Secure Mailbox with Mobile Connectivity

ECE 445 Project Proposal - Spring 2023

Team 26

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1. Introduction

1.1 Problem:

Mail is one of the biggest forms of communication in today's world and sees the transfer of sensitive information such as bank statements and checks to millions of households throughout the nation. While apartment buildings have keys which are only possessed by a mailman and tenant that unlocks a unit's mailbox, many single family and townhomes have a conventional mailbox which can be easily opened by anyone. This means that millions of Americans do not have any means of securely storing their mail as they often do not pick their mail up immediately, leaving mail unprotected and easily stolen for long periods of time. As seen in the WFMY local news article, checks in the mail are frequently stolen and authorities warn citizens to not leave sensitive material in mailboxes overnight and instead hand them directly to the mail carrier. Currently, electronically locking boxes exist which let packages be stored outside of your door securely, but a similar solution does not exist for mail that is both secure and can be mounted in place of an existing mailbox.

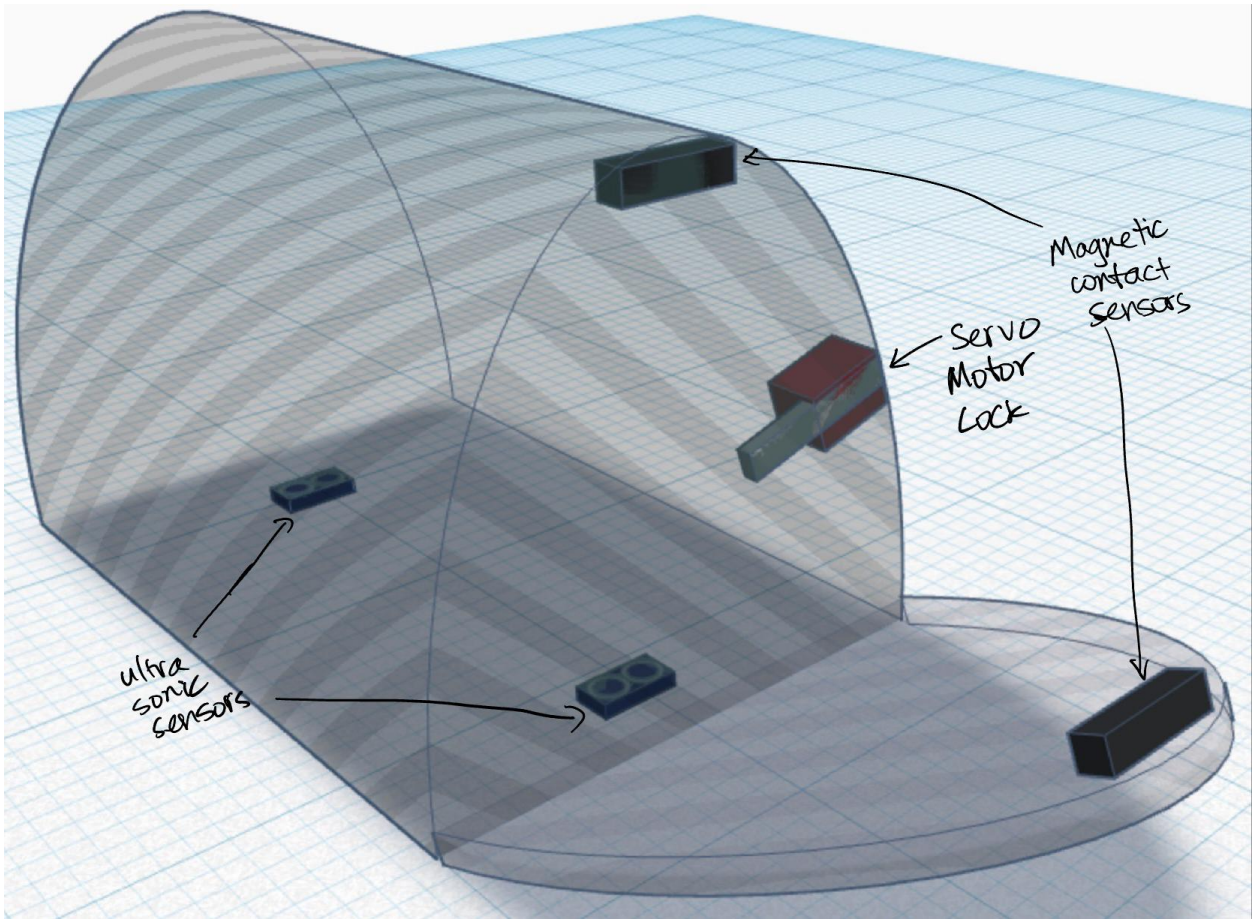
https://www.wfmynews2.com/article/news/local/2-wants-to-know/stop-putting-checks-in-your-mailbox-thieves-steal-checks-wash-change-amount-cash-dont-put-mail-in-blue-usps-mailboxes-overnight-post-office/83-fc6b3146-5565-4a32-8a58-e22b2bab835d

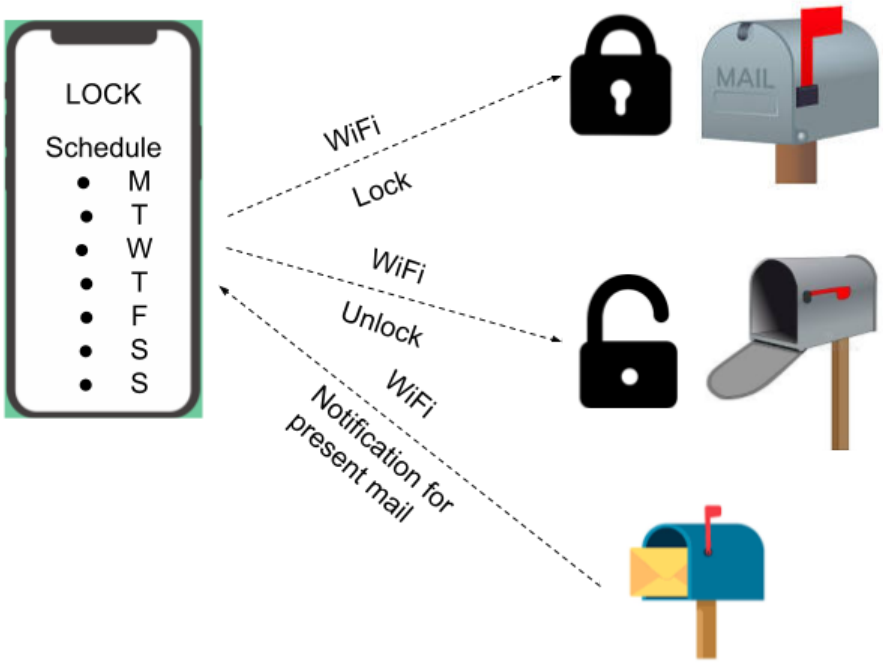
1.2 Solution:

Our solution is to create a mailbox that will have two primary features. The first feature will be the ability to automatically lock once mail is placed inside of it. The second feature allows the user to schedule a time period for the mailbox to remain unlocked in the case of multiple deliveries happening throughout the course of a day. Any time the mailbox is opened, closed, or mail is placed inside the mailbox the user will be notified. These notifications will be sent to the user via a mobile application. Additionally this mobile application will allow the user to interact with the mailbox. In the application the user will be able to manually unlock/lock the mailbox and set a schedule for the mailbox to remain unlocked. If there is no schedule set, the mailbox will act under the assumption that only one mail delivery will occur that day and will lock after mail is placed into the mailbox for the first time and the door is closed.

When it comes to the implementation, the mailbox will use a magnetic contact sensor to determine when the mailbox is opened and then send a signal to the PCB that sets a ready state and waits for the close signal. Once the door is closed, the magnetic contact sensor will send another signal to the PCB which in turn instructs the lock to close. The PCB will also interface with the mobile application, via a wireless module, which will send unlock and lock signals to the PCB to control the actions of the locking mechanism. This system will also be used for unlocking the mailbox during a scheduled window which can be controlled in the app. In order to notify the user if mail is present in the mailbox, multiple ultrasonic sensors will be used to detect if mail is covering any one of them. This information will be sent back to the PCB and then be sent to the mobile application to alert the user of mail. A small, low powered, motor will be used to lock and unlock the mailbox. It will be attached to a metal extension to secure the lock.

1.3 Visual Aid:





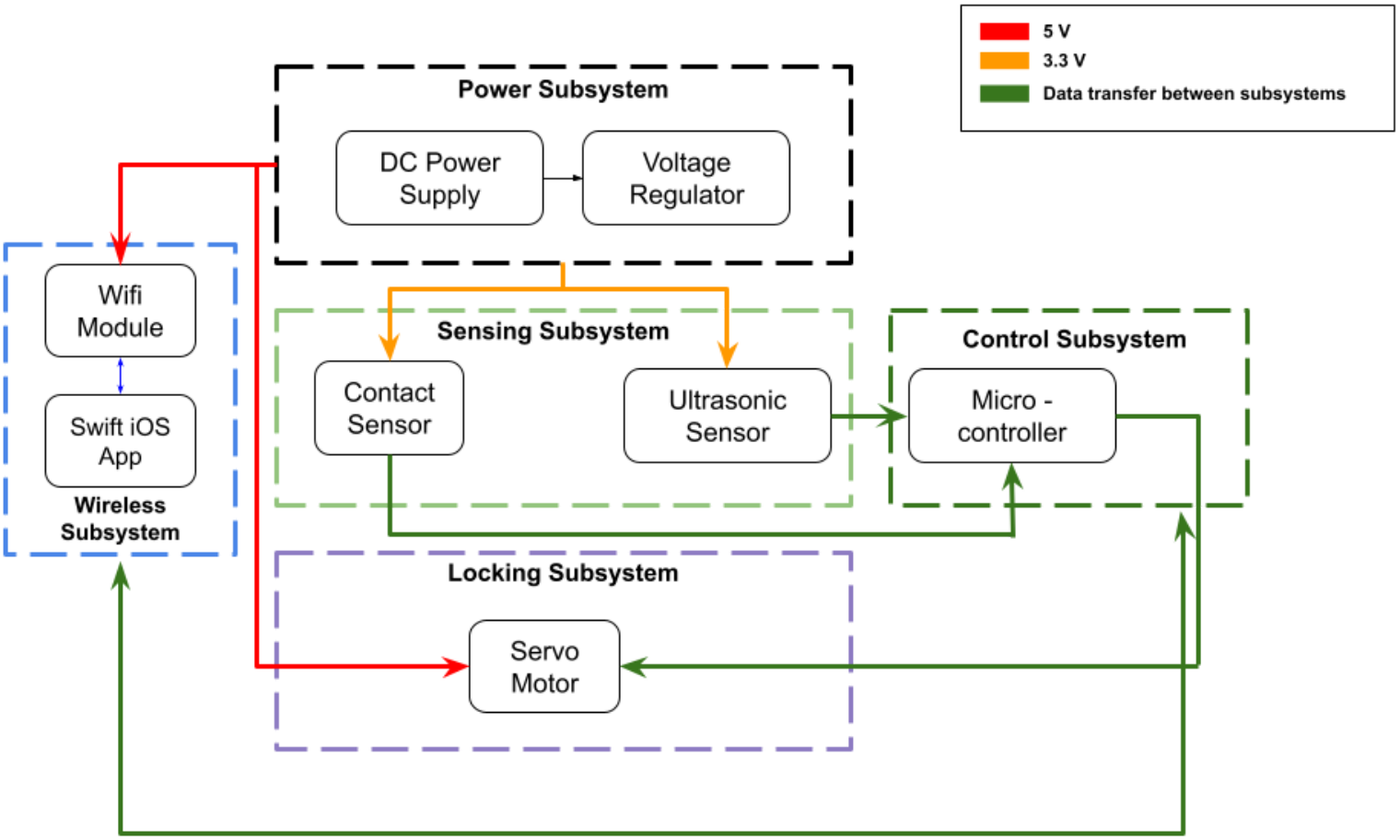
1.4 High-level Requirements List:

For our project to be successful, we will implement these requirements:

1. The mailbox must automatically lock within 10 seconds of the door being closed if mail is placed inside and there is no schedule set to leave it unlocked.
2. The mailbox must lock and unlock within 5 seconds of pressing the corresponding button on the application.
3. The mailbox must send a notification within 30 seconds of an action being made on the mailbox. This includes opening and closing the mailbox as well as whether mail is present.

2. Design

2.1 Block Diagram:



2.2 Subsystem Overview and Requirements:

i. The Sensing Subsystem

The sensors from our system will have two main components: the magnetic contact sensor (COM-13247) and the ultrasonic sensor (SEN-15569). The magnetic contact sensor will be placed on the door and on the roof of the mailbox to determine whether the door is closed. The ultrasonic sensor will be placed at the bottom of the mailbox to determine if there is mail in the mailbox. Both of these components are powered by 3.3V from the Power Subsystem. The

magnetic contact sensor and the ultrasonic sensor both send data to the microcontroller to control both the locking mechanism and wireless subsystem for notifications.

https://www.sparkfun.com/products/13247

https://www.sparkfun.com/products/15569

ii. Power Subsystem

The power to our system will be provided by a wired connection to a wall outlet which will pass through a voltage regulator. The voltage regulator will allow us to manipulate the voltage required for each sensor or module. This will supply 500 mA to the magnetic contact switch as well as 15mA to the ultrasonic sensors. The system must source 5V into our system.

iii. Wireless Subsystem

The iOS application will be a user interface consisting of two main features. The first piece of functionality is having a toggle button that will be able to lock and unlock the mailbox manually by the user. The second piece is having a scheduling element that will allow the user to input what times of day the mailbox is unlocked. This application will communicate with the mailbox via the wifi module that will be built into the microcontroller (D1 Mini NodeMCU LUA MicroPython WiFi ESP8266 ESP-12 WeMos Microcontroller) that transfers data to the rest of the mailbox and the locking mechanism.

iv. Control Subsystem

The control subsystem will be relaying information throughout the various subsystems of the product. The data regarding the state of the mailbox door will be sent from the magnetic contact sensors along with the data from the ultrasonic sensors to the microcontroller. This will also receive data from the application in the wireless subsystem where the microcontroller will then send data to the locking subsystem.

v. Locking Subsystem

A servo with a connector (Analog Servo - FeeTech S0005) will be mounted inside the mailbox which works in conjunction with a piece mounted to the mailbox door. The locking

subsystem will receive its information from the microcontroller after taking into account the status of the magnetic contact and ultrasonic sensors from the sensor subsystem as well as the manual unlock and lock of the mobile app from the wireless subsystem.

https://www.sparkfun.com/products/18285

2.3 Tolerance Analysis:

When using ultrasonic sensors, we must ensure that mail is being detected in an accurate manner. If this is not being done accurately, mail will not be secured properly inside of the mailbox. An ultrasonic sensor can detect the nearest object to it within 2 to 400 cm. Our mailbox will be a height of 20.5 cm, so if our ultrasonic sensor detects an object between 2 and 20 cm away from it, then we will know that there is mail in the mailbox. An ultrasonic sensor outputs the amount of time it takes a sound wave to bounce back to it if there is an object within 400 cm of it. The equation for the amount of time a sound wave will take to bounce back to an ultrasonic sensor is the following: $T = (2 * D) / v$, where T is time, D is the distance between the ultrasonic sensor and the object, and v is the speed of sound. The reason it is $2 * D$ is because we have to account for the sound wave to make two trips: one to the object and one back to the ultrasonic once it bounces off the object. The speed of sound is around 340 m/s which is 0.034 cm/µs. We will be testing to see if there is an object within 2 and 20 cm. For 2 cm the time it will take is $T = (2 * 2) / 0.034 = 117.65$ µs. For 20 cm the time it will take is $T = (2 * 20) / 0.034 = 1{,}176.47$ µs. This means we will have to continuously monitor our ultrasonic sensor and if we ever see a time output between 117.65 µs and 1,176.47 µs, we will know that mail is in the mailbox.

3. Ethics and Safety

- Misuse of our product could result in violations of the IEEE code of ethics. The first code includes the products ability to “protect the privacy of others”, however with the functionality of the mobile application being able to unlock the mailbox at any time, this could give anyone who has access to the app access to the home owners mail as well.
- The reliability of our product could result in violations of the ACM code of ethics. The code states that you must “Design and implement systems that are robustly and usably secure”. A safety issue that may arise is if one of the components in our product malfunctions. This has the potential of either locking the door permanently or always leaving it unlocked. If it is locked permanently, the user will not be able to safely access their mail. If it is always unlocked, the user will have a false sense of security that their mailbox is locked when it is not. To ensure that this does not occur, we will be testing our product under a plethora of different scenarios to make sure that it does not malfunction.