Letter Shredder: Automatic Mail Sorting System

TEAM MEMBERS:

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PROBLEM AND SOLUTION

It is common for many residents to encounter mail that does not belong to them from prior tenants. The mail may contain personal information about that tenant that could risk security threats and negative legal implications. There are also many occasions where tenants currently living in apartments get unwanted mail from senders they would like to blacklist, or from advertisers. Moreover, in apartment complexes with many mailboxes for each resident, mail delivery workers have to tediously open and close every mailbox that receives mail. In some cases, the mail rooms in the apartment complexes have no option to selectively open and close individual mailboxes. Instead, there is a universal open button that opens up all the mailboxes at once giving thieves and vandals an opening to act. This has happened many times around the country. For instance, at a luxury apartment complex in Ooltewah, mail hasn't been delivered due to an "hostile environment" whenever the mail delivery worker arrives to deliver the mail.[1] This project can greatly decrease the time and resources taken to deliver mail by efficiently and effectively completing the task.

We propose a mail sorter and shredder that would organize mail based on the names of the tenants and the senders that are allowed/blacklisted from the mail system. Names on the allowlist are sorted into the respective bins. Blacklisted names are sent to the shredder. This would be done by scanning the mail, extracting the necessary information from the labels of the mail, and comparing all features to determine bin placement.

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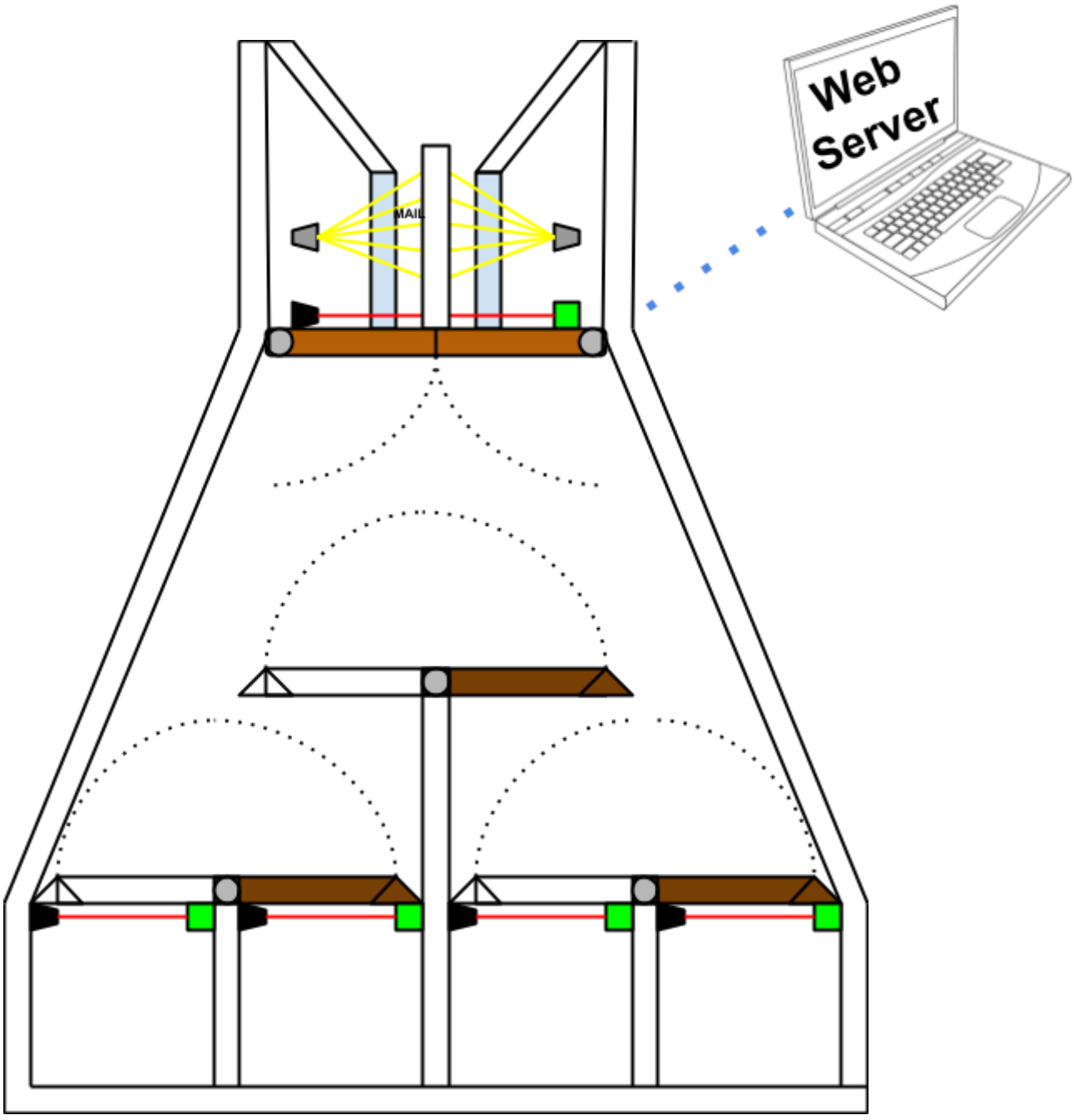
[1]Ptimesadmin2015. "Post Office Says It Will Stop Delivering Mail to Luxury Ooltewah Apartment Complex; Cites 'Hostile Environment.'" Postal Times, 18 Aug. 2022, postaltimes.com/postalnews/post-office-says-it-will-stop-delivering-mail-to-luxury-ooltewah-apartment-complex-cites-hostile-environment.

VISUAL AID



HIGH-LEVEL REQUIREMENTS LIST

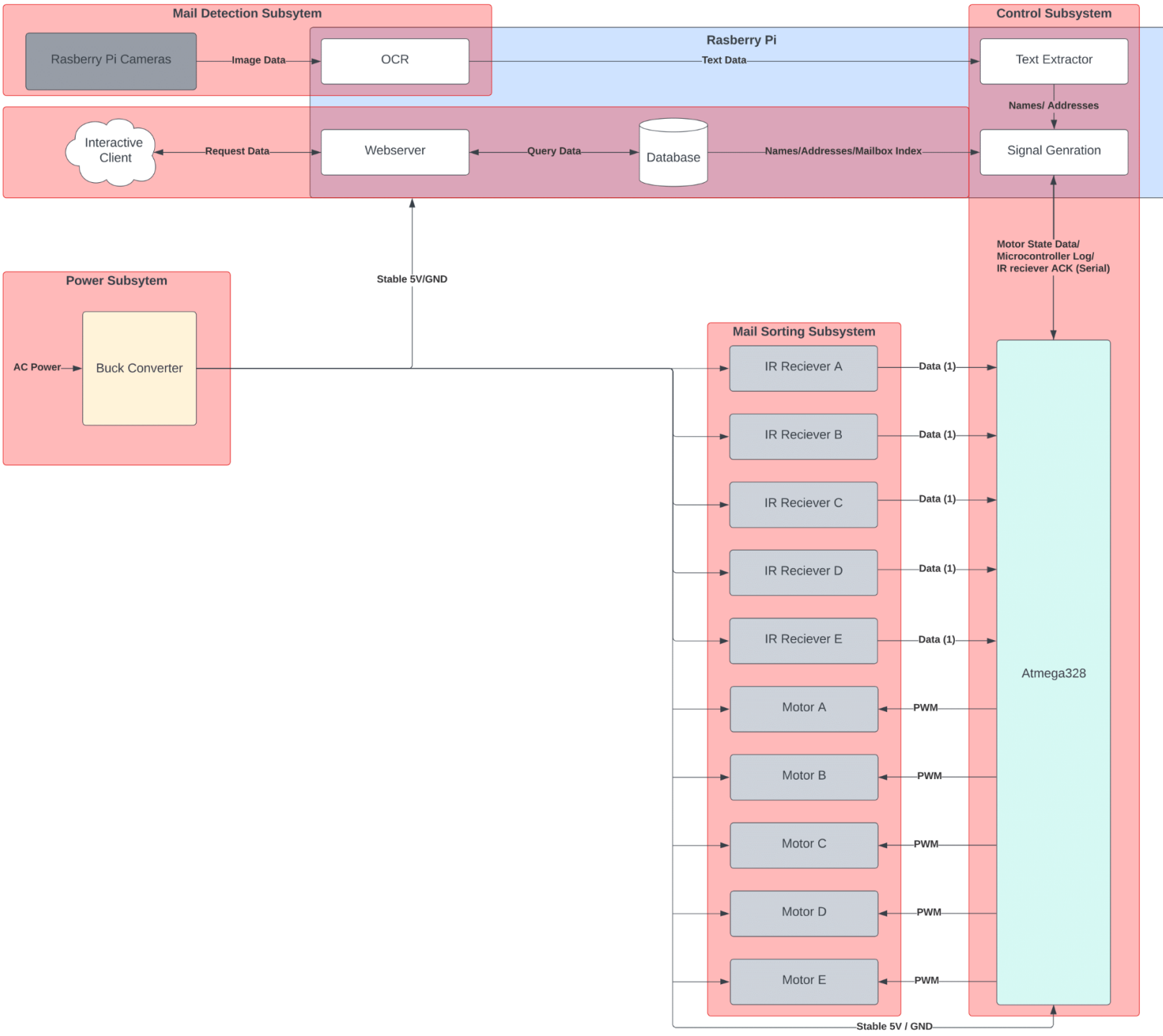
- Mail sorter is able to correctly extract names from the mail, with a character accuracy of 90%, the printed names on the cards.

- Mail Sorter hosts a web server that provides a user interface for changing the name-based filter settings of the OCR software and stores the preferred filter settings on the raspberry pi.

- Mail sorter, once determining a slot to place the mail in, is able to physically guide mail through the system with an 80% accuracy. - (8/10 mail succeeds)

DESIGN

Block Diagram



Power

The sorter will be powered through a 12v wall plug. The voltage will need to be adjusted for the small electronics, and the full 12 volts must be available to the motors and their drivers.

Control

The microcontroller will send control signals to the motor drivers and read from the various sensors in the sorter. It will communicate over UART to the raspberry pi which runs the image analysis and hosts the webserver. The raspberry pi will tell the microcontroller which paddles to move, and the microcontroller will tell the rpi when to take a picture.

Webserver

The webserver, hosted on the raspberry pi, is how users can set filters and monitor the sorter. It will also store pictures of all the mail processed through the sorter.

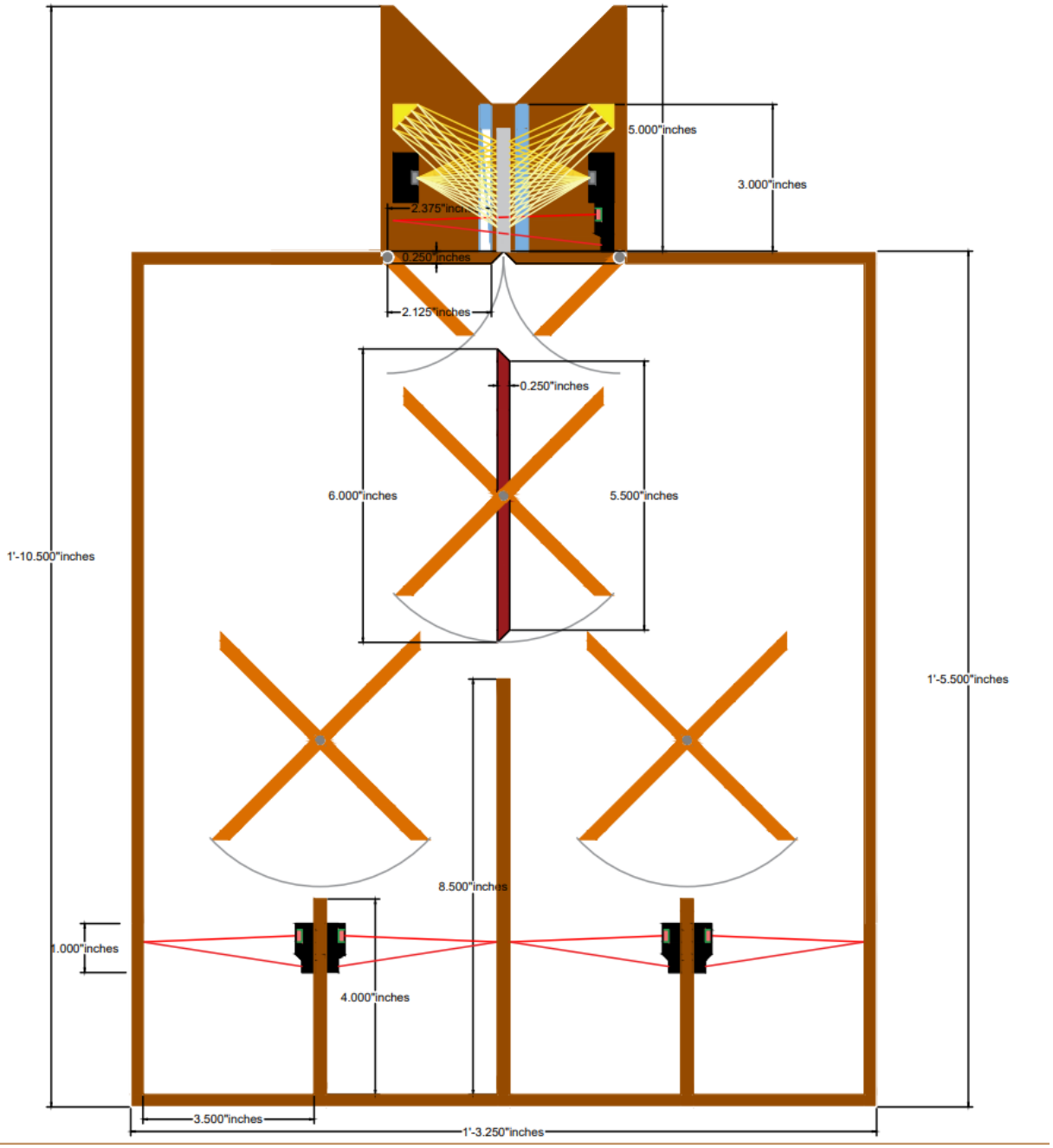
Mail Sorting

The paddles that control where the mail falls are controlled by stepper motors. They receive their instructions from the control unit. Limit switches are placed at the desired paddle angles for safety, and allow the microcontroller to guarantee the position of the paddles.

Mail Sensing

To read any information on both sides of the mail, 2 raspberry pi cameras will communicate with the raspberry pi. When the mail is in the slot and ready to scan, the laser break sensor will signal the microcontroller.

PHYSICAL DESIGN



For our physical design, the overall build will be composed of wood with a base dimension of 22.5 inches x 15.25 inches. The front of the apparatus will be covered with a see-through acrylic or plastic to be able to see the workings of the motorized parts and to make debugging much simpler. At the entryway of the mail, there will be a 0.5 inch opening to fit the size of our mail

and have it sit upright for the picture to be taken properly. At the bottom, on both sides of each mailbox, there will be a 1 inch gap saved for the sensors to be placed. As can be seen in the diagram, there is more than enough space in the corners of the module to fit the power source input, and raspberry pi. This setup will include at least 5 inches of space in length to support wiring between the components.

SUBSYSTEM 1: MAIL RECOGNITION/DETECTOR

This component will consist of an optical switch connected to the main control unit that will determine if mail is placed properly in the scanner. It will also contain 2 cameras and light sources to capture images of both sides of the mail.

Requirements:	**Verification:**
The cameras should be triggered to capture data into the raspberry pi when mail has entered the slot.	With only the image capturing unit active along with the laser detection sensors, we will test how often an image is captured when mail is placed in.
The mail should remain in the slot and the camera should not capture an image if the prior mail has not yet reached it's destination.	This requirement can be tested by modifying the motors in the sorting subsystem. If we allow one of the motors to block the mail from entering the box and place another mail in the divot, we will then be able to check if the mail has left recognition module.
Text recognition from the OCR module should produce the correct text from the mail 85 +- 5% of the time.	We will create a sample set of 20 different mail printouts. We will then compare the output from our OCR tests to the data on the printouts to evaluate the failure rate of this module.

SUBSYSTEM 2: CONTROL UNIT

Controls the image capturing of the camera based on the optical switch, and runs an OCR to determine the sender and receiver from the printed or handwritten text. It will then compare the data to names/aliases within a local database to determine the destination of the mail being processed. It will also host the web server that can allow the host to append or change the database externally. Further, it will send control signals to different electric motors in the organization system.

Requirements:	**Verification:**
The Raspberry Pi should host a webserver that will interact with this database to update the names of the users that are meant to receive the mail along with the destinations in terms of the mailbox number.	We will connect to the web server from a website, change the name of the recipient in mailbox #1. Then, drop a piece of mail with that new name, and observe that the mail enters that mailbox#1. We will also place mail for the recipient name that was changed and observe that the mail enters the trash slot.
The webserver should also be able to update and modify the blacklisted senders for each of the users dynamically to allow user control for mail.	We will add/modify the blacklisted list and place mail from a sender in that blacklist into the chute. We should see that the mail enters the trash slot.
Raspberry Pi should be able to capture images and store locally on a signal from the microcontroller to begin visual processing.	Insert a piece of mail into the mail sorter so that the microcontroller can trigger a picture to be captured. Inspect the image is saved properly via ssh.
Raspberry Pi can send signals to the microcontroller for the motor controls based on data captured from the cameras.	Insert a piece of mail, and let the OCR software do its thing. Inspect through the system log that the microcontroller received the instructions to move the servos to guide the mail.
Microcontroller can load signal from Raspberry Pi to control motors to move the paddles for the mail to move into the correct mailbox.	Insert a piece of mail with a specific name. Verify on the raspberry pi log that the correct name and mailbox were extracted and selected. Then Visually inspect that the paddles are moved to guide the mail.

SUBSYSTEM 3: MAIL SORTING SYSTEM

This is the physical system that controls the directional movement of the documents such that it reaches the intended destination. This subsystem will consist of multiple paddles along with a dropoff chute for the mail.

Requirements:	**Verification:**
The motor dropoff only releases the mail once it has been successfully scanned.	Run a piece of mail through the system, and verify using the system log stored on the raspberry pi that the image was processed and the mail slot determined before the motors moved.
The paddles are in the precise orientation that allows the mail to enter its respective box.	Run a piece of given mail through the system and visually check that the paddles get set to the correct position.
The mail should remain in the slot if the prior mail has not yet reached it's destination.	This requirement can be tested by modifying the motors in the sorting subsystem. If we allow one of the motors to block the mail from entering the box and place another mail in the divot, we will then be able to check if the mail has left recognition module.

SUBSYSTEM 4: POWER SUBSYSTEM

This is the subsystem that will provide the power for the entire project.

Requirements:	**Verification:**
This subsystem must be able to take in power from an AC to DC converter connected to an outlet.	Run the motors on the same powerline and check that the voltage remains at 5V using a voltmeter.

The voltage and energy provided from this converter must be enough to provide stable power to all the components, along with the appropriate voltages needed by any of the devices.	Test the amperage across the different motors using an ammeter and see that each one has at least 1 amp when all motors are being run simultaneously.

COST AND SCHEDULE

Hourly Rate: $50/hr
Estimated Hours to complete: 100 hrs
Labor Cost: $50 x 2.5 x 100 = $12,500

Parts:

Raspberry Pi	1	$135	Image analysis + Webserver
Pi Camera	2	$15	Image analysis
ATMega328p Microcontroller	1	$3	Main Control Unit
Stepper Motor Controller L298N	4	$10	Motor Control Unit
Stepper Motor	4	$11	Motor Control Unit
Laser Break Sensor ADA2169 x5	4	$10	Main Control Unit
¼” Plywood	1	$20	Physical Construction
¼” Acrylic	1	$20	Physical Construction
3.5x5 Envelopes (100 pack)	1	$11	Testing

Parts total cost: $343

Project Total Cost (Labor + Parts): $5343

Tolerance:

This subsystem may fail mechanically due to the physical limitations of the materials used to construct the sorter. If there are any unwanted gaps in the system for the mail to fall into the wrong chute, it may diminish the use of our system. This can be mitigated through design choices and calibration of the motors controlling the paddles/latches. We will also have to run tests for the optimal timing of the mail release and paddle movement.

Schedule

<table>
<tr><th>Date</th><th>Day</th><th>Whole Group</th><th>Angelo Santos</th><th>Sahas Munamala</th><th>Lisa Pachikara</th></tr>
<tr><td colspan="2">Week 9</td><td colspan="4">This week we plan on finalizing the changes to the design document and begin the programming of the various components</td></tr>
<tr><td>3/20/2023</td><td>Monday</td><td></td><td>Finalize the inidividual and overall schedules for the project.</td><td>Order the components necessary for the machine shop to finalize design.</td><td>Begin modifying the design document to reflect changes requested by the TA.</td></tr>
<tr><td>3/21/2023</td><td>Tuesday</td><td></td><td>Finalize the different dimensions for objects in the visual dimensional diagram.</td><td rowspan="2">Gather the names of all the different circuit components necessary for building the final PCB and testing, such as resistors, capacitors, oscillators ect.</td><td rowspan="5">Begin researching the programming of the ATmega328. Become familiar the testing environment for the controlling of the different motors and processing of different light sensor signals.</td></tr>
<tr><td>3/22/2023</td><td>Wednesday</td><td></td><td>Modify the block diagram to reflect appropriate control signals between components.</td></tr>
<tr><td>3/23/2023</td><td>Thursday</td><td></td><td rowspan="2">Begin researching the methods for multithreading within the raspberry pi to control the image processing of OCR along with the hosting of a webserver. Also begin researching the method for interacting with the webserver.</td><td rowspan="2">Begin researching the python OCR library along with the methods for gathering and controlling the raspberry pi camera.</td></tr>
<tr><td>3/24/2023</td><td>Friday</td><td>Meet together to read through the final design document, make any final touches, and send the final design document to the website.</td></tr>
<tr><td colspan="2">Week 10</td><td colspan="4">This week we plan on unit development of the different components. We will also begin testing the given PCB design for errors.</td></tr>
<tr><td>3/27/2023</td><td>Monday</td><td>Meet with TA to discuss progress.</td><td rowspan="3">Complete the programming of the webserver/database. This module should be able to be interacted remotely. Changes must be reflected onto the local database.</td><td rowspan="3">Images should be able to be captured from a rasberri pi camera and text must be able to be extracted. All text must be parsed to extract important details such as names and addresses.</td><td rowspan="5">Complete a sample program that handles the control logic between the different light sensors and simultaneously changes the PWM frequencies of the different motors based on the control signal given by the raspberry pi.</td></tr>
<tr><td>3/28/2023</td><td>Tuesday</td><td></td></tr>
<tr><td>3/29/2023</td><td>Wednesday</td><td></td></tr>
<tr><td>3/30/2023</td><td>Thursday</td><td></td><td rowspan="2">Test for continuity between components on the PCB. Make changes for the next</td><td rowspan="2">Find a way to program the ATmega through a breadboard to test the different components</td></tr>
<tr><td>3/31/2023</td><td>Friday</td><td></td></tr>
</table>

			PCB round as necessary.	physically.	
Week 11		**This week we will begin integration of all components for proper sequential programming.**			
4/3/2023	Monday	Meet with TA to discuss progress	Work on ensuring that memory on the raspberry pi is reflective on the data within the database.	Work on getting the Rasberry pi and ATmega on one breadboard together along with test motors and sensors. At this time, given a signal to where the mail should arrive, the different PWM signals of the ATmega should give the correct output to the different motors. The following control flow must be demonstrated at this time: Camera captures text, text is processed and parsed, fixed memory contains the user details of the mail being simulated, pwm signals are generated at the right frequencies, IR outputs are also read and raspberry pi is brought back to the image capturing state.	
4/4/2023	Tuesday	Ideally we are able to pick up the physical design sometime during the week.	Begin soldering wires and components together to the PCB. Test for any errors and make any necessary changes for the next PCB round.		
4/5/2023	Wednesday		If the physical design is ready, begin organizing the wiring of the different components.		
4/6/2023	Thursday		Alternatively, assist on the organization of the integration breadboard with the rest of the team.		
4/7/2023	Friday				
Week 12		**This week we will begin soldering all items to the final PCB board and connecting the different components to the physical design.**			
4/10/2023	Monday	Meet with TA to discuss progress	If the physical design is ready, begin organizing the wiring of the different components.	Work on getting the Rasberry pi and ATmega on one breadboard together along with test motors and sensors. At this time, given a signal to where the mail should arrive, the different PWM signals of the ATmega should give the correct output to the different motors. The following control flow must be demonstrated at this time: Camera captures text, text is processed and parsed, fixed memory contains the user details of the mail being simulated, pwm signals are generated at the right frequencies, IR outputs are also read and raspberry pi is brought back to the image capturing state.	
4/11/2023	Tuesday	Ideally we are able to pick up the physical design sometime during the week.	Alternatively, assist on the organization of the integration breadboard with the rest of the team.		
4/12/2023	Wednesday		Place all the items in their appropriate postions on the final PCB and test for any errors within the mechanical design. Tune any parameters for change.		
4/13/2023	Thursday				
4/14/2023	Friday				

DISCUSSION OF ETHICS AND SAFETY

We believe that this project is fairly ethical, safe to the public and is beneficial for everyone involved. Referencing the IEEE Code of Ethics, our project would comply with all of the requirements, however, we can see some possible violations if this project is carried out as intended. The first foreseeable issue comes into play when unauthorized users try to access the residents' private data from our database such as name, address, and the photos of the mail received. Another similar issue can arise as an unauthorized user could change the dataset for residents in terms of what mail they block and receive. This could be a possible violation of the IEEE Code of Ethics Section I-1[2]. We strive for our project to be non-discriminatory, lawful, and well-cited. Overall, we seek to create a product that can be efficient and helpful for mail industry workers.

We see no physical safety concerns in regard to this machine other than general concern for the in-wall plug. General wall power safety measures should be taken when plugging the machine into the wall and keeping wall sockets out of reach of children. The only openings accessible to the customer would be the mailbox slots and which are safe and have no hazardous parts in them. The entry point of the mail would only be big enough for the width of the mail causing no concern for the person inserting the mail into the machine.

[2] IEEE. "IEEE Code of Ethics." IEEE, Institute of Electronics and Electrical Engineers, https://www.ieee.org/about/corporate/governance/p7-8.html.