

Menstrual Product Bathroom Tracker

By

Sarah Lau (lau29)

Erin Rothenbaum (eroth8)

Anna Wilkowski (annaw7)

Project Proposal for ECE445, Senior Design, Spring 2026

TA: Eric Tang

18 September 2026

Project No. 3

Table of Contents

Table of Contents.....	2
1. Introduction.....	3
1.1 Problem.....	3
1.2 Solution.....	3
1.3 Visual Aid.....	4
1.4 High-Level Requirements.....	4
2. Design.....	5
2.1 Block Diagram.....	5
2.2 Subsystem Overview.....	5
2.2.1 Sensing Subsystem.....	5
2.2.2 MCU Subsystem.....	6
2.2.3 Power Subsystem.....	6
2.2.4 Backend Subsystem.....	6
2.2.5 User Subsystem.....	6
2.3 Subsystem Requirements.....	6
2.3.1 Sensing Subsystem.....	6
2.3.2 MCU Subsystem.....	7
2.3.3 Power Subsystem.....	7
2.3.4 Backend Subsystem.....	7
2.3.5 User Subsystem.....	7
2.4 Tolerance Analysis.....	7
3. Ethics, Safety, and Societal Impact.....	7
3.1 Ethics and Safety.....	7
3.1.1 IEEE Code of Ethics I.1: Safety, Health, and Welfare of the Public.....	7
3.1.2 IEEE Code of Ethics II.1: Fair Treatment of Individuals.....	8
3.2 Societal Impact and Accessibility.....	8
3.2.1 Overall Societal Impact.....	8
3.2.2 ADA Dispenser Compliance.....	8
References.....	9

1. Introduction

1.1 Problem

Finding menstrual products on a college campus can be unexpectedly difficult. At UIUC, some bathrooms may have menstrual products available while others may be empty or not stocked at all. When someone unexpectedly needs a product, they may have to check multiple bathrooms or ask staff where products are located. This can be inconvenient, time-consuming, and especially frustrating when they are in a hurry.

There is currently no centralized way for students to determine which campus bathrooms have menstrual products available and how much stock remains.

1.2 Solution

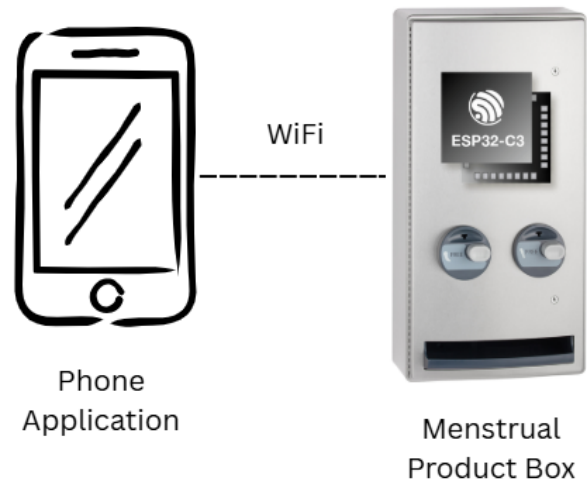
We propose an IoT-based system that monitors menstrual-product availability in bathrooms across UIUC and makes this information accessible through an app.

In boxes made specifically for the project, time-of-flight sensors would be installed on the inside of the lid; these sensors would bounce an IR light signal off the top of the period product stack, and use the time it takes for the signal to return to calculate the distance to the top of the stack from the lid. We can use the inverse of that, i.e. the distance from the top of stack to the bottom of the box (total height - distance from top of stack to lid), to measure the total height of the stack and divide by the individual height of a pad container, confirming the amount of products available. This sensor would periodically transmit its measurements to a centralized server.

The mobile application would aggregate this information and display nearby bathrooms along with their estimated product availability. Users could quickly identify the closest bathroom with products rather than searching multiple locations.

The system could also provide useful information to campus facilities staff. When a bathroom's supply falls below a predefined threshold, the system could automatically flag the location for restocking.

1.3 Visual Aid

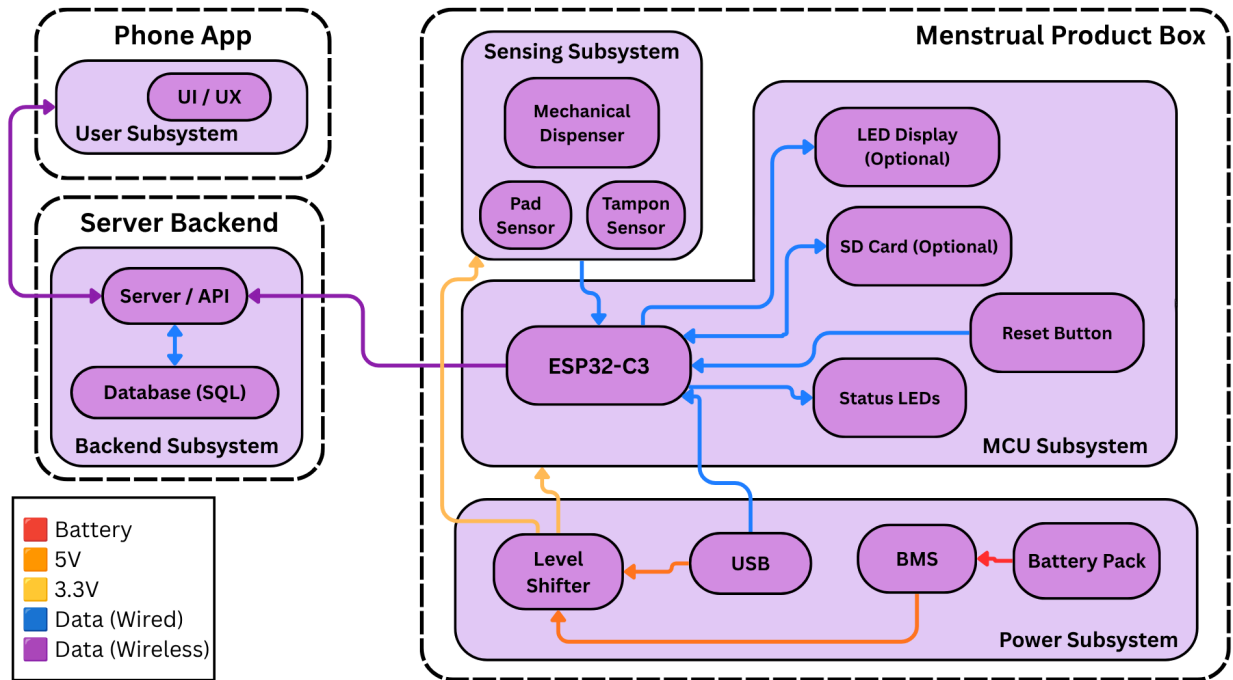


1.4 High-Level Requirements

- The final product must display the number of products on the application within 90% accuracy.
- The final product must update inventory data on the phone application within 10 seconds of restock or dispensing.
- The mobile application must determine the user's location within 20-30 m and display the nearest available dispenser.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Sensing Subsystem

The sensing subsystem is used to find the height of the stack of menstrual products so that the device can count the number of menstrual pads and tampons. Two separate time-of-flight (ToF) sensors will be attached to the lid of the dispenser, one per stack of menstrual products. The mechanical dispenser is similar to the typical menstrual product dispensers used in university bathrooms. The pads and tampons will be stacked one on top of the other, as per a typical dispenser, to obtain the correct distance from the lid. The products will be able to dispense simply with a click of a button.

2.2.2 MCU Subsystem

The MCU subsystem is used to process the data from the sensing subsystem to be sent to the backend subsystem. Using an ESP32-C3, data will be sent to the server over WiFi. Any GPIOs, such as the status LEDs and the reset button, will be managed by the microcontroller. The data from the ToF sensors is sent over I2C to the MCU.

Optionally, the MCU will be connected to an LED display to indicate the number of available products in the bathroom. An SD card may be utilized for additional memory to store average user data.

2.2.3 Power Subsystem

The power subsystem is used to provide power to the necessary components of other subsystems. A battery pack and BMS is used to provide 5V to the board. The level shifter converts 5V to 3.3V. The USB connector will be used to provide power and update the microcontroller firmware.

2.2.4 Backend Subsystem

The backend subsystem will provide communication between the ESP32-C3 dispenser units and the mobile application. A REST API will be implemented using Python and FastAPI to receive inventory measurements from each dispenser and provide current inventory information to the mobile application. A PostgreSQL database will store dispenser locations, product counts, and timestamps of the most recent measurements.

2.2.5 User Subsystem

The user system consists of the mobile phone app designed in React which displays to the user the number of products available in the dispenser remotely. The app organizes the data for ease of use. The GPS data of the user's phone will be used to determine the nearest dispenser.

2.3 Subsystem Requirements

2.3.1 Sensing Subsystem

- Each time-of-flight sensor must measure a distance of at most 2ft (60.96 cm) with at least 95% accuracy.
- Each time-of-flight sensor must update distance within 200ms of restocking or dispensing.
- The box must dispense one menstrual product when the corresponding mechanical button is pressed.

2.3.2 MCU Subsystem

- Must process time-of-flight sensor data within 5 seconds.
- Must maintain Wi-Fi connection with the server continuously.

2.3.3 Power Subsystem

- Must provide 5V and 3.3V +/- 0.2V to the system.
- Must supply at least 500 mA continuously.

2.3.4 Backend Subsystem

- Must store the most recent inventory measurement for each dispenser.
- Must update inventory data in the database within 3 seconds of receiving a measurement over Wi-Fi from the dispenser.
- Must provide dispenser inventory data to the mobile application through REST API.
- Must associate each dispenser with its corresponding bathroom location.

2.3.5 User Subsystem

- Must receive updates from the backend subsystem over Wi-Fi continuously.
- Must accurately display data retrieved from the backend subsystem.
- Must be easy to navigate such that desired data is displayed within the home screen.

2.4 Tolerance Analysis

6.3 Ranging accuracy

6.3.1 Standard deviation

The ranging accuracy can be characterized by the standard deviation. It includes measure-to-measure and part-to-part (silicon) dispersion.

Table 13. Ranging accuracy

Target reflectance level, full FoV	Indoor (no infrared)			Outdoor		
	Distance	33 ms	66 ms	Distance	33 ms	66 ms
White target (88%)	At 120 cm	4%	3%	At 60 cm	7%	6%
Gray target (17%)	At 70 cm	7%	6%	At 40 cm	12%	9%

Measurement conditions

- Target reflectance used: Gray (17%), White (88%)
- Offset correction done at 10 cm from sensor
- Indoor: No infrared
- Outdoor: 5 klx equivalent sunlight (10 kcps/SPAD)
- Nominal voltage (2.8 V) and temperature (23°C)
- All distances are for a complete FoV covered (FoV = 25°)
- Detection rate is considered at 94% minimum

6 Performance

6.1 Measurement conditions

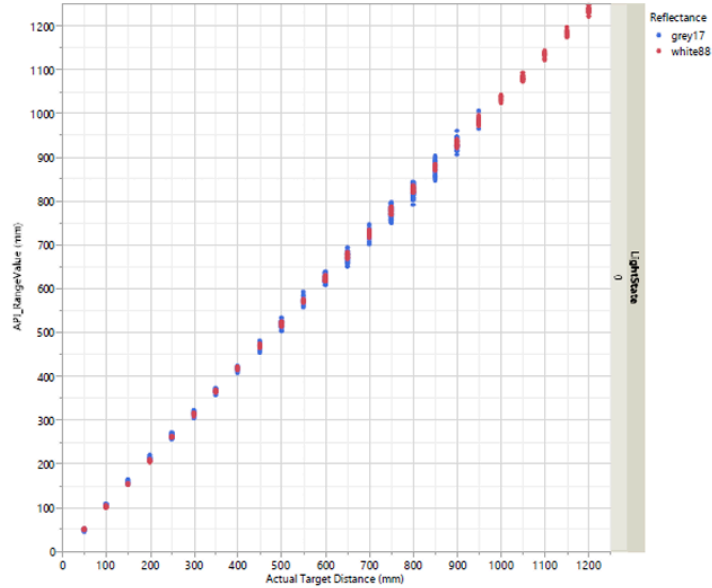
In all the measurement tables of this document, it is considered that the full FoV is covered.

The VL53L0X system FoV is 25°.

Reflectance targets are standard ones (gray 17% N4.74 and White 88% N9.5 Munsell charts).

Unless mentioned, the device is controlled through the API using the default settings. Refer to the VL53L0X API user manual (UM2039) for API setting descriptions.

Figure 20. Typical ranging (default mode)



Ranging Accuracy: Table 13 of the ToF datasheet [1] gives an accuracy rating for white and gray targets. Assuming a distance of 70cm, a gray target (which has a reflectance level of 17%) will have a guaranteed minimum accuracy of about 7% with a 33ms timing budget. If we assume that this accuracy holds at shorter distances (i.e. the noise grows with distance, so that the noisiest signal is when the sensor is looking into an empty container), then it is possible that at a height of 30 cm that one reading could have a higher percentage of error.

Error_noise = (0.07 * 30cm) = 21mm which is a height of about 2mm; realistically, this could cause the sensor to detect +/- 1 layer of period products in the box.

Given that the ToF sensor takes N readings, however, this accuracy decreases:

$$N = 36: \sigma_{noise} \approx (0.07 * 300mm) / \sqrt{36} = 3.5mm$$

$$N = 64: \sigma_{noise} \approx (0.07 * 300mm) / \sqrt{64} = 2.6mm$$

$$N = 144: \sigma_{noise} \approx (0.07 * 300mm) / \sqrt{144} = 1.75mm$$

Error in scaling: There is a 10cm offset calibration mentioned in the datasheet in tandem with a 3% distance-dependent error. So, for a full stack height where the distance from the ToF sensor is 100mm:

$$\epsilon_{error} = 0.03 * 100mm + 10cm = 13mm$$

So an error distance of about +- 13mm.

3. Ethics, Safety, and Societal Impact

3.1 Ethics and Safety

3.1.1 IEEE Code of Ethics I.1: Safety, Health, and Welfare of the Public

In our project, it is paramount that the health and safety of our user base is prioritized [1]. This is a project that is specifically targeted towards individuals in need of health resources. Since this is a product that would be utilized in a public restroom, it is important that user data is kept private and that no individuals are harmed due to the use of our project. All information specific to a user, such as GPS information, will be properly disclosed and optional. No unnecessary or unauthorized information about our user base will be utilized for our design.

For safety, the battery management system is used to monitor the battery such that there is no risk of endangering the health of the user. All important hardware will be encased by the dispenser to prevent tampering and/or damage.

3.1.2 IEEE Code of Ethics II: Fair Treatment of Individuals

The menstrual product bathroom tracker is created to improve access to menstrual products, thus it is paramount that no individuals are discriminated against and are treated fairly when utilizing our project. We do not tolerate using the tracker for the harassment of others.

3.2 Societal Impact and Accessibility

3.2.1 Overall Societal Impact

The menstrual product bathroom tracker is meant to improve the quality of life of its user base by providing an efficient way to locate available menstrual products. The current dispensers at the university are useful since they are free to use and disability

friendly. The project is meant to improve on what is already offered by increasing accessibility and ensuring that menstrual products are available at all times.

3.2.2 ADA Dispenser Compliance

Ideally, our dispenser would be ADA compliant such that it is accessible to all individuals in need of access. All menstrual product dispensers located at the university are already ADA compliant, so it is integral that our product is put to the same standards.

According to 205 and 309 (Operable Parts) [2], a dispenser should be operable with one hand and not require tight grasping, pinching, or twisting of the wrist. The location of the dispenser must also comply with 308.2.1 (Unobstructed Forward Reach) such that the highest accessible reach is 48" maximum from the ground and the lowest accessible reach is 15" minimum from the ground.

References

- [1] "VL53L0CXV9DH/1 Datasheet," ST Microelectronics, 2018. Accessed: Sep. 18, 2026. [Online]. Available: <https://www.st.com/resource/en/datasheet/vl53l0x.pdf>

- [2] IEEE, "IEEE Code of Ethics | IEEE," [ieee.org](https://www.ieee.org). Accessed: Sep. 18, 2026. [Online]. Available: <https://www.ieee.org/about/corporate/governance/p7-8>

- [3] "U.S. Access Board - Chapter 6: Toilet Rooms," [Access-board.gov](https://www.access-board.gov). Accessed: Sep. 18, 2026. [Online]. Available: <https://www.access-board.gov/ada/guides/chapter-6-toilet-rooms>