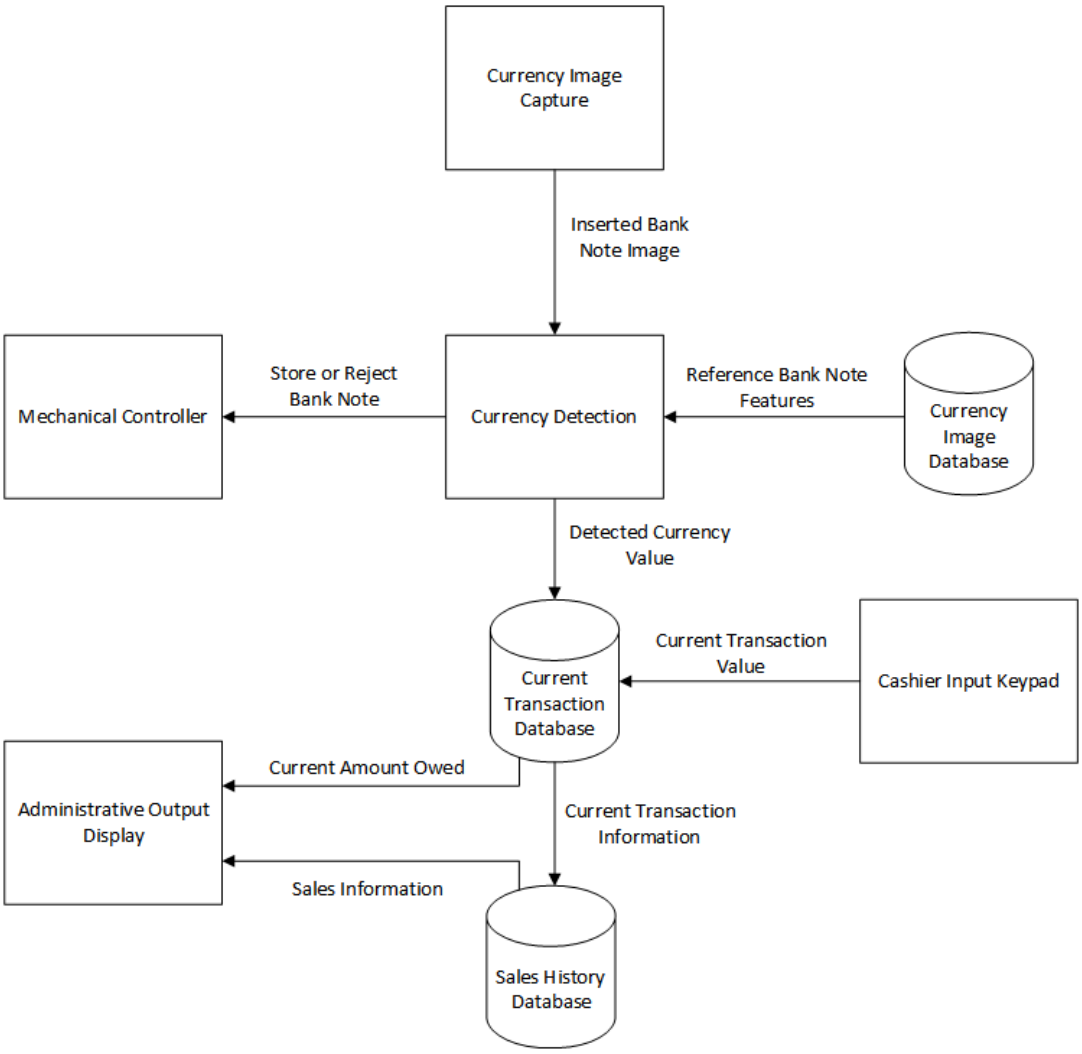

Figure 13 - Block Diagram of Software Subsystems

2.3.1 Currency Image Capture Software Design Specification

Images of the inserted banknotes will be captured from the camera and formatted using the OpenCV library [10]. Because the image processing algorithm is also implemented using the OpenCV library, the image data captured through OpenCV can be easily stored in a compatible format. Specifically, the open() method of the cv::VideoCapture class will be used to receive data input from the camera, and the read() method will be utilized to decode and store each video frame received from the camera. Figure 14 shows a single frame of an image captured from the camera and decoded with the read() method of the cv::VideoCapture class.

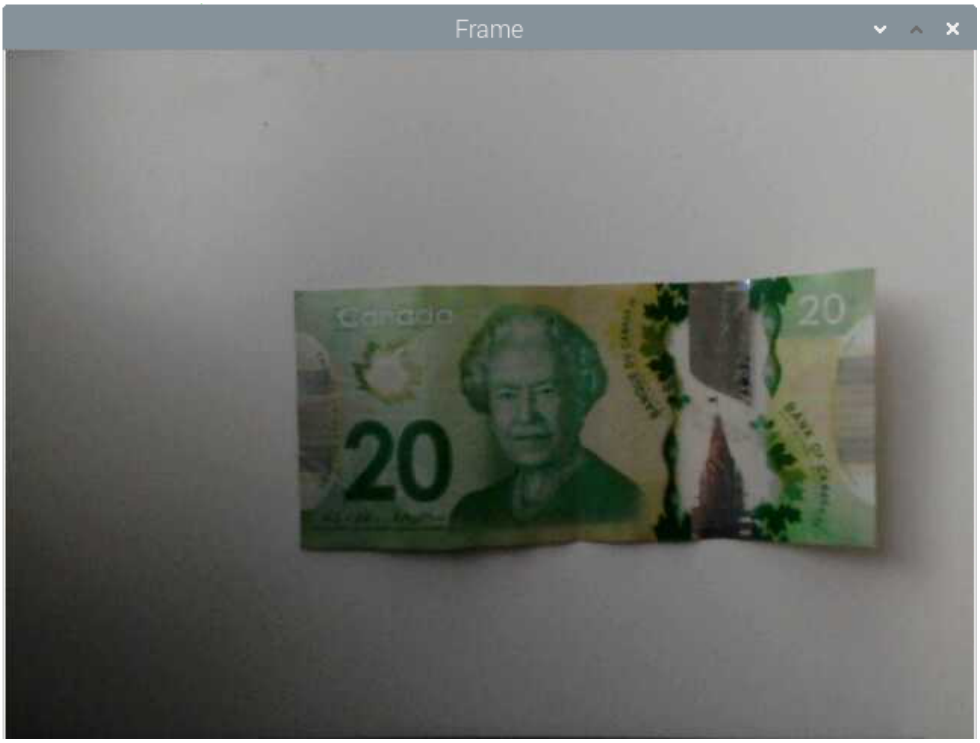

Figure 14: Camera feed via the cv::VideoCapture class

2.3.2 Currency Detection Design Specification

Design ID	Requirement ID	Description
Des 2.3.2.1 A	Req 3.1.2 A Req 3.4.2.1 A	Feature detection and feature matching is used for detecting Canadian bank notes.
Justification		Features can be used to detect matching objects in different images.
Des 2.3.2.2 A	Req 3.4.2.2 A Req 3.4.2.4 B	Feature detection will be performed using SIFT.
Justification		SIFT is robust with respect to rotation, and slight changes in image quality [1].
Des 2.3.2.3 A	Req 3.4.2.3 A	The strength of the set of matches between features will be quantified to determine if the inserted bank note is recognized and which denomination the bank note is.
Justification		Quantification of the match is needed to determine the strength of a match between the input bank note and internally stored master copy bank notes.
Des 2.3.2.5 B	Con 3.7.4 B	Bank note feature matching will be performed using FLANN.

Justification		FLANN is significantly more performant compared to linear feature matching algorithms [2].
Des 2.3.2.6 C	Req 3.4.2.5 C Req 3.5.3 B	Canny edge detection will be used for detecting counterfeit currency.
Justification		Canny edge detection has been successfully used prior for detecting counterfeit currency [11].

Table 9 - Design Specification of the Currency Detection Subsystem

The currency detection subsystem is responsible for detecting the value of the inputted currency. The image of the inserted bank note is sent from the image capture subsystem and received by the currency detection subsystem. The denomination of the inserted bank note is detected, that information is used to instruct the currency transportation system, and to update the customer's amount owed. Feature detection, description, and matching are performed using Scale-Invariant Feature Transform (SIFT) and Fast Library for Approximate Nearest Neighbours (FLANN), and are implemented with OpenCV. Figure 15 illustrates the logical flow of the currency detection algorithm.

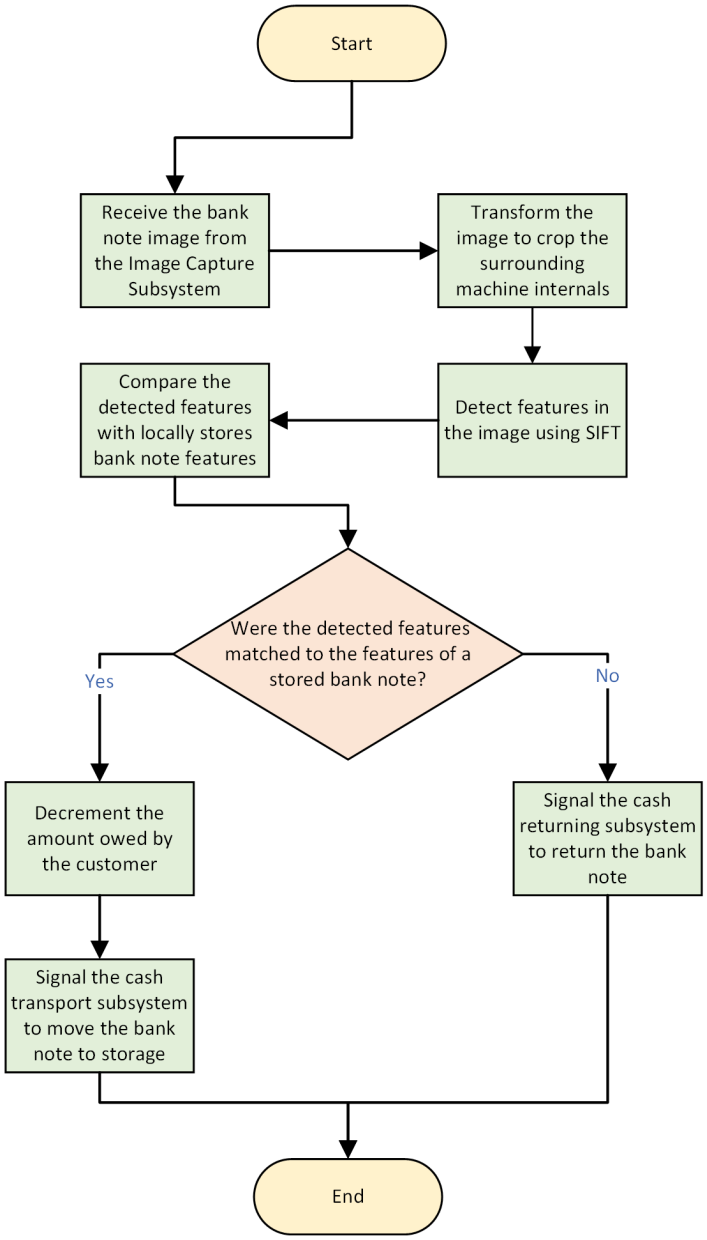

Figure 15 - Flowchart of the functionality of the currency detection subsystem

The image received from the currency image capture subsystem must be preprocessed before feature detection is performed as the received unaltered image will contain detrimental graphical information such as the internals of the device, and the transparent strip visible on most Canadian bank notes which could cause false positives. Preprocessing begins by performing contour detection on a masked version of the received bank note image. The mask is selected to ignore graphical information outside of the space in the image which will contain the bank note. After the resulting contours are obtained, the image of the bank note enclosed by the bank note's contour is projected onto a plane and cropped. Two visions of the cropped are created, both cropped images measure 55% of the width and 100% of the height of the bank note. One of the cropped images should be cropped such that only the

left-most 55% of the bank note is captured, the other copped image should be cropped such that only the right-most 55% of the bank note is captured.

Currency feature detection and description is performed using SIFT. The preprocessed bank note's image is received by the currency detector. The image is processed by SIFT to record the feature locations and descriptors of the image. An example of SIFT features detection in Canadian currency can be found in figure 16.

Figure 16 - SIFT features detected on a Canadian $50 bank note

In memory there is a master set of features for the front and back of the modern iteration of every Canadian bill denomination. The feature descriptors extracted from the preprocessed bank note images are compared to pre-computed reference feature descriptors. The features of the received image are compared to each of the stored master set of features. The matches are filtered to remove weak matches using a ratio of distance test with a ratio of 0.7. The number of strong matches between the image of the inserted bank note and the master set of features are compared to determine if a match occurred, and to determine the denomination of the inserted bank note.

```
image = GetImage()
(keypoints, descriptors) = SIFT(image)
bestMatch = (denomination = 0, matchCount = -inf)
for (denomination, referenceDescriptors) in masterFeatures
    matches = FLANN(descriptors, referenceDescriptors)
```

```
    for match in matches
        if isWeakMatch(match)
            matches.remove(match)
        if matches.count > bestMatch.matchCount
            bestMatch = (denomination, matches.count)
if bestMatch.matchCount >= MATCH_THRESHOLD
    return bestMatch.denomination
else
    return NO_MATCH_FOUND
```

Code Snippet 1 - Currency Feature Description and Matching Pseudocode

2.4 Administrative Web Interface Design Specification

Design ID	Requirement ID	Description
Des 2.3.3.1 A	Req 3.4.1.1 A Req 3.4.1.2 A	API Endpoints will be created on the backend that will update the database when cash is deposited or withdrawn
Justification		This allows us to follow a REST API standard which is powerful and popular throughout web applications
Des 2.3.3.2 A	Req 3.4.1.3 A Req 3.4.1.4 A	The price of the product and the amount of money owed or required will be displayed on the web interface using the UI
Justification		Using the web interface to display transaction details will allow for a clear interface where workers and customers are on the same page
Des 2.3.3.3 A	Req 3.4.3.1 A	The web interface will display the current balance stored in the system on the dashboard page using a React UI interface
Justification		This will allow for a clear interface for users to look up important information
Des 2.3.3.4 A	Req 3.4.1.6 B Req 3.4.3.3 B Req 3.4.3.5 C Req 3.4.1.11 C	Users will login and logout on their devices and be authenticated through their Google accounts in order to access features like transaction history and records
Justification		It is becoming increasingly common to use Google authentication, eliminating the need for users to create a new account.

Des 2.3.3.5 B	Req 3.4.1.5 B	Ability to add multiple items to a transaction will be implemented and will be reflected in endpoint calls
Justification		Will reduce need to use multiple endpoints and will minimize data storage
Des 2.3.3.6 C	Req 3.4.1.7 C Req 3.4.1.8 C	Functionality to add user permissions and privileges will implemented through admin account on the frontend
Justification		Specific abilities should be reserved for specific users
Des 2.3.3.7 C	Req 3.4.1.9 C Req 3.4.1.10 C	Functionality to add/remove and edit item info will be on the frontend and will granted to eligible users
Justification		Users should be able to tailor the UI experience to their business needs
Des 2.3.3.3 C	Req 3.4.3.4 C	Financial data and transaction history will be able to be exported in .csv or .xlsx formats
Justification		Exporting financial data in .csv or .xlsx formats allows for storage in an accepted format, making it a useful tool for managing financial information.

Table 10 - Design Specification of the Administrative Web Interface

To design a responsive, user-friendly web interface, we are utilizing a MERN Stack web framework to ensure optimal performance and seamless integration of the various components that compose the application. The MERN stack allows for the development of full stack web applications and is composed of four major technologies: MongoDB, Express.js, React, and Node.js. Figure 17 illustrates the structure of this technology stack further. The application will also be designed with scalability and maintainability in mind, to ensure its long-term viability and ability to accommodate future updates and enhancements.

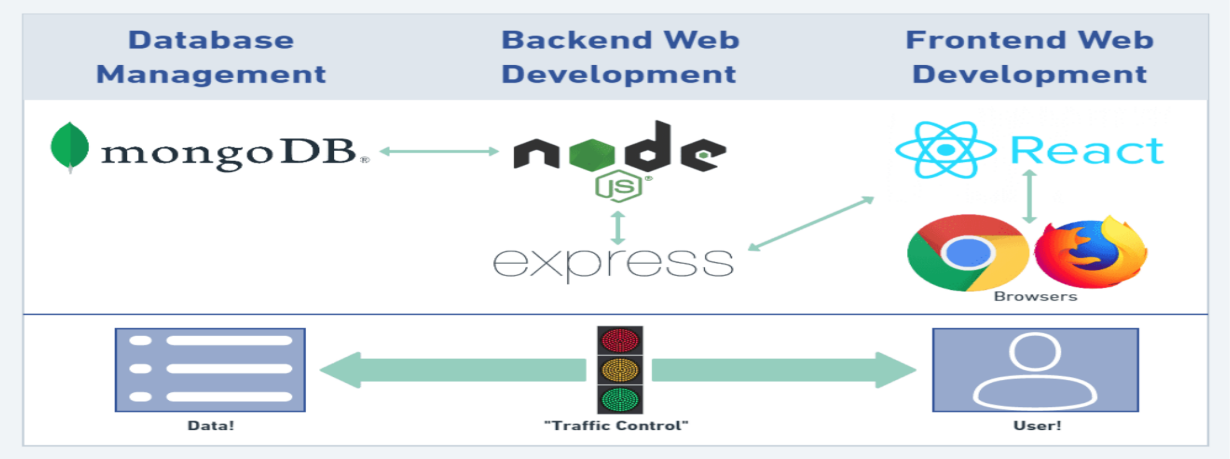

Figure 17 - MERN Stack Architecture [12]

2.4.1 Frontend Design Specification

In order to present an interactive and intuitive user interface, React, and its variant Typescript will be used in the creation of the frontend for several reasons. Being the most popular JavaScript framework, React is widely used in the development of dynamic interfaces and easily allows for the maintainability and reusability of different UI components. This popularity has also resulted in a large and active community of developers who continuously contribute to the growth and development of React. As a result, developers can find a plethora of resources, tools, and documentation available online, easing the process of debugging issues and implementing new features efficiently. Using TypeScript as a specification of React will allow us to develop robust and reliable code by enacting strict error checking in the form of structural and strict type checking.

To create a pleasurable user experience, we intend on implementing separate modules for transactions, managing income, and statistics. Building a transactions module will allow us to perform actions such as displaying transaction details to customers and providing an organized history of transactions to the user. Users will also be able to deposit and withdraw cash from the device through the web interface which will enable them to track and manage their income efficiently. Figure 18 illustrates our current dashboard interface.

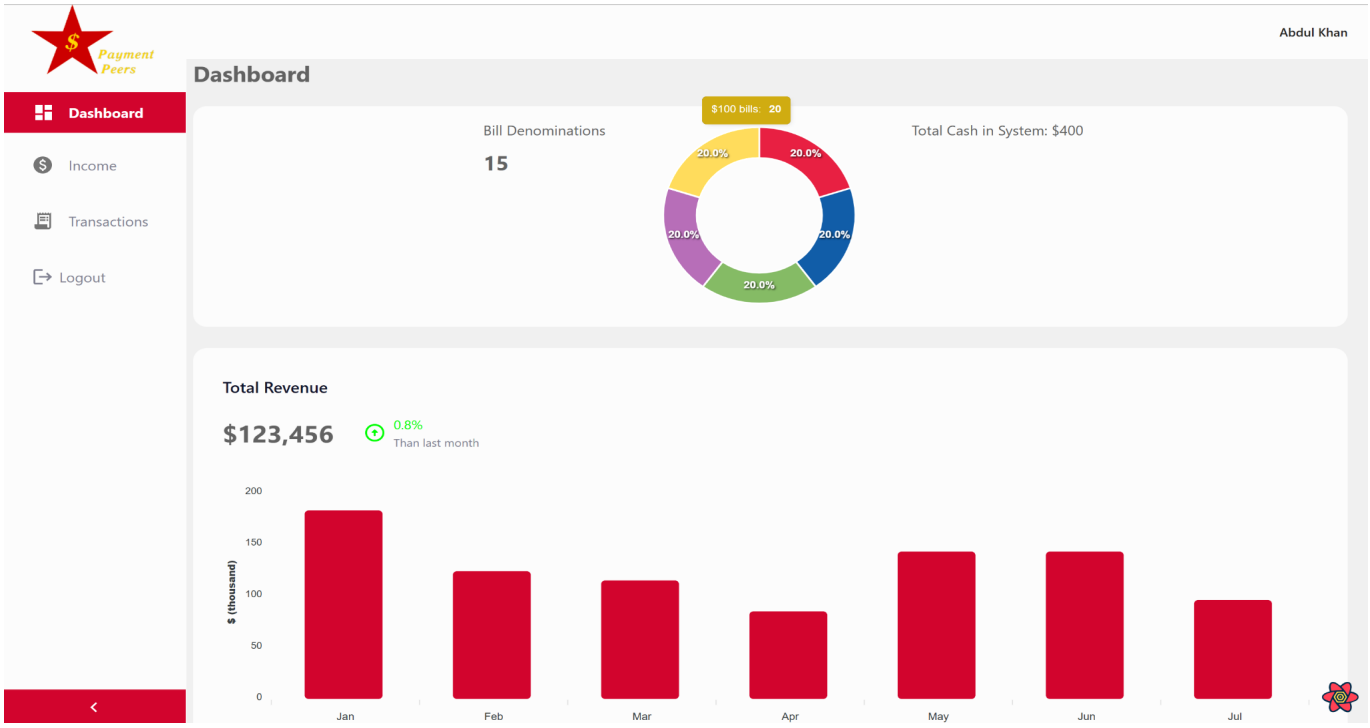

Figure 18 - Web Interface Dashboard Page

When managing sensitive information such as earnings and business data, confidentiality is a top priority. Therefore, to provide user specific privileges and abilities, we will also be implementing roles and permissions on the front end. Tools such as LoginRadius can be used to simplify the process while providing a built in API which we can utilize. Furthermore, by integrating Google authentication, we can provide users with a seamless way to login into their accounts while eliminating the need for users to

create and manage separate login credentials for the application. In addition, Google provides strong security features and useful API services which can be used to help protect against unauthorized access and enhance the functionality of the application.

2.4.2 Backend Design Specification

Our Backend Architecture will consist of 3 main technologies: MongoDB, Express.js, and Node.js. MongoDB, a NoSQL database will be used to host our database. MongoDB's ability to retrieve and store complex data efficiently in a flexible JSON-like format quickly will complement our user interface quite nicely. Furthermore, MongoDB's cloud-based database service, MongoDB Atlas will allow us to run our database in the cloud through Amazon Web Services (AWS), enabling access to any user or device connected through the internet.

To run and execute our web application, Node.js will be used. Utilizing Node.js will allow us to perform tasks such as building web servers and running scripts on the server side. The biggest advantage of using Node.js is that it allows us to use Express.js to create a RESTful API. Express.js will be used to create the backend server that will communicate with the frontend React application. Express will also facilitate the routing and handling of various requests from the frontend through endpoints, which will be executed by defined controllers. These endpoints will be able to process requests and transactions by using appropriate HTTP methods to send data to the server, which can then be processed and stored in the database.

2.5 Electronics Design Specification

Design ID	Requirement ID	Description
Des 2.5.1 B	Req 3.3.1A	Ensure that the wiring is correctly sized and rated for the power requirements of the components, and that it is properly grounded to prevent electrical hazards.
Justification		Most of our wiring will be 14 awg, since most of our components are rated for low power
Des 2.5.1 C	Req 3.3.1A	We will choose appropriate connectors to ensure reliable connections between components, and use waterproof connectors for outdoor installations
Justification		The system will rated for indoor and outdoor use having water proof connection is necessary for and outdoor usage
Des 2.5.3 C	Req 3.3.1A	The system will include circuit protection measures such as fuses or circuit breakers.
Justification		To prevent damage to the system in case of power surges or short circuits

Des 2.5.4 C	Req 3.3.2 C	Provide adequate ventilation and cooling to devices
Justification		To prevent overheating of the components and ensure reliable operation.

Table 11 - Design Specification of the Electronic Devices

2.5.1 Display Output

To show both users the total amount of the transaction, we will use a monitor connected via HDMI cord from the raspberry pi.

Figure 19 - HDMI logo [13]

2.5.2 Motors

Our top servo motor will be connected to GPIO 24 going clockwise, and bottom motor connected to GPIO 23 moving counterclockwise. The motors we will be using for cash insertion rollers will be the DS04-NFC which has a stall torque of 5.5kg/cm at 4.8V, operating voltage of 4.8-6V, and an operating current of less than 1 Amp [14]. FS90R will be our reserve motor that hasn't been included in our design yet but will be in future designs. It has a stall torque of 1.3kg/cm at 4.8V, and operating voltage of 4.8-6V [15]. Both motors have 3 pins; power, ground, and a signal pin.

2.5.3 Power

We will have an external power supply unit capable of supporting 5V-24V to power our system, which includes wiring to the raspberry pi microcontroller, two servo motors, LED light, and a camera which will get its power via usb connected to raspberry-pi.

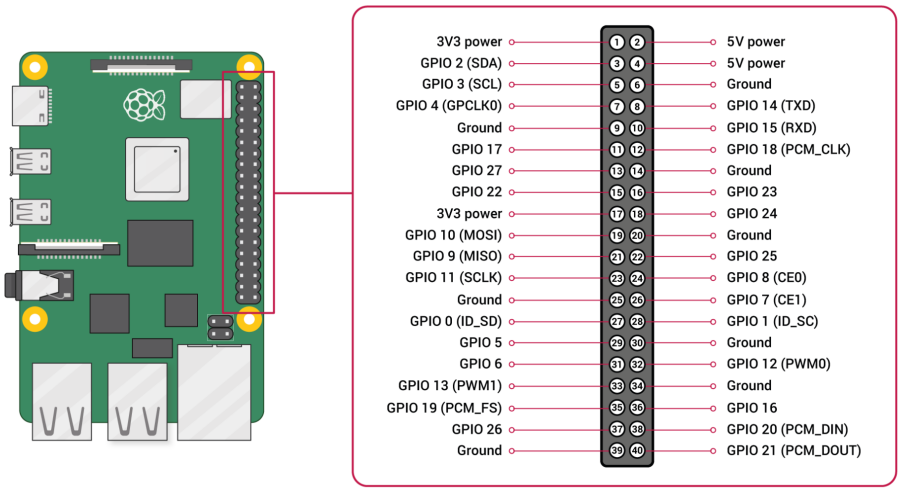

Figure 20 - Raspberry Pi 3 Model B Pin Diagram [16]

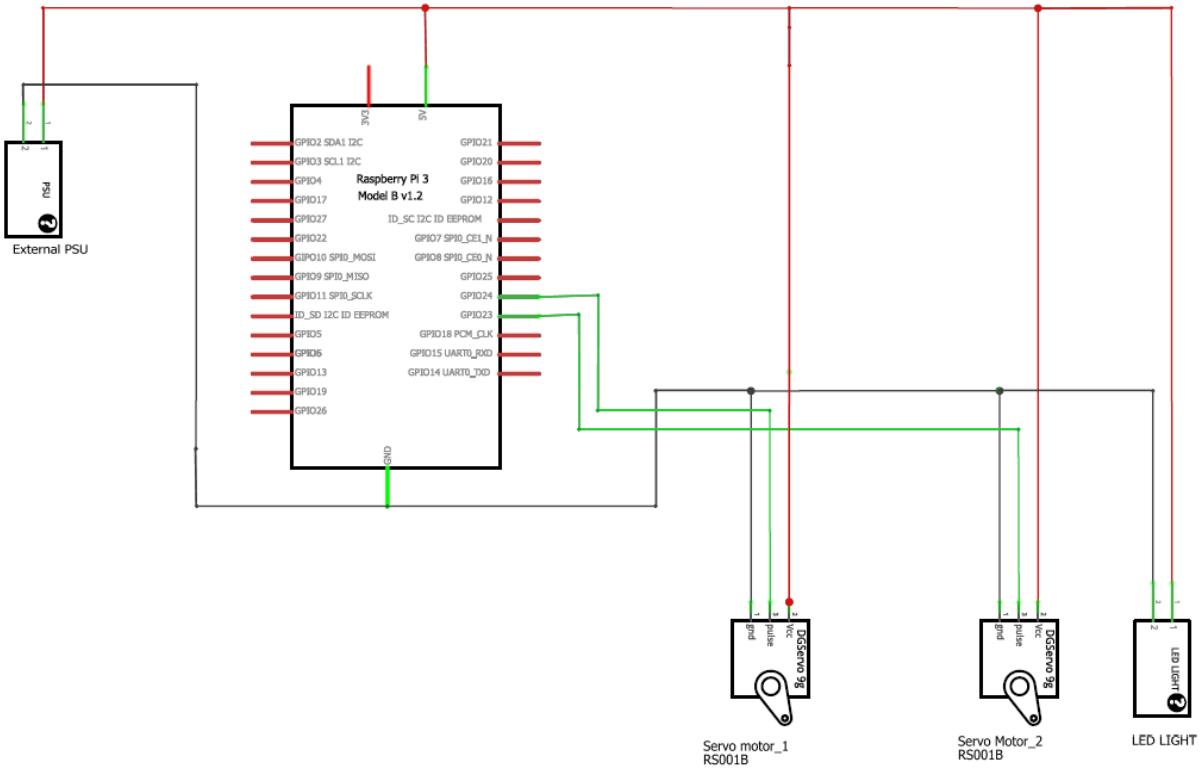

Figure 21 - Power Schematic

2.6 Engineering and Government Standards

Design ID	Requirement ID	Description
Des 2.7.1 A	Req 3.5.2 A	Bank note moving mechanisms are designed such that no two sets of motors are driving the bank note's movement at the same time.
Justification		Moving the bank note with only one set of motors at a time prevents tensile forces from being applied to the bank note which could rip or damage the bill.
Des 2.7.2 B	Req 3.5.3 B	The currency detection subsystem will use canny edge detection to identify and reject counterfeit currency.
Justiciation		Canny edge detection had previous success in detecting counterfeit currency [11].
Des 2.7.3 B	Req 2.5.4 B	Transactions will be facilitated through the prior outlined mechanical and software designs.
Justiciation		The mechanical and software designs will facilitate payment prompts, payment, and storing of transactional data.
Des 2.7.4 C	Req 3.5.5 C	Financial records will be available through the administrative interface.
Justiciation		The administrative interface is ideal for transactional records due to the subsystem's security features.
Des 2.7.5 C	Req 3.5.6 C	The device will use a pre-manufactured power supply which confirms to energy regulations.
Justiciation		Usage of a pre-manufactured and compliant power supply will ensure adherence to power efficiency regulations.

Table 12 - Design Specification of Engineering and Government Standards

Upholding engineering and government standards has been facilitated through several different mechanisms, components and subsystems. Requirement Req 3.5.1A: Adherence to the EGBC code of ethics is not fully covered by any one specific portion of the design and will be facilitated throughout development where applicable.

2.7 Safety and Sustainability Design Specifications

Design ID	Requirement ID	Description
Des 2.7.1 B	Req 3.6.1 B	All power wiring will be electrical shielded by electrical tape.
Justification		Having the wiring shielded will prevent any shocks to users or damage the equipment.
Des 2.7.2 B	Req 3.6.2 B Req 3.6.4 B Req 3.6.7 C	The internal mechanical and electronic components of the system will be enclosed in a 3D printed ABS material box.
Justification		ABS material is flame retardant and has a wide range of operating temperatures from negative twenty degrees celsius to eighty degrees celsius [5]. Additionally, ABS is easily recyclable so the CashGrab device will be environmentally friendly [17].
Des 2.7.3 C	Req 3.6.3 C	The 3D printed enclosure will have rounded edges.
Justification		Having rounded edges on the enclosure will prevent the users from being cut.
Des 2.7.5 C	Req 3.6.5 C	A temperature monitor will be installed in the CashGrab device enclosure and a threshold maximum temperature will be set.
Justification		If the value reported by the temperature monitor surpasses a threshold value, then a shutdown event will be triggered.
Des 2.7.6 A	Req 3.6.6 C	The bill insertion point is designed to have a five millimeter slot.
Justification		Five millimeters is sufficiently small to avoid users from accidentally inserting body parts.

Table 13 - Design Specification for Safety and Sustainability

3. Conclusion

This design specification document has outlined the implementation detail of the following systems and design considerations involved with CashGrab:

- Currency insertion mechanism
- Currency transportation mechanism
- Currency returning mechanism
- Currency image capture
- Cash deposit box and storage
- Currency detection
- Administrative web interface
- Engineering and government regulations
- Safety and sustainability

This design specification is a living document, and is expected to be updated as research and development progresses. Testing and iteration of the mechanical systems, and the currency detection subsystem are expected to induce the most impactful design alterations. In spite of expected design changes, we intend to design new iterations to be largely compatible with previous designs when possible.

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Appendix A: Design Alternatives

A.1 Mechanical Design Alternatives

A 3D printed ramp is the alternative method for transporting bank notes through the PoS system. One advantage of this method is that it does not require any motors to transport the bank notes, instead, bank notes are transported via gravity. Additionally, this method saves us both cost and implementation time. This ramp would come immediately after the two insertion rollers and transport the inserted bank notes from the insertion point to the currency detection platform, where the denomination of the bills are identified. The length of the ramp would be fairly short (151 mm) and the angle of the ramp is fairly steep (39.5°) allowing bank notes to be transported through the system quickly. However, one disadvantage of using this method is that there will be difficulty keeping folded and crumpled bills flat. Another disadvantage of this method is that the bank notes fall at the control of gravity. Using the conveyor belts to transport the bank notes allows us to have complete control over the motion of the bank notes.

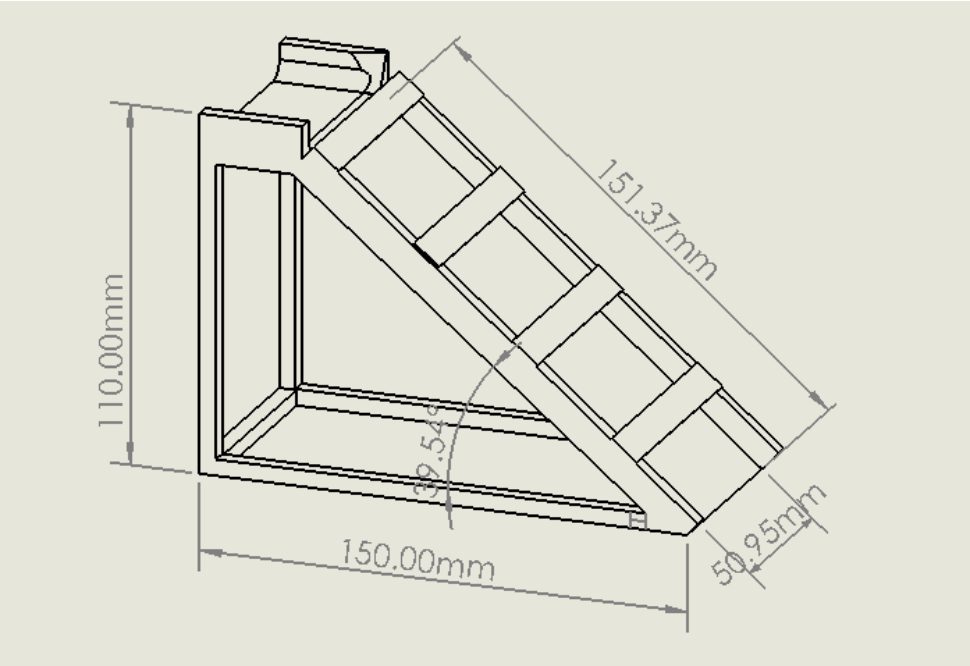

Figure 22 - Banknote Transportation Ramp

A.1.1 Raspberry Pi Camera Modules

In the event that the ASUS Webcam C3 falls short of meeting our image capturing requirements, we have identified an alternative solution in the form of the official Raspberry Pi Camera Module. This camera module is designed specifically for use with the Raspberry Pi and features a 5 Megapixel sensor with adjustable focus. The Raspberry Pi Camera Module attaches via a 15cm ribbon cable to the CSI port on the Raspberry Pi which supports a high-speed data transfer from the camera to the processor. While it

may require more computational power to process images captured with this camera, it offers greater customization options as well as higher resolution images than the ASUS Webcam C3.

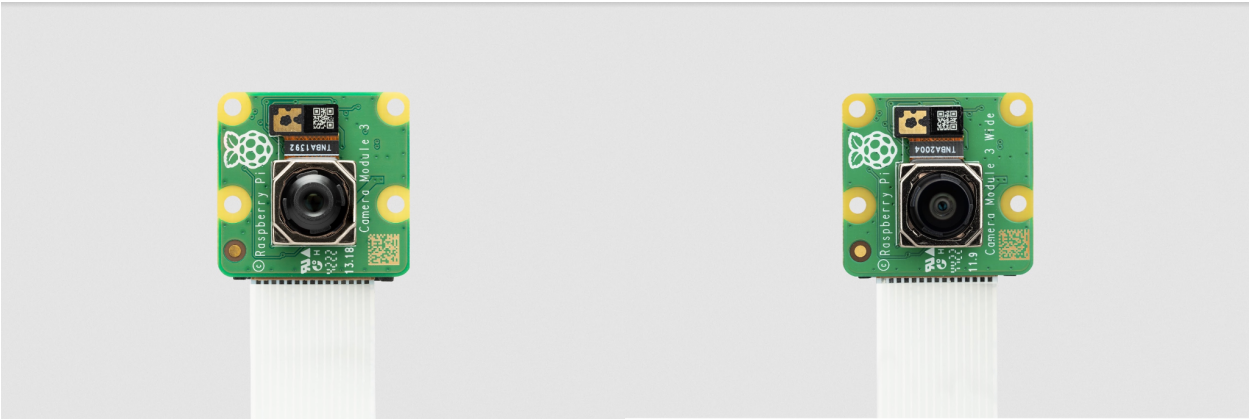

Figure 23: Camera Module 3 (left) and Camera Module 3 Wide (right) [18]

A.1.2 Cashier Controlled Currency Detection

In the case where a software-based solution for currency recognition is insufficient a electrical-mechanical solution could be used as an alternative. The cashier would be given a display of the currently inputted bank note, facilitated through the currency image capture subsystem. The cashier interface would include several push buttons for the possible denominations of the inserted currency along with a reject button for the case in which the customer inputs an invalid bill. The cashier would input the currency denomination based on the bank note displayed on the cashier's display.

This solution would fulfill requirements: Req 3.1.2 A, Req 3.4.2.1 A, Req 3.4.2.2 A, Req 3.4.2.3 A, Req 3.4.2.4 B. Additionally, the solution would circumvent constraints: Con 3.7.3 B Con 3.7.4 B.

A.2 Software Design Alternatives

A.2.1 Convolution Neural Network Based Currency Detection

An alternative solution to using a traditional algorithm such as SIFT that is being considered is a deep learning approach, specifically a convolution neural network (CNN). A CNN is able to recognize patterns in data and can be trained to classify images. Once trained, a CNN could be faster than a traditional algorithm because it can be trained upon images taken from the device itself. There is also no risk of overfitting the data because the training data will encompass all possible inputs that it will be expected to identify.

A.3 User Interface Design Alternatives

A.3.1 Built in LCD displays

In the event that the current display design is deemed unsuitable we will use an alternative design of multiple screens with certain screens dedicated to only the cashier and customer. These screens will be embedded in the side of the device. The Cashier facing side of the device will have two segmented LCD screens, as shown in figure 22, with the first one displaying total amount owing for current transaction and the second one displaying the current amount of money stored in the CashGrab cash drawer. The customer facing side of CashGrab will have two LCD screens. One non-segmented LCD will show either a livestream or periodically updated photos of each bill being inserted to accommodate any currency insertion disputes between the device and the customer. The second screen below will be a segmented LCD that will show current balance owed and will decrement after each successful bill insertion.

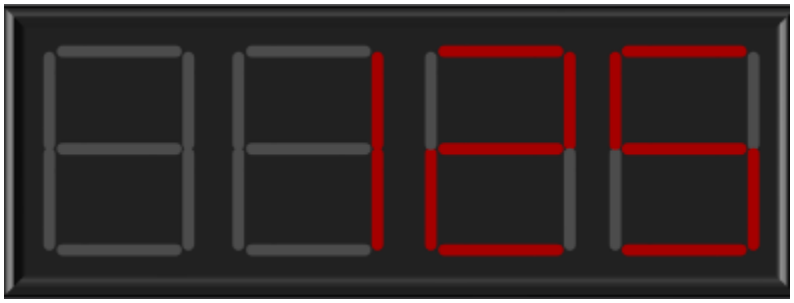

Figure 24: Segmented LCD

Appendix B: Test Plan

Test: Canadian Currency Detection	**Time:** _____	**Date:** _____
Testing Procedure ● The tester will sequentially place each Canadian bank note bill ($5, $10, $20, $50, $100) in the frame of the camera.		
Expected Outcome: ● The currency detection algorithm will process the captured images and print an ‘accept’ message with the bill denomination to the Raspberry Pi’s terminal.		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Detection of fraudulent currency	**Time:** _____	**Date:** _____
Testing Procedure ● The tester will sequentially place various objects (e.g. monopoly money, a phone, etc…) in the frame of the camera.		
Expected Outcome: ● The currency detection algorithm will process the captured images and print a ‘reject’ message to the Raspberry Pi’s terminal.		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Web Interface Transaction Processing	**Time:** _____	**Date:** _____
Testing Procedure ● Tester will insert cash to process transaction		
Expected Outcome: ● Cash that is inserted should be reflected in web interfaces's transaction history and should be present in database		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: User interface physical usage test	**Time:** _____	**Date:** _____
Testing Procedure ● The user interface will be tested simulating a simple point-of-sale transaction with the cashier turning the screen towards the customer to pay ● The LCD screen swivel base will be tested to ensure it is smooth and does not delay the transaction		
Expected Outcome: ● The LCD screen will rotate smoothly and not delay the transaction ● The LCD screen will remain in place without external help		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Display image of current bill being inserted	**Time:** _____	**Date:** _____
Testing Procedure ● A bill will be inserted into CashGrab ● The corresponding option on the web interface to display the image will be chosen		
Expected Outcome: ● A photo of the current inserted bill will be displayed on the LCD screen of the device		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Performance	**Time:** _____	**Date:** _____
Testing Procedure ● The currency detection subsystem will be given a set of several valid and invalid bank notes. ● The duration needed to process the entire set of bank notes will be recorded.		
Expected Outcome: ● The currency detection subsystem will process inputted bank note images at a rate of at least 10 Hz.		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Transaction Output LCD Display Update	**Time:** _____	**Date:** _____
Testing Procedure ● An amount owed will be inputted into the device using the external keypad. ● Observe the owed amount displayed on the customer balance owed LCD display. ● Observe the owed amount displayed on the cashier current transaction LCD display. ● A Canadian bank note will be inserted into the device. ● Observe the change of the owed amount as displayed on the customer balance owed LCD display. ● Observe the change of the owed amount as displayed on the cashier current transaction LCD display.		
Expected Outcome: ● Upon inputting a price with the external keypad the customer's balance owed LCD display will update to the inputted amount. ● Upon inputting a price with the external keypad the cashier's current transaction LCD display will update to the inputted amount. ● Upon inputting a Canadian bank note the amount displayed on the customer's balance owed LCD display will decrease by the denomination of the inserted bank note. ● Upon inputting a Canadian bank note the amount displayed on the cashier's current transaction LCD display will decrease by the denomination of the inserted bank note.		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Cashier Cash Storage LCD Display Update	**Time:** _____	**Date:** _____
Testing Procedure ● An amount owed will be inputted into the device using the external keypad. ● Observe the value as displayed on the cashier's cash storage LCD display. ● A Canadian bank note will be inserted into the device. ● Observe the change in the cash storage as displayed on the cashier's cash storage LCD display.		
Expected Outcome: ● Upon inputting a Canadian bank note the amount displayed on the cashier's cash storage LCD display will increase by the denomination of the inserted bank note.		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Rejection of multiple inserted bills	**Time:** _____	**Date:** _____
Testing Procedure ● Attempt to insert multiple (3 or more) Canadian bills into the cash insertion slot ● Denomination of bills is not important ● Do not apply excessive force		
Expected Outcome: ● User is unable to insert 3 or more bills into the cash insertion slot ● Bills are not damaged in any manner		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Transport of cash via insertion mechanism	**Time:** _____	**Date:** _____
Testing Procedure ● Insert Canadian bills of any denomination, along its short side, into the cash insertion slot		
Expected Outcome: ● Bills enter the cash insertion mechanism with no observed damage ● Bills successfully arrive at the currency detection platform after they are inserted ● Bills do not get stuck at any point between the cash insertion point and the currency detection platform ● Bills do not get folded on itself		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	

Test: Returning rejected cash	**Time:** _____	**Date:** _____
Testing Procedure ● Insert in cash like bill (such as monoply money) into system		
Expected Outcome: ● Image detection system will recognize cash is not real ● Reverse motors to reverse feed cash bill		
Observed Outcome:		
Comments:		
Score:	**Tester Signature:** _____	