SECUFOAM

MAE 4151: Final Presentation

Anton Yanovich, Oscar Southwell, Moustafa Montaser,
Yahya Aliyu, and Huzeyfa Telha

(12/12/22)

Functional Requirements – Sanitizing Station

Functional Requirement	Engineering Characteristic	Units	Direction of Improvement	Target Value
The device is sturdy and structurally sound	The device enclosure should be able to support a necessary load	kg	up	1 kg
The device can fit 4 c-type battery	Battery compartment should have appropriate dimension	in	up	1x1x2 in
The device is compatible with a 1000mL sanitizer bottle	Storage compartment should have appropriate dimensions	in	up	6x6x10 in
Stores discrete values for temperature & records time stamp	Average space taken by individual data points in array cumulatively	Kilobytes (KB)	up	200 KB
Transmits sensor inputs to server over wireless modality	Frequency of Wi-Fi/Bluetooth Radio Band	Hertz (GHz)	up	2.4 GHz
Functions with ≤ 6 V power, for duration of 3 weeks.	Average battery consumption rate	Voltage (V)	down	5 V
Hand sensing is reliable	Percentage of successful object sensing trials Sensing response delay time	Percentage (%) Milliseconds (ms)	up down	99.9% (≤1 failure per 1,000 tests) <200ms
User Temperature is accurately recorded for each activation	Average accuracy of station temperature measurement	Range of Degrees Celsius (°C)	down	± 0.2 °C

Functional Requirements – Sanitizing Station

Functional Requirement	Engineering Characteristic	Units	Direction of Improvement	Target Value
Reliable Pump Dispensing mechanism	Percentage of successful tests of dispensing pump mechanism upon signal activation (from 1000 mL container, 1333 test runs)	Percentage (%)	up	≥99%
Rapid sanitizer fluid dispensing	Time for 0.75 mL of sanitizer fluid to be dispensed by pump	Seconds (s)	down	≤1.5s
Consistent volume of fluid dispensed	Standard Deviation of average volume of sanitizer fluid dispensed by pump	Milliliters (mL)	down	≤0.05 mL
Reliable foaming of sanitize fluid	percentage of sanitizer fluid volume dispensed by pump converted into foam by nozzle	Percentage (%)	up	≥99%

Overview of Preliminary Design Accomplishments

- Phase 1: Alpha prototype – Completed. Undergoing Testing with respect to functional requirements.
    - Arduino, temperature sensor, (WIP) IR sensor circuitry completed
    - Application layer in progress, near completion.
- Phase 2: Minimum Viable Product. - In progress.
    - CAD remodeling of station interior/exterior housing.
    - Optimization of circuitry.
    - Integration of stations with WIFI module and LoRa-WAN, data upload to application layer
    - Data collection within public setting.

Work on Alpha Prototype: Overview of Motion/Temp Subsystem

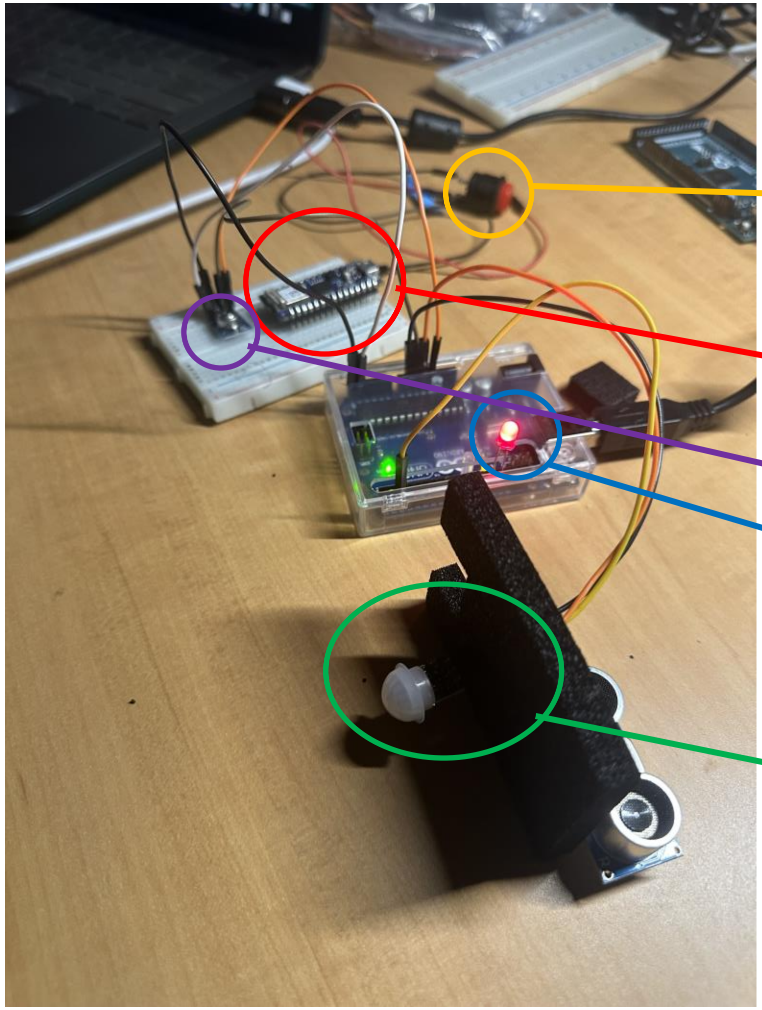


Fig 1. *Integrated system with IR Temp. Sensor, PIR, and WiFi module*

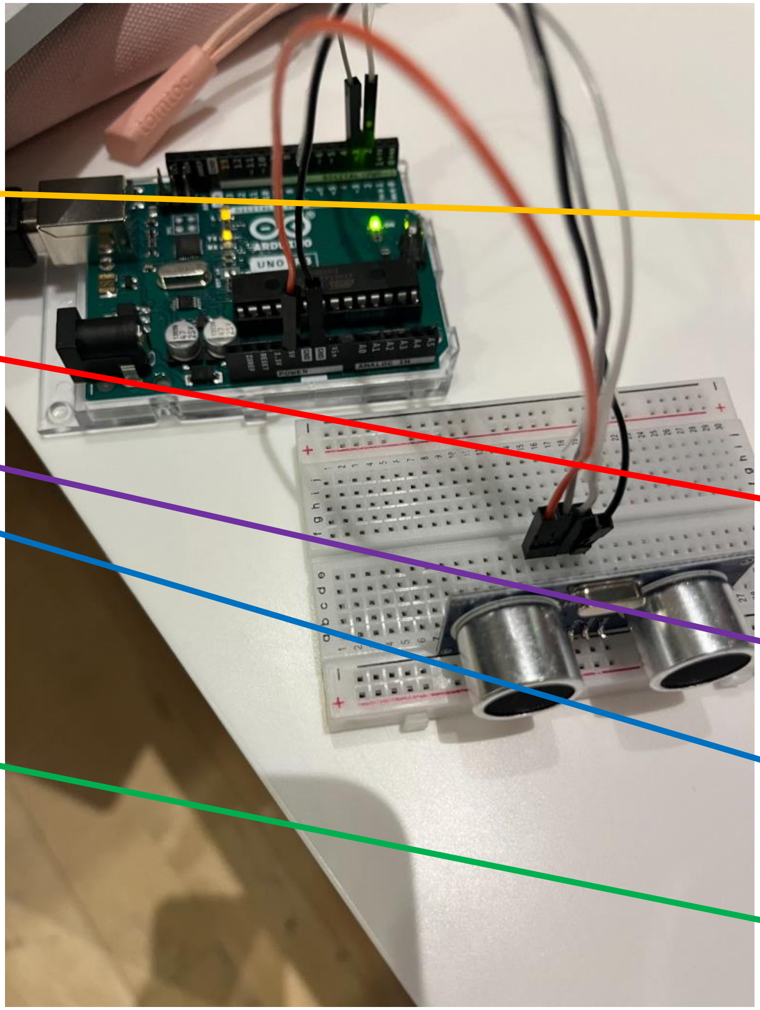


Fig 2. Ultrasonic motion sensing *testing*

Switch controlling temp. Subsystem/WiFi Module

WiFi/Bluetooth Module

Contactless IR Sensor (Ambient + Object)

LED Indicating motion detection

Passive IR Sensor

Alpha Prototype: Discrete Transmittable Outputs

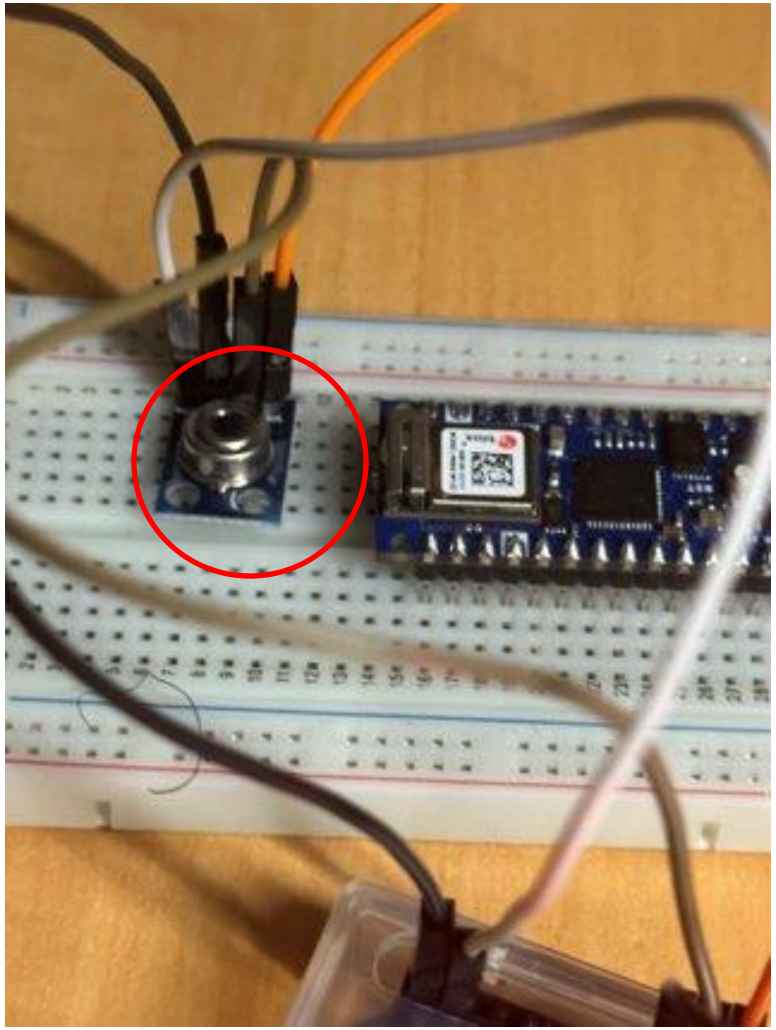


Fig 3. IR Temperature sensing module

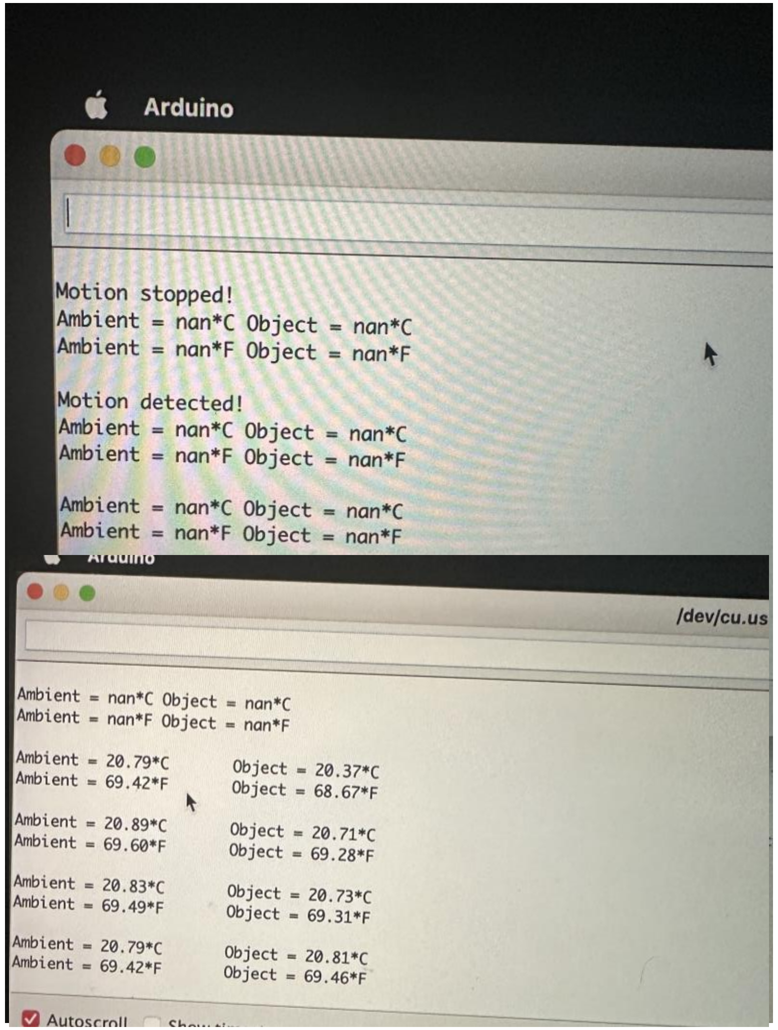


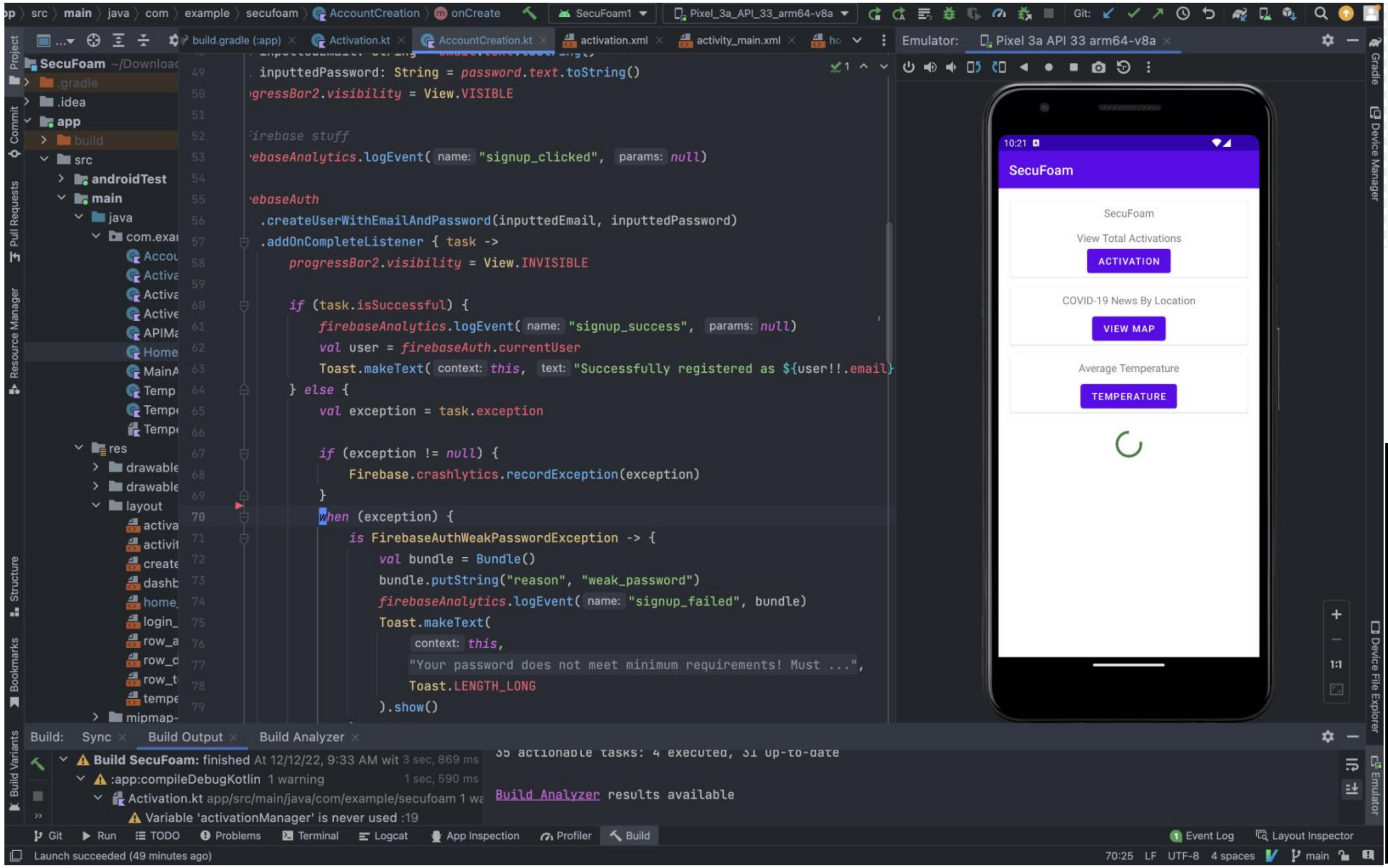
Fig 4. Serial monitor output of temperature and motion detection*

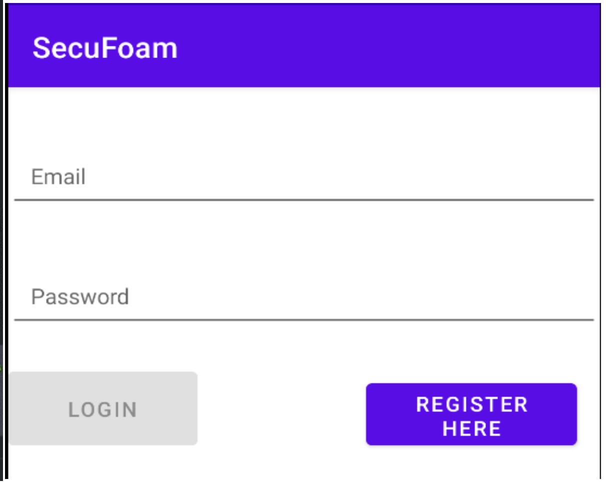
- Successfully acquires ambient and individual temperatures
- PIR Successfully detect individual motion within 10m (range optimization to be explored)

Current Direction

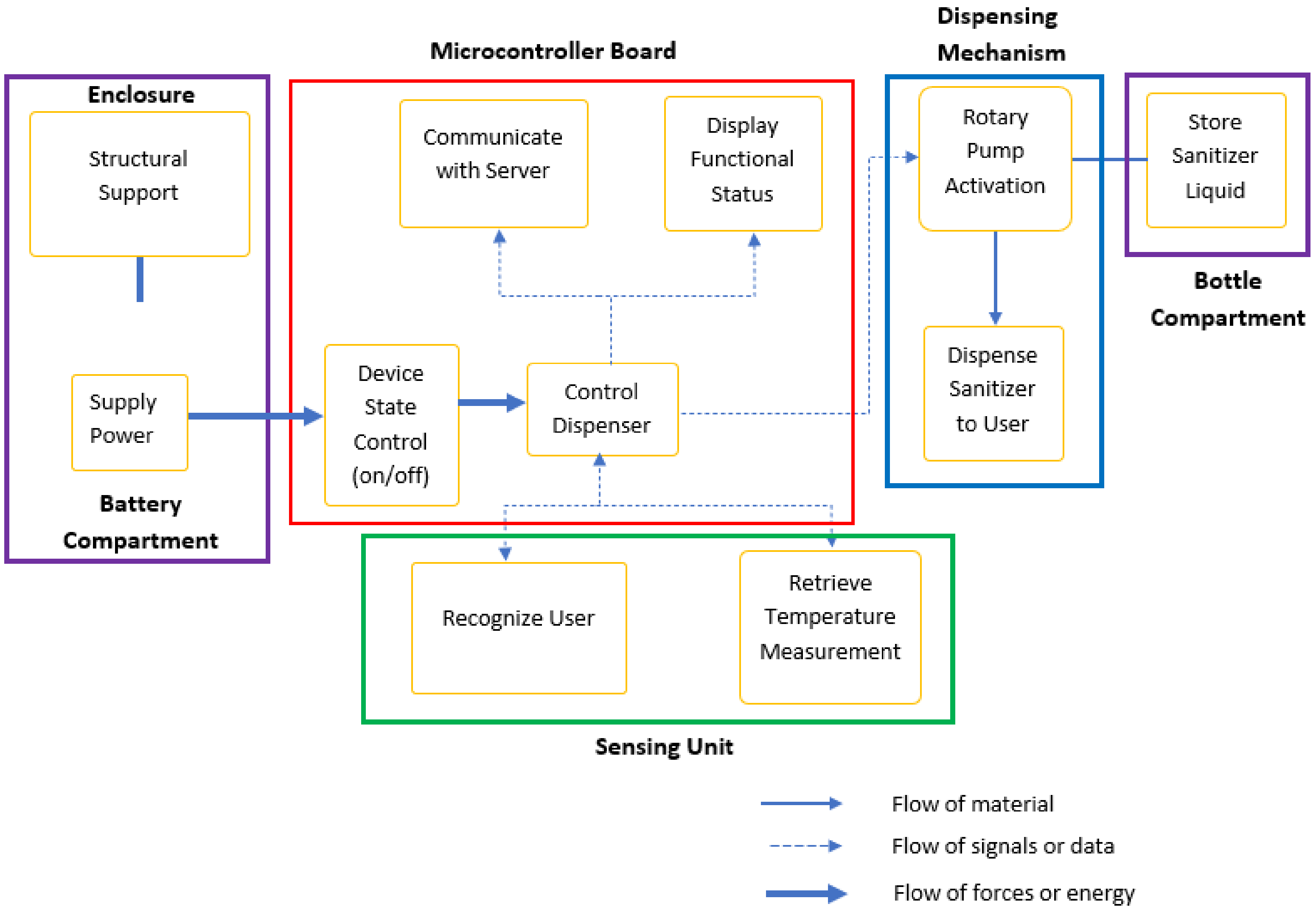
- Optimizing PIR range and compare sensitivity and specificity with ultrasonic motion
- Correlating extremity temperature with normal body temperature to create adjustment/normalizing factor
- Integrating WiFi module with FireBase Cloud Network
- Linking circuit with indigenous power supply

Alpha Prototype: Work on Application Layer





System Architecture (Device)



System Architecture (Application)

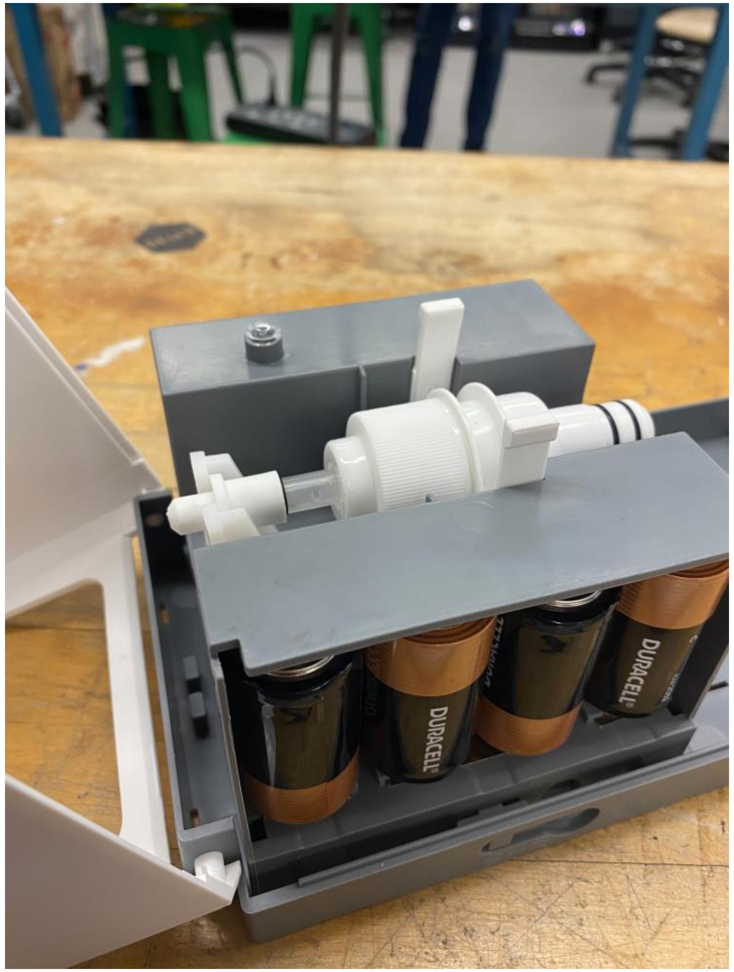
Key:

Flow of signals or data

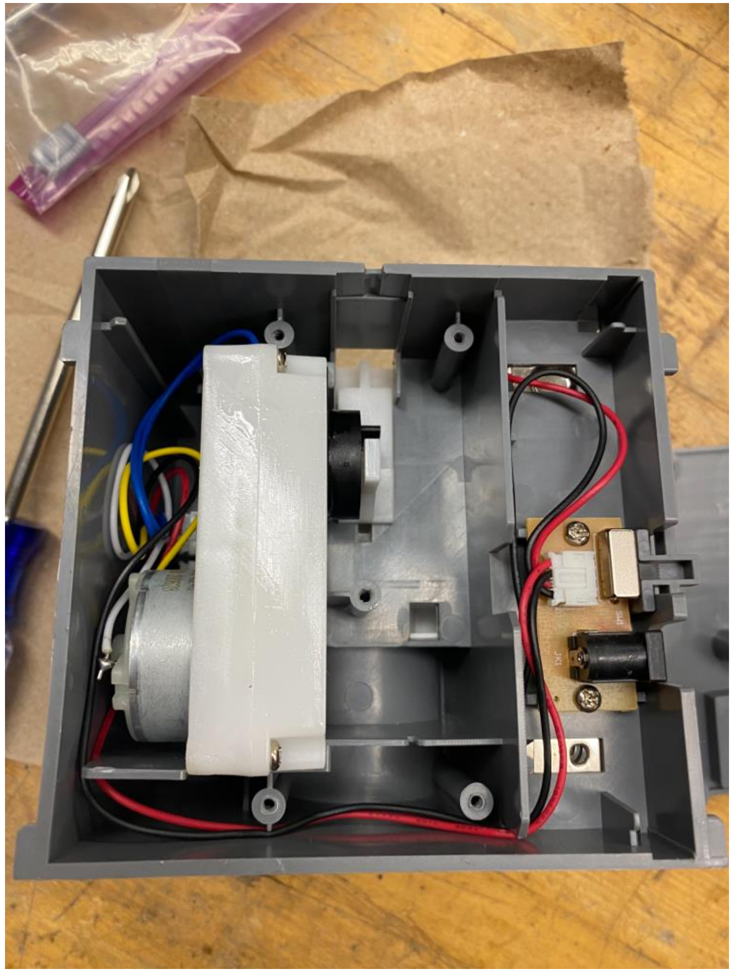
Dispensing Unit: Sanitizer Pump and Nozzle

Oscar Southwell

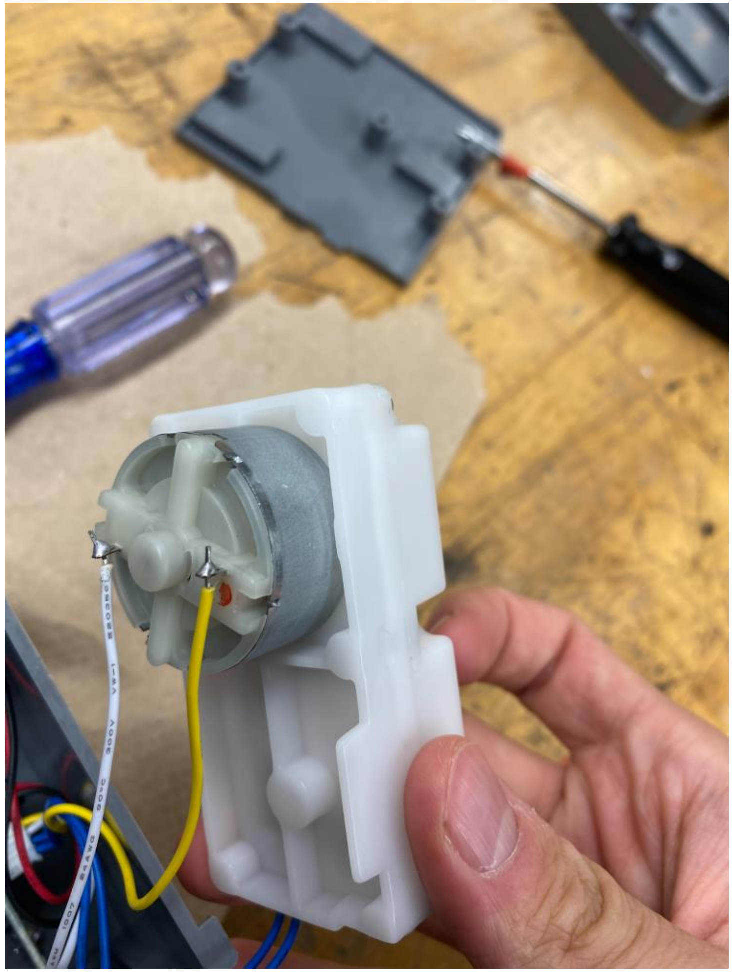
Functional Requirements	Design Parameters*	Analysis	References	Risk	Counter-measures
Reliable Pump Dispensing mechanism (sanitizer fluid dispensed by pump with ≥99% consistency) **Rapid sanitizer fluid dispensing** (0.75 mL of sanitizer fluid fully dispensed by pump within 1.5 seconds of motion activation) **Consistent volume of fluid dispensed** Standard Deviation of average volume of sanitizer fluid dispensed by pump less than 0.05 mL **Reliable foaming of sanitizer fluid**	**Rotary Drive Pump** (dispenses sanitizer fluid, powered by 4C batteries. Internal pressure gradient configured to dispense 0.75 mL of fluid within 1.5 seconds of signal activation) **Mesh foaming nozzle attachment** (converts sanitizer fluid into foam as it passes through)	**Prototype testing of pump mechanism** - successful dispensing of at least one full 1000 mL container of sanitizer fluid, or 1333 dispenses. Testing results recorded in excel spreadsheet. Weight of fluid before and after test compared to determine overall system accuracy; individual dispensing tests recorded to determine individual use accuracy.	(https://www.kutol.com/articles/how-much-hand-sanitizer-do-you-need/) (https://www.medicaldesignbriefs.com/component/content/article/mdb/pub/features/technology-leaders/27842)	**Low:** Sanitizer pump can clog when dry fluid builds up. Very low probability of occurrence (only a few reported instances, none at GW by housekeeping staff or station users) **Medium:** Sanitizer fluid can leak from joint between foaming nozzle and sanitizer pump tube.	**Dispensing angle:** Risk of dry fluid buildup is almost entirely mitigated by vertical dispensing angle (nozzle aimed downwards) **Specialized Foaming pump:** Sanitizer pump with built in foaming nozzle ordered for alpha prototype, mitigates any risk proposed by attachment to existing sanitizer pump



Sanitizer Station Pump – Exterior Casing Removed



Internal wiring within Interior casing



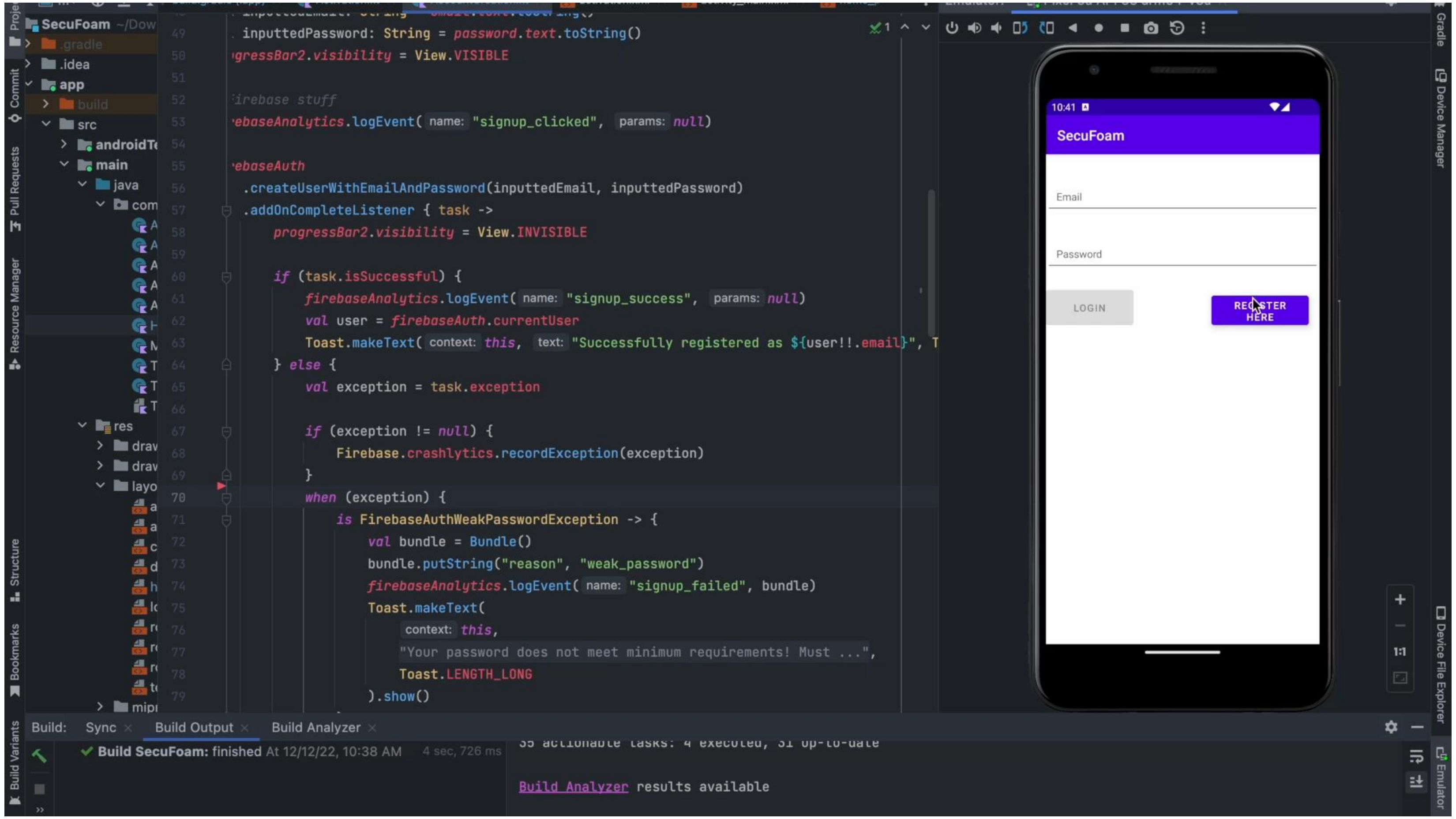
Motor for Sanitizer Dispensing Pump Mechanism (removed from internal casing)

Application

Huzeyfa Telha, Yahya Aliyu, Anton Yanovich

Functional Requirements	Design Parameters*	References	Risk	Counter-measures
Predictive Analysis: Predict when each sanitizing station will be empty by measuring past history. **Display Average temperature**: Display the average temperature sensor data	Real-Time Monitoring of refill levels, battery statuses, and expiration information with alerts Usage and trend data improve workflows and increased inventory and order accuracy.	**API** https://rapidapi.com/apininjas/api/weather-by-api-ninjas/ https://rapidapi.com/apidojo/api/similar-web https://developers.google.com/maps	**High:** Potential Risk of Security vulnerabilities. **Medium:** Unreliable Data Storage. **Low:** Poor UI/UX Design.	**Words** Use secure pre-built-in packages to protect against vulnerabilities. Use encryption for sensitive user data.

Analysis and Design Accomplishments for Subsystems 2 Application Layer



Sensing Unit: Motion and Temperature Sensors

Anton Yanovich & Yahya Aliyu

Functional Requirements	Design Parameters	Analysis	References	Risk	Counter-measures
Reliable user hand sensing (>99% reliability and 0.2 second response delay time) **Accurate user temperature measurement** (±0.2 °C)	**Ultrasonic sensor** to detect hand motion **Infrared sensor** to measure temperature	**Response time** model estimates a response under 1ms **Thermopile** provides the necessary accuracy if temperature within 32-42°C	(*IRJET- Automatic Sanitizer Sprayer with Liquid Level Indicator and Counter*, 2021) (*Make a Non-Contact Infrared Thermometer with MLX90614 IR Temperature Sensor*, 2021)	**Low:** The sensor are cheap and may fail after a period due to frequent use	The application layer will provide tracking of each station and will flag device function failures

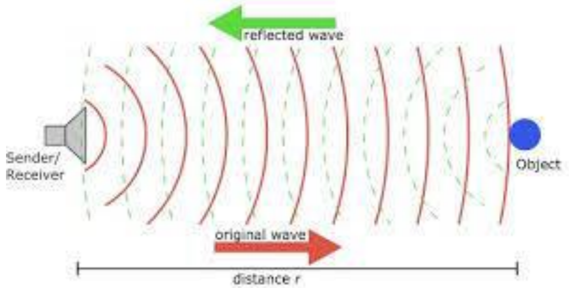
Sensing unit: Analysis

Ultrasonic Sensor:

Response Time Equation: $T = \frac{2D}{C}$

- D: distance
- C: speed of sound ~ *343 m/s*
- T: time

Ex: *5 cm* object distance = <*1 ms* response time (2*00ms* target)



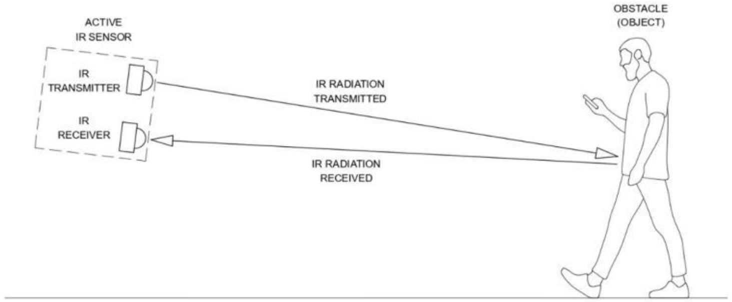
Source: TutorialsPoint, 2022

Infrared Sensor:

Radiation Flux Equation:

$$q = \varepsilon_1.\alpha_1.\left(T_1^{\,4}\right)\sigma.A_1.F_{a-b} - \varepsilon_2.\left(T_2^{\,4}\right)\sigma.A_2$$

- ε1 & ε2: emissivity of sensor and object
- α1: absorptivity of the sensor
- σ: Stefan-Boltzmann constant
- Fa-b: sensor shape factor
- T1 & T2: temperatures of sensor and object



Thermopile Output Equation:

$$V_{ir}(T_a, T_0) = A(T_0^{\,4} - T_a^{\,4})$$

- To & Ta: temperatures of object and sensor
- A: overall sensitivity

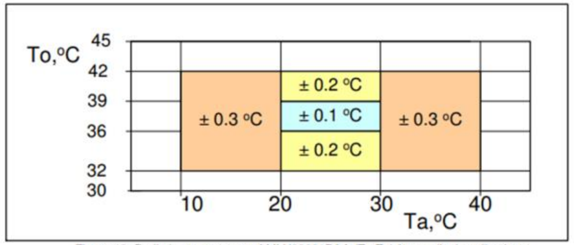


Figure 18: Preliminary accuracy of MLX90601BAA (Ta,To) for medical applications.

Source: MLX90614 Spec Sheet

Enclosure, Battery Compartment, Bottle Compartment
Moustafa Montaser

Functional Requirements	Design Parameters*	Analysis	References	Risk	Counter-measures
The device is sturdy and structurally sound	An existing enclosure design will be selected.	The proposed design is able to support device features requirements and necessary load rating	https://www.treetopproducts.com/touch-free-automatic-hand-sanitizer-dispenser-with-floor-stand?sku=4ZB4243&st-t=ttgoogshop&gclid=Cj0KCQiAyMKbBhD1ARIsANs7rEGX7q1tzlqmAaL-6jWii6XxJw-MUhUkqg-C6Io28qEwnlH_DlBfYWQaAiDGEALw_wcB	The selected enclosure might require modifications to fit each system requirement	Enclosure will be modified by integration of 3D printed custom parts as needed
The device can fit four c-type batteries	An appropriate battery compartment will be designed and 3D printed	Compartment dimensions will be 1x1x2 in	https://en.wikipedia.org/wiki/C_battery	Battery needs to change from time to time	The application will track power status and create an alert in the system
The device is compatible with a 1000mL sanitizer bottle	An existing enclosure design will be selected to match this requirement	Compartment dimensions will be 6x6x10 in	https://www.treetopproducts.com/touch-free-automatic-hand-sanitizer-dispenser-with-floor-stand?sku=4ZB4243&st-t=ttgoogshop&gclid=Cj0KCQiAyMKbBhD1ARIsANs7rEGX7q1tzlqmAaL-6jWii6XxJw-MUhUkqg-C6Io28qEwnlH_DlBfYWQaAiDGEALw_wcB	The compartment might require modifications to account for additional system requirements	The compartment will be modified by integration of 3D printed custom parts as needed

Existing Sanitizer Station
fluid storage unit

Researched bag sanitizer
fluid storage unit

Issues or Concerns for Success

- Although internal circuitry completed, considerable optimization for MVP required

- Station fluid level tracking functionality in place, but battery level tracking still work in progress

- Uncertainty of design quality under real-world working conditions, considerable testing required.

Thanks for watching!