ECE 445
SENIOR DESIGN LABORATORY
PROJECT PROPOSAL

Secure Food Delivery Dropbox

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1. Introduction

1.1 Problem:

In 2024, there were approximately 311.1 million users of the online food delivery market in the United States alone, and this number is projected to continuously rise.[1] One prevailing problem in the food delivery industry is theft. Some services try to combat this problem by requiring delivery drivers to take pictures of the food once it's dropped and sending it to the user to confirm delivery. However, there is no safeguard preventing passersby or even the delivery drivers themselves from taking the food after taking a picture. Another annoyance with this process is that users might order ahead to have food waiting for them upon arrival, although the convenience of having food waiting for you is offset by the fact that the food will get cold.

1.2 Solution:

To address this issue, we propose a secure food drop system/box that remains locked and can only be opened by the person who placed the order. The overall idea of the box is to have a box that is perpetually locked but allows the user to give access to open the box to the delivery driver through entering a keycode. Once the driver opens the box and puts the food inside the box, the box will be locked again. Then, the user will be the only person able to open the box through fingerprint. Additionally, we propose integrating a heating system inside the box that will maintain the food's warmth.

To start the process, weight must be temporarily added inside the box so that a randomly generated code can be created and sent to the user's email. The user must then text this code to their driver so that they can open the and place food inside. Once the food is placed inside, a weight sensor will trigger a solenoid lock to move a deadbolt and automatically lock the box as well as generate a new code, locking the driver out. The microcontroller will use its wifi capability to send the new code to the user through a program to be ready for the next order. The box will also keep the food at a high enough temperature to continually stay warm. When they arrive, the user will use a calibrated fingerprint on the fingerprint sensor so they can open it at any time securely.

1.3 Visual Aid:

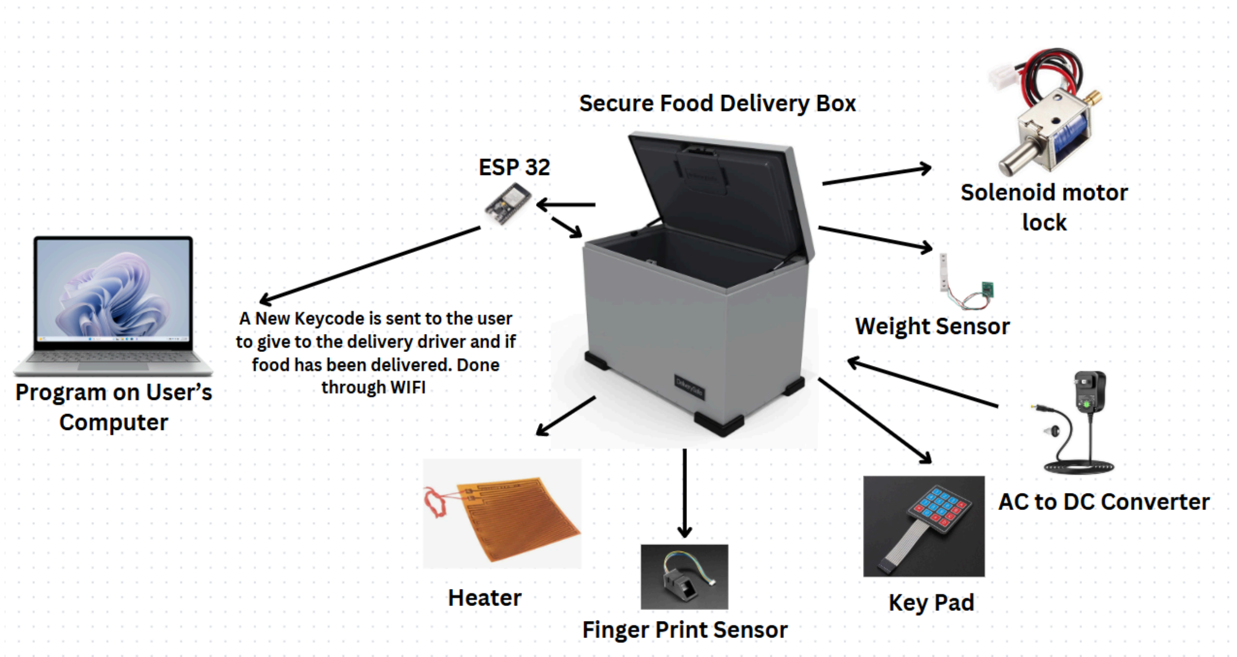

Figure 1: Visual Aid for Secure Delivery Dropbox

1.4 High-level requirements list:

- Authentication inputs should be recognized and should unlock the box at least 12 times out of 15.
- The box should detect objects of at least 50 grams inside of it at least 12 times out of 15 and will automatically lock approximately 20 seconds or less after the food has been placed inside and the box has been closed.
- The box should generate and send a new passcode to the user within 1 minute after last use and the user must receive this new passcode within 5 minutes 12 times out of 15.

2.Design

2.1 Block Diagram:

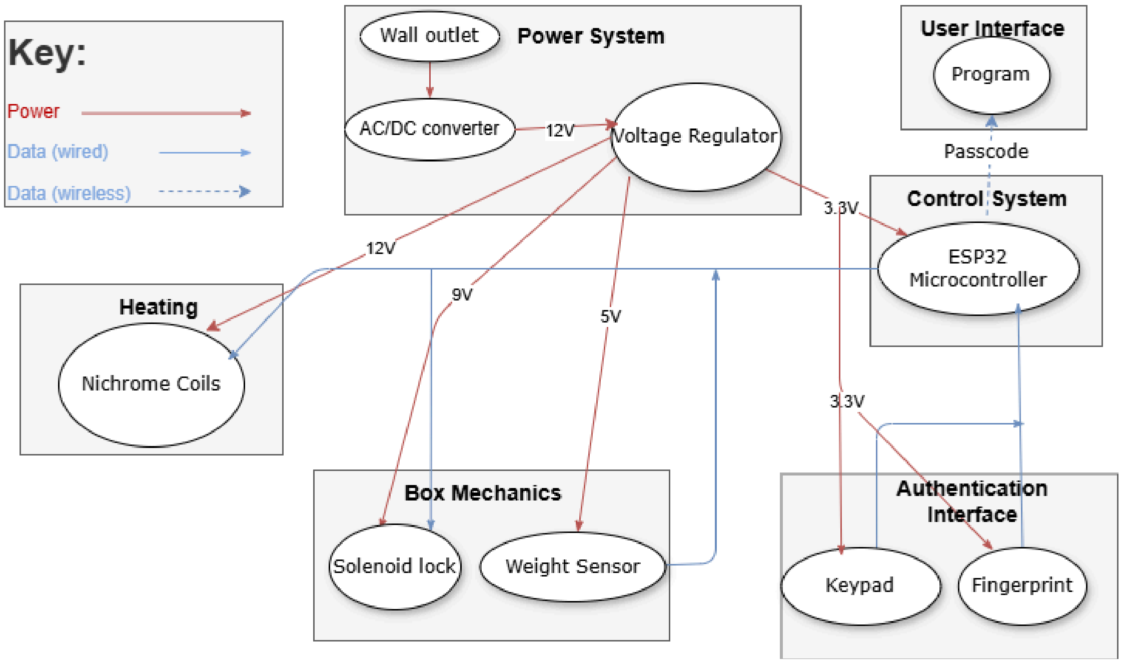

Figure 2: Block Diagram for the Secure Food Dropbox

2.2 Subsystem Overview:

2.2.1 Subsystem 1: Authentication interface (keypad and fingerprint)

Functionality: The Authentication interface will recognize the users attempting to open the box and provide them access. The driver will get a one-time passcode to open the box through the keypad[2] so they cannot reopen it once the food is placed in. Once the box relocks, the passcode will not work anymore. The fingerprint sensor [3] will recognize only a master fingerprint and deny access to all others.

Contribution: This subsystem receives power from the power subsystem and will send a confirm or deny signal to the control system. The control system will then send the appropriate response to the locking mechanism to ensure the security of the box.

2.2.2 Subsystem 2: Power (converter and voltage regulator)

Functionality: The Power subsystem provides the necessary power for the entire device. It will consist of a power converter[4] and a voltage regulator. The converter will change the 120 volts AC source of a wall outlet into a 12 volts DC source. The voltage regulator will step down the voltage to the required levels for each component.

Contribution: The Power subsystem provides the necessary voltage to power all sensors, motors, and heating coils. This ensures that when any component is called it can correctly and consistently complete its required operation.

2.2.3 Subsystem 3: Box Mechanics (weight and solenoid)

Functionality: These components are built into the box and control the state of operation. When the weight sensor[5]exceeds its threshold, the box will automatically lock, turn on the heating, and generate a new passcode, stopping the driver from reopening. The solenoid lock[6] activate an electromagnet that will move the deadbolt to complete the actual lock.

Contribution: The mechanics are powered by the power system and controlled by the control system. The weight sensor will send a signal to the microcontroller that the solenoid will receive to lock the box, tell the heating system to activate, and also tell the microcontroller to generate a new code to send to the user interface for the next order.

2.2.4 Subsystem 4: Control (microcontroller)

Functionality: The ESP32 microcontroller [7] is the brains of the operation that controls the operation of the other subsystems. The microcontroller will parse the signals from other systems as acceptable or unacceptable, and tell other subsystems to activate in response.

Contribution: When the control system receives confirmation from the authentication interface it will unlock the box, and confirmation from the weight sensor will relock the box, turn on the heating, and send a new passcode. The power subsystem powers the microcontroller.

2.2.5 Subsystem 5: User interface (Program)

Functionality: The user interface receives the code from the box over wifi on a separate program on their computer, so the user can send the code to the driver with instructions of operation.

Contribution: The user interface receives a confirmation of the delivery from the box as well as new code generated by the microcontroller for the next delivery in the future.

2.2.6 Subsystem 6: Heating

Functionality: The heating subsystem will keep the food warm when placed in the box. A nichrome heating coil placed under a false bottom will warm up the floor increasing the temperature inside the box.

Contribution: When the weight sensor is triggered, it will send a signal to the control system to turn on the power to the heating coils. Once the weight sensor feels the weight leave, it will turn off the heating.

2.3 Subsystem Requirements:

2.3.1 Subsystem 1: Authentication interface (keypad and fingerprint)

- Keypad:
  - The keypad component of this subsystem must take 3.3 volts from the voltage regulator in the power subsystem to operate.
  - The keypad portion of this subsystem must be able to read the inputted 4 digit keycode successfully and send this 4 digit code to the control unit to initiate unlocking the box.
  - Successful reads are measured as being able to send the user inputted code to the control system 12 times out of 15.
- Fingerprint:
  - The fingerprint component of this subsystem must take 3.3 volts from the voltage regulator in the power subsystem to operate.
  - The fingerprint portion of this subsystem must be able to read the user's fingerprint successfully 12 out of 15 times and send this data to the control unit to initiate unlocking the box.
  - The fingerprint sensor should deny any false fingerprints that don't match the master 12 out of 15 times.

2.3.2 Subsystem 2: Power (battery and voltage regulator)

- AC to DC Converter:
    - An AC to DC converter will be plugged into a wall outlet. A wall outlet provides 120 volts AC and then this will then be converted into a 12 volts DC source for our pcb to use.
    - The AC to DC converter must successfully turn off power to the heating subsystem 100% of the time when not in use as leaving the heating system on can create large problems.
- Voltage regulator:
    - The voltage regulator will successfully separate and send the correct voltage for each component within 5%.
        - The voltage regulator will give 3.3 volts to the control system.
        - The voltage regulator will give 3.3 volts to the keypad portion of the authentication subsection.
        - The voltage regulator will give 3.3 volts to the fingerprint portion of the authentication subsection.
        - The voltage regulator will give 5 volts to the weight portion of the box mechanics subsection.
        - The voltage regulator will give 12 volts to the solenoid portion of the box mechanics subsection.

2.3.3 Subsystem 3: Box Mechanics (weight and Solenoid)

- Weight sensor:
    - The weight sensor component of this subsystem must take 5 volts from the voltage regulator in the power subsystem to operate.
    - The weight sensor portion of this subsystem must be able to successfully recognize when food is inside the box and send a signal to the control system that the box is in use to initiate locking the box and generating a new keycode.
    - Successfully detecting food inside the box is measured as being able to recognize an object of at least 50 grams has been placed inside the box 12 times out of 15.
- Solenoid:
    - The solenoid component of this subsystem must take 9 volts from the voltage regulator in the power subsystem to operate.
    - The solenoid component of this subsystem must successfully lock the box upon signal from the control subsystem.
    - Successfully locking is measured by the box being unable to be opened without successfully inputting authentication inputs and approximately 20 seconds after food has been placed inside the box.

- The solenoid motor will move a lock back and forth between locking and unlocking based on what should be done.

2.3.4 Subsystem 4: Control (microcontroller)

- Micro controller (ESP 32):
    - The microcontroller must take 3.3 volts from the voltage regulator in the power subsystem to operate.
    - The microcontroller must take inputs from the authentication subsystem and correctly verifying the inputs, then successfully initiate box unlocking when necessary.
    - Correctly recognizing verifying inputs is measured by the control system recognizing the correct keycode and or fingerprint at least 12 times out of 15.
    - Successfully initiating unlocking the box when necessary is measured by sending a signal to the box mechanics subsection to unlock the box upon successful authentication attempts.
    - The microcontroller must successfully take input signals from the weight sensor portion of the box mechanics subsystem to generate timely box locking and box heating signals. Once the box locking signal is generated, it is sent to the solenoid portion of the box mechanics subsystem to carry out locking the box, and once the heating signal is generated, it is sent to the heating subsystem to turn on heating inside the box.
    - Successfully taking inputs from the weight sensor is measured as getting a signal from the weight sensor whenever an object of at least weight 50 grams has been placed inside the box 12 times out of 15.
    - Timeliness of generating the signals is measured as sending the lock signal and heating signals to the designated subsystems within 20 seconds of receiving signals that the box is in use.
    - The microcontroller must timely and successfully generate a new 4 digit keycode within 5 minutes of the food being placed.
    - Successfully generating a new 4 digit keycode is measured as being able to generate only when it gets a signal that the box is in use.
    - The timeliness of the keycode generation is measured as being able to generate the keycode and send it in a notification to the user within 1 minute of an object being placed inside the box.
    - The microcontroller must successfully generate and send a on signal to the heating system.

2.3.5 Subsystem 5: User interface (keycode notification)

- Keycode notification:
  - The user interface subsystem must successfully receive the 4 digit code from the control subsystem.
  - Successfully receiving the 4 digit code from the control subsystem is measured as the user receiving a notification via email of the delivery arriving within 5 minutes 12 out of 15 times.

2.3.6 Subsystem 5: Heating (Nichrome)

- Nichrome:
  - The heating subsystem will take 12 volts of power from the power subsystem.
  - The heating subsystem must successfully regulate heating inside the box upon signal from the control subsystem.
  - Successfully heating is measured by the heating system inside the box being able to keep the temperature inside the box within the range of 25 degrees celsius to 40 degrees celsius upon signal that the box is in use and turning off heating when nothing is inside the box .

2.4 Tolerance Analysis:

One aspect of our design that can be suspect to variation is the fingerprinting sensor. The accuracy of many modern fingerprint sensors can be as high as 99% if in the correct conditions with a high enough quality sensor [5]. We aim to get at least an 80% accuracy with a lower quality sensor rate by reducing variability and using specific algorithms fine tuned to our prototype.

To measure accuracy, we need to calculate the False Acceptance Rate (FAR) and False Rejection Rate (FRR). The FAR is (# of incorrectly accepted unauthorized fingerprints/total number of unauthorized fingerprints)*100. FRR is (# of incorrectly rejected authorized fingerprints/total number of authorized fingerprints)*100. The Accuracy can be calculated by 1 - (FAR+FRR), assuring that both false negatives and positives are accounted for in measurements. On top of this, statistical variation analyses like a t-test or ANOVA can be used to determine the reliability over a much larger sample size than our tests.

To improve accuracy, we need to reduce environmental variability. Variables like dust, temperature, and humidity can make it difficult to get an accurate scan and increase the FAR and

FRR. To combat this, we will add a shield around the sensor to protect it from the elements and get more consistent results.

Finally, we can increase accuracy through our algorithm. One main variable we can control is the sampling rate. A higher rate of sampling will lead to more accuracy but after a certain point the increase in accuracy has diminishing returns while taking longer to compute. Thankfully the National Institute for Standards and Technology (NIST) has already done a test using 2484 fingerprints from 207 subjects at a variety of sampling rates[6]. They found that the output that corresponds to the center peak frequency decreases with a higher sampling rate exponentially, as seen below.

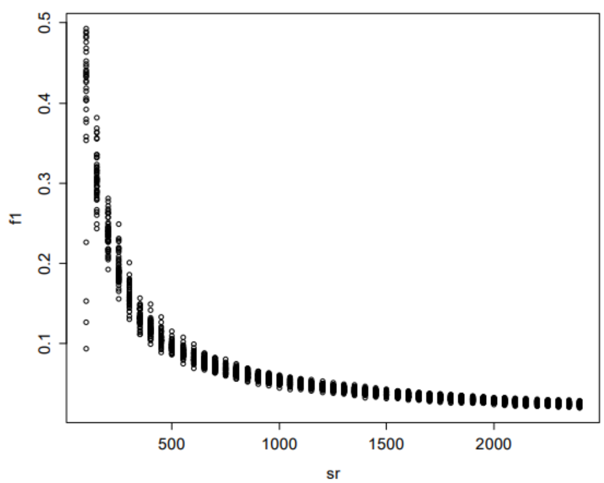

Figure 3: Peak Frequency of Strongest Peak as Detected by SIVV (fr) vs. Image Sample Rate (sr)

We can utilize these results to determine what our sampling rate should be for our fingerprint sensor.

3. Ethics and Safety

Use of Open Source Projects:

The work that we will be doing in this project will use open source projects as needed. It is important to make sure that the open source projects that we use get credit. This is in accordance with the ACM code of ethics 1.5[8]. It is important to recognize those who have helped us make this project by giving them credit.

Privacy:

Because our project requires us to use fingerprints we will not use the fingerprints that users store for anything other than opening the secure box. The fingerprints will be directly stored on the microcontroller and will not be sent anywhere else. This is in accordance with the ACM code of ethics 1.6[8]. It is to make sure that users know that their information is being stored securely.

Safety:

Voltage regulators will be used in this project to ensure that the voltage source and that the pcb do not overheat and /or short circuit. Using Lab safety equipment when appropriate also will be done to uphold maximum safety. The heating subsystem also must not overheat to dangerous levels above 80 degrees celsius. To make sure this does not happen we will perform calculations to make sure the voltage and current we are supplying the nichrome make it so it never reaches above 80 degrees celsius. Also rigorous safety testing of all parts of the project will be done before it is finished to ensure it works as intended. This is to ensure that IEEE I.1[9] is followed and that no one is harmed because of an error this project has made.

Unlawful/Unethical Conduct:

We will not perform any unlawful/unethical activities to create this project such as but not limited to using code/hardware that is not available to use and bribery. IEEE I.4[9] says that bribery and unlawful conduct should not be done to uphold high standards of integrity.

4. References

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[4]"Amazon.com: Basicvolt Universal AC/DC Adapter Multi-Voltage Regulated Switching Power Supply with 11 Selectable DC Plugs for 3V 4.5V 5V 6V 7.5V 9V 12V Household Electronics 2.0A 24Watt Max : Electronics," *Amazon.com*, 2025. https://www.amazon.com/Basicvolt-Universal-Bluetooth-Household-Electronics/dp/B09J4GBWF5?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=A1APYMMM12ELOR&gQT=1 (accessed Feb. 13, 2025).

[5]"Weight Sensor (Load Cell) 0-500g SKU 314990000." Accessed: Feb. 13, 2025. [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Seeed%20Technology/314990000_Web.pdf

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[8]Association for Computing Machinery, "ACM code of ethics and professional conduct," *Association for Computing Machinery*, 2018. https://www.acm.org/code-of-ethics

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