Senior Design Project Final Report for Year 2023

Forget Me Not

Byron Griggs, Computer Engineering/Embedded Systems Design

Faculty advisor: Dr. Venki

1. Introduction

Describe the background and motivation of your topic/project.

I tried to come up with inspiration for this project by thinking about problems in my day to day life and how they could be solved. Because I lose things constantly, I decided to design something that would help people like me find lost items, and avoid losing them in the first place.

A more helpful description of the problem that this design addresses is the following: Many people struggle with losing personal items, such as their wallet or keys. Losing these items, even for a few minutes, can have consequences both large and small, and can cost people time, money and opportunities. This design seeks to, above all, reduce the frequency at which the user loses personal items, and the amount of time it takes to find those items.

Illustrate the existing product(s) in the market, and compare the advantages and disadvantages.

The most popular personal device tracking product on the market is Tile. Tile uses a combination of bluetooth and gps to track devices on the user's phone. However, as the trackers themselves do not have gps capability, it's unclear what benefit gps provides to this product.[4]

- Advantages
    - Thin tracker, about the size of a double-thick credit card[5]
    - Extremely long battery life (3 years) [6]
    - Can track your phone [6]
- Disadvantages
    - Does not warn you when leaving without item[6]
    - Does not tell you where the item is located[6]
        - Beeps item
        - Graphically shows RSSI
        - Does not show direction

Another product that I didn't know about until the judges mentioned it is AirTag.

- Advantages
    - Even smaller, a bit larger than a quarter[3]
    - Very long battery life (1 year)[3]
    - Can find a device at long ranges, provided it's within Bluetooth range of an apple device[1]
    - Tells you when the tracker has gone out of range[7]
    - Can locate your phone[3]
- Disadvantages
    - Does not warn you immediately upon opening the door without the item on you[2]
    - Does not work at long ranges without apple products nearby[1][3]
    - Uses other people's devices to find your tags without their consent[1][3]
        - I just found out about this today, and I'm fine with it, but I'm sure a lot of other people are not.
        - If you're wondering how this is legal, I'm sure it's in one of those long terms and conditions that people never read

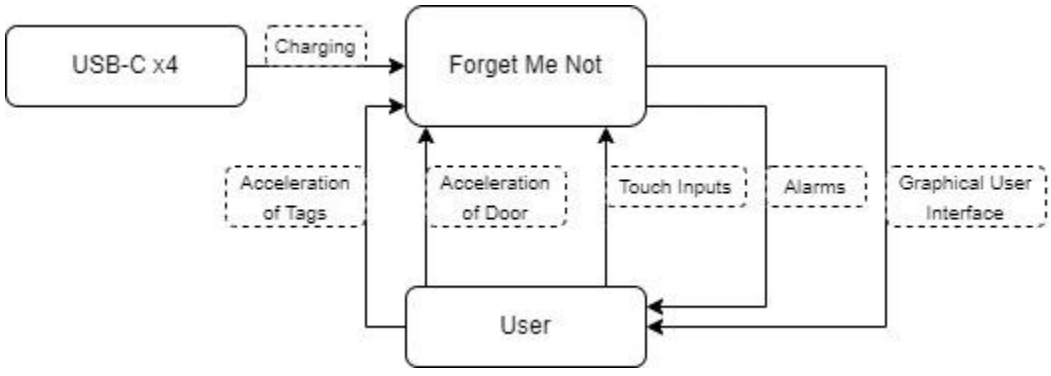
You may include the information you provided in the proposal, but with an updated edition.

Citations are required, in IEEE format. Include all references in the end of the report. Same as the rest of the report.

2. Proposed Solution and Accomplished Design

System modeling and analysis

Updated/Final system diagram



Explain the key principle(s), algorithm(s) and/or modeling of your system.

- Principles
    - The design consists of a central brain and a number of tags (0-3). The brain tracks the tags and commands/communicates with them. The user would tape or otherwise attach the tags to their personal items and carry them around.
    - The design assumes that if a tag is moving, it is on the user's person. This is usually true, and is almost always true when more than 1 tag is moving.
    - The brain is attached to a door, usually the external door to the user's house, apartment, dorm, etc. When the user opens the door without all of the tags on their person, the brain will alert them by flashing and beeping.
- Algorithms
    - After the initial setup, there is a loop that serves as a hub from which any of the 5 major functions can be reached. These functions have their own sub-loops for menuing, submenuing, etc.
    - When user input is needed, the program updates the system, delays, and checks input repeatedly until input is received. A similar algorithm is used when waiting for the user to let go of a button before moving on.
    - When it comes time to poll the IMU data, the brain asks each tag if it has moved in the last 10 seconds. It takes note of how many, but not which, tags say yes. It then polls it's own IMU data and does a simple(it's not simple) logic statement.
        - Vibration resistance: I didn't want the brain to freak out from people walking down the hallway, so I put some rudimentary vibration resistance in. It's not consistent, but when it works, it works surprisingly well. It's a bit complicated but the simple version is that the brain samples its IMU 10 times per second, and if any sample is in the opposite direction of the last sample the brain ignores it.
    - Clock Algorithm
        - Before I realized I could just use the onboard clock, I spent hours making my own clock through software. Oops. It takes up a lot of memory, and I'm sure it wastes a few clock cycles, but the end impact on the design is negligible.
        - This algorithm simply consists of a timer interrupt modifying a set of global time values (hours, minutes, seconds, with tens and ones places for each, as time is not base 100).

Function breakdown and descriptions

Fully describe the functionalities of your project and what you have accomplished at the end of senior design. List all the functions.

These functions are listed in the order that a user would commonly use them in upon starting up the device. All functions use a GUI unless otherwise specified.

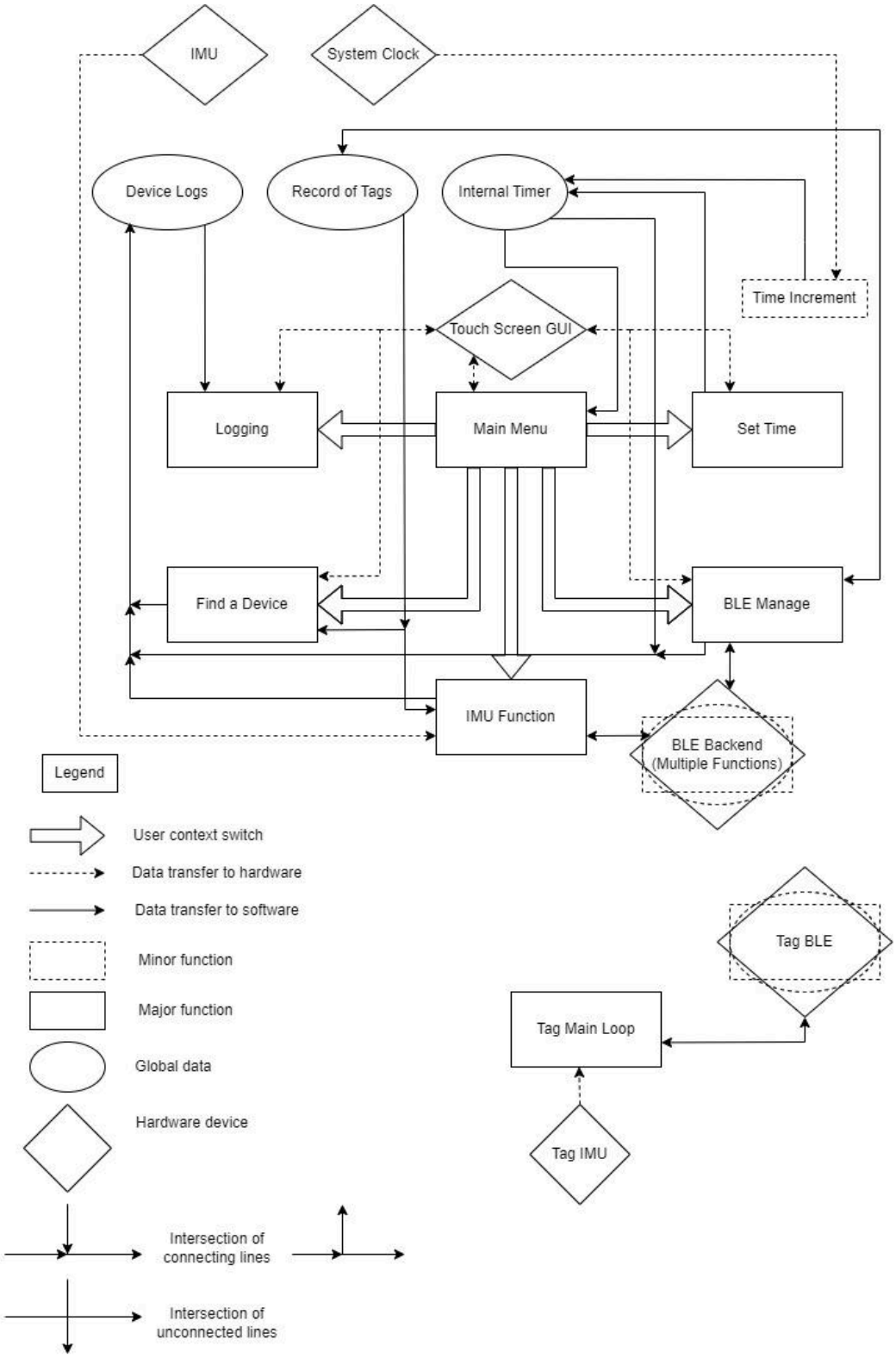
- Set Time
    - The time function doesn't do much on it's own– it's not even directly visible to the user– but it is used by the other functions and should be set first.
    - Time can be set in hours, minutes, and seconds.
- BLE Manage Function
    - This function opens up a new menu with 2 options: 'View Connected Tags' and 'Connect Tag'. There's also a back button to go back to the main menu.
    - View Connected Tags shows all tags that have been connected, including name and MAC address.
    - Connect Tag scans BLE for 5 seconds, automatically connecting to any device with a name *starting* with 'Byron's Device'.
- Find Device Function
    - This is the common, often used function that other similar products have. You push a button on the brain and it causes a tag of your choice to beep and flash.
    - Contains a submenu for selecting different tags.
- IMU Function
    - This is the function that sets this design apart from most commercial products. When the user opens the door that the brain is attached to, and the tags registered on the brain are not on the user's person, the brain beeps and flashes for 20 seconds or until touched.
    - This function activates when the brain has been idle on the main menu for 10 seconds.
    - The X and Z accelerometer values are vector-added together and compared to a set value.
    - Vibration Resistance: When the brain would beep, it instead checks this awful logic expression:

      ```
      if ((abs(accX-xCalib)>=sqrt(0.0144-pow(accZ-zCalib,2.0)) and
      samesign(accX-xCalib, prevX-xCalib)) or
      (abs(accZ-zCalib)>=sqrt(0.0144-pow(accX-xCalib,2.0)) and
      samesign(accZ-zCalib, prevZ-zCalib))){..... bool
      samesign(float a, float b){return (a>=0 and b>= 0) or (a<0 and
      b<0);}
      ```

      what this means is that if an accelerometer value in the x or z direction is significant enough to cause the IMU to beep, it must be the same sign as its value 0.1 seconds ago.

- Logging functions
    - All other functions, as well as automatic disconnect and reconnect events, are saved in the device logs. These logs can be accessed from the main menu, and include device name, MAC address, event type, and timestamp.
    - This is useful for security or debugging purposes

Full function breakdown diagram, and the data/control flow among each functional module.



Explain why you breakdown your system function like this?

I like to say there are 5 main functions, because from the user's viewpoint that is clearly what there are. There are 4 buttons on the main menu screen, plus an additional function when the user does not press any buttons.

Specification and design constraints

List and describe the updated specification of the entire project and each module in details, including (if applicable) but not limited to the following.

- Inputs and outputs of the entire project and each module

    Project

    - Inputs
        - Charging
        - Acceleration of Tags
        - Acceleration of Door
        - Touch Inputs
    - Outputs
        - Alarms
        - Graphical User Interface

    Brain

    - Inputs
        - Charging
        - Acceleration of Door
        - Touch Inputs
    - Outputs
        - Graphical User Interface
        - Alarms

Tags

- Inputs
  - Charging
  - Acceleration of Tag
- Outputs
  - Alarms

- Power/voltage/current requirements of each module

  Brain
  - 2.5W
  - 5V
  - 500 mA[10]

  Tags
  - 2.5W
  - 5V
  - 500 mA[9]
- Mechanical power/workload (if applicable) requirements

  N/A
- Data transmission protocol/standard among each module

  BLE (Bluetooth Low Energy)
- Responding time/delay, data throughput, etc.

  BLE throughput ~=0.381 Mbps[8]

  Screen refresh rate<=40 Hz

  IMU Sample Rate = 10 Hz
- Measurement range, sensitivities, etc.

  BLE range = 26m [11]
- Physical dimensions, weight, etc.

  Tag Dimensions = 48.2*25.5*13.7mm[9]

  Tag Weight = 15g[9]

  Brain Dimensions = 54*54*16.5mm[10]

  Brain weight = 52g[10]
- Weather proof, safety, insulation, etc.

  Unknown[9][10]
- Libraries/Datasets/Open sources used

  ESP32 Libraries: https://github.com/espressif/arduino-esp32/tree/master/libraries

  Arduino IDE https://www.arduino.cc/en/software

Some of standardization organizations are:

- Institute of Electrical and Electronic Engineers (IEEE)

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- NFC Forum for NFC-related Standards
- American National Standard (ANS)
- ASTM International (ASTM)
- Society of Automotive Engineers (SAE)
- National Standards Network (NSSN)

Table of specification & design restrictions

Function module	Specification (use bullets)	Why chooses this specification?
Brain	• M5Core2 Specifications: http://docs.m5stack.com/en/core/core2	This MCU was recommended by Dr. Venki.
Tag	• M5Stick C Plus Specifications: http://docs.m5stack.com/en/core/m5stickc_plus	This MCU was recommended by Dr. Venki.

Table of employed libraries/datasets/open sources:

Resource name	Resource type & description	Link or References
ESP32 Libraries	APIs, demos, config files, etc	https://github.com/espressif/arduino-esp32/tree/master/libraries
Arduino IDE	MCU programming IDE with some minor demos	https://www.arduino.cc/en/software

Table of employed standards (related to safety, materials, workload, power rate, data transmission, etc.):

Standard	Description	Link or References	Why this standard is employed/necessary?
BLE	Bluetooth Low Energy	https://en.wikipedia.org/wiki/Bluetooth_Low_Energy	Microcontrollers can't connect to school WiFi, so BLE was the only wireless communication method I had available to me

Table of hardware/budget use and all costs

part description	function	amount needed / unit price	subtotal	purchase link	datasheet link
STM32WL54CC	Tracker and Brain	1/$11.69	$11.69	https://estore.st.com/en/products/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus/stm32-wireless-mcus/stm32wl-series/stm32wl5x/stm32wl54cc.html	https://www.st.com/resource/en/datasheet/stm32wl54cc.pdf
3V Battery	Power	4/$1.93	$7.72	https://www.amazon.com/AmazonBasics-CR2032-Lithium-Coin-Cell/dp/B0787K2XWZ	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwim05qt4KT9AhVKOkQIHTWVCw4QF

					noFCIgBEAE&url=https%3A%2F%2Fdata.energizer.com%2Fpdfs%2Fcr2032.pdf&usg=AOvVaw1qrY22Kugll9Oz17_h_eyp
Piezoelectric Disk	Beeper	15/$0.60	$8.99	https://www.amazon.com/15Pcs-Trigger-Acoustic-Pickup-Guitar/dp/B07B8RJ8NX?th=1	
Keypad	User Input	1/$6/95	$6.95	https://vetco.net/products/16-button-numeric-membrane-keypad-matrix-d71?gclid=Cj0KCQiAgOefBhDgARIsAMhqXA4g5dx_4HvJLnzWjRN_pG1KkepL0nguseyTmabqmCrZ-gQC3UUpfeYaAu6vEALw_wcB	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwizrq_XrLH9AhViDkQIHSvyDXIQFnoECBwQAQ&url=https%3A%2F%2Fcdn.sparkfun.com%2Fassets%2Ff%2Ff%2Fa%2F5%2F0%2FDS-16038.pdf&usg=AOvVaw1GugQR_K74A8CZdp0CSw1P

Servo	Doorstop	1/$4.99	$4.99	https://graysonhobby.com/drone-airplane-electronics/servos/tower-pro-servos/sg90-robotics-360-degree.html	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiVi5nYrrH9AhWNEUQIHe0ZCggQFnoECBEQAQ&url=http%3A%2F%2Fwww.ee.ic.ac.uk%2Fpcheung%2Fteaching%2FDE1_EE%2Fstores%2Fsg90_datasheet.pdf&usg=AOvVaw0mGSoDobEfBgrMGA5MSSwn
Servo	Doorstop	4/$4.33	$17.32	https://www.amazon.com/dp/B09Y55C21K?psc=1&smid=A10MX0RD2LYNQR&ref_=chk_typ_imgToDp	http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf

Total = $57.66

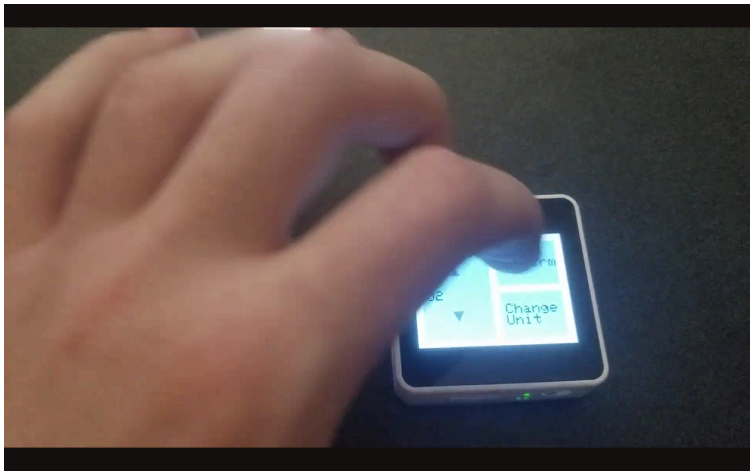
3. Results Evaluation and Demonstration

Tested Function/Module 1: Time Set

Demo video link:
https://www.youtube.com/watch?v=LBUUYm_Ppj8&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=1&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Going through the menus, pushing buttons.



Tested Function/Module 2: BLE Manage

Demo video link:

https://www.youtube.com/watch?v=OiL5wrHpO04&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=2&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Observe no connected tags, then connect to all 3 and observe the connected tags.

Tested Function/Module 3: Find Device

Demo video link:

https://www.youtube.com/watch?v=T8EpE-Tzug0&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=3&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Beep devices in reverse order that they were connected.

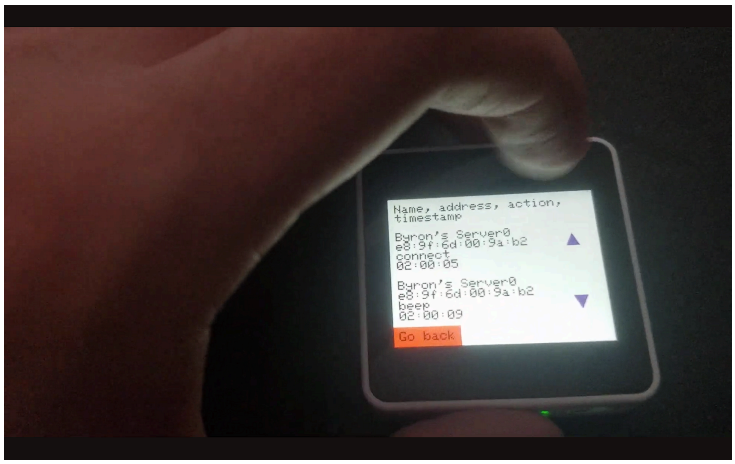
Tested Function/Module 4: Logging

Demo video link:

https://www.youtube.com/watch?v=B1tftoM5xiA&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=4&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Observe logs after each test.



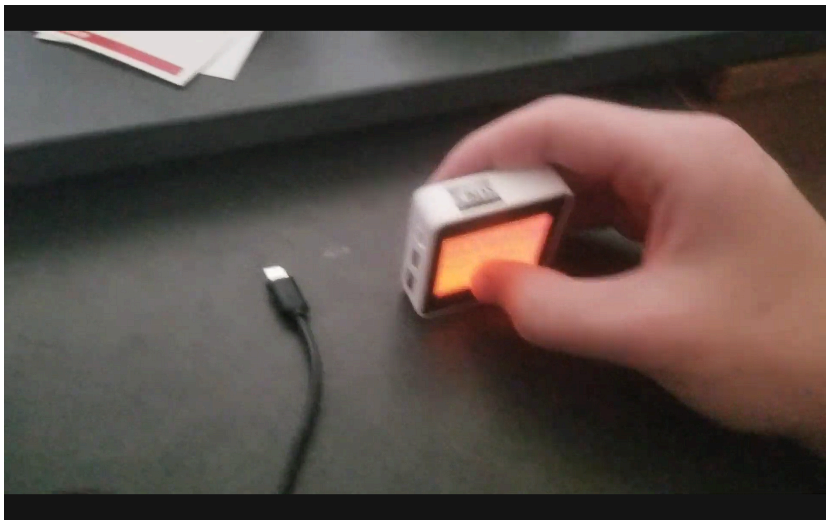
Tested Function/Module 5: IMU

Demo video link:

https://www.youtube.com/watch?v=m9z74_4s8oE&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=5&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Test both off door.



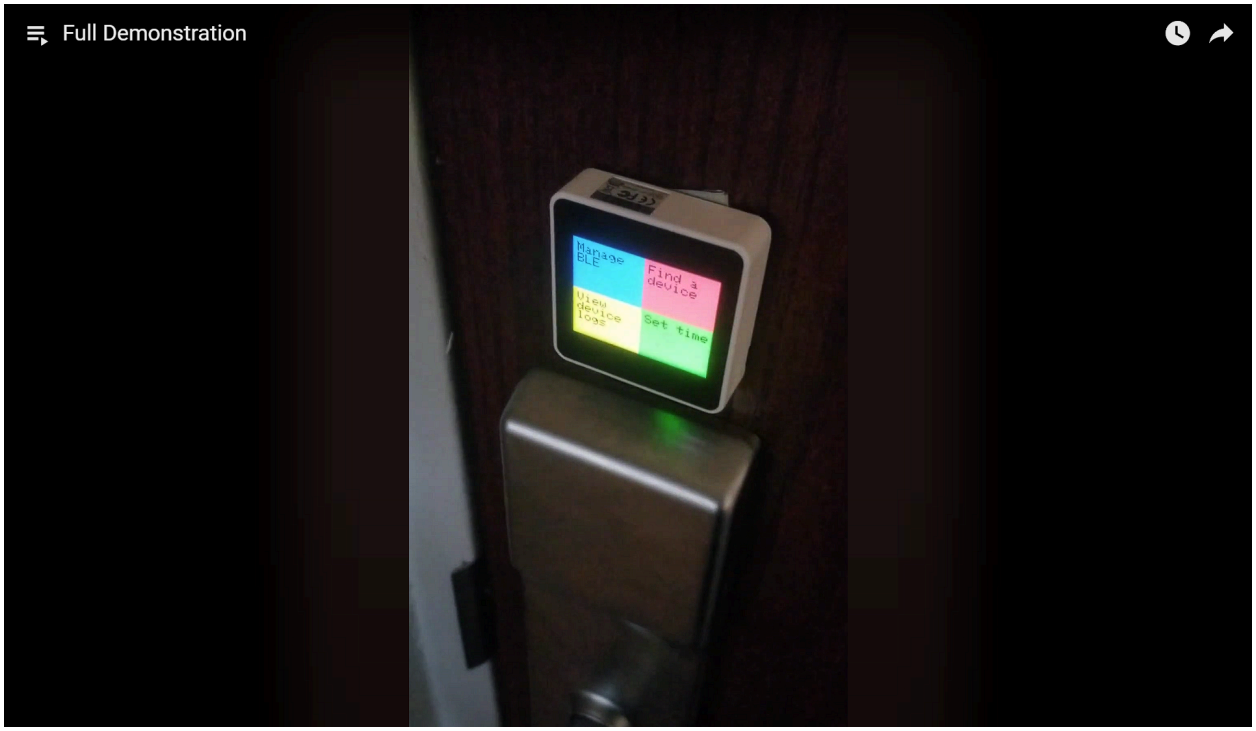
Demo/Testing of the entire project:

Demo video link:

https://www.youtube.com/watch?v=xc-bYkFgU-Q&list=PLLojGxkbJn60zzmKg4Se6Xe0mIOYT0m2y&index=6&ab_channel=PhyrnnaDeAngelo

Description (with screenshots and/or photos if applicable):

Test of all of the above.



4. Conclusions/Summary

Conclude your accomplishment

The device works as intended. Some sacrifices had to be made along the way to fit the limitations of the hardware, but the core goal is still very much intact. I've used this device for its intended purpose, and it has helped me. I learned a lot designing this project, and I hope I can keep designing products that help people.

What future works/improvement can be done to your project?

A central charging hub would be very helpful. As it stands 4 charger cables are needed to charge the brain and 3 tags, which is not practical. Alternatively, if the tags can be made much more power efficient, the battery could last 1-3 years like in commercial products.

Permanent logs (persistent after power cycle) would be much more helpful, particularly for security purposes. Storing data in the permanent memory rather than the RAM would solve this issue.

More responsive touch screen. The touch screen right now is a bit glitchy, which I believe to be merely hardware limitation.

More users. Right now only one person can use the device. I originally had a plan for more people to use the device, but that plan required at least 4 tags, and the hardware only supports 3.

5. Contribution and Acknowledgement

List the contribution of each team member

Team member name	**Contributions (use bullets)**
Byron Griggs	● ○ ■ ● ○ Everything

Acknowledge the contribution of advisors, non-team member peers, etc.

Thanks to Dr. Ming Zhu, for brainstorming, evaluation, and instruction

Thanks to Dr. Venki for brainstorming, microcontrollers, and pointing me to the right resources.

References

[1] A. Inc., “Find my network,” Apple Developer, https://developer.apple.com/find-my/ (accessed Dec. 8, 2023).

[2] B. Dirks, “What is the range of Apple AirTags?,” MUO, https://www.makeuseof.com/apple-airtag-range/#:~:text=What’s%20the%20AirTag%20Range%3F,you%20can%20use%20Precision%20Tracking. (accessed Dec. 8, 2023).

[3] “AirTag,” Apple, https://www.apple.com/airtag/ (accessed Dec. 8, 2023).

[4] Tracking moving objects with tile – tile support, https://support.thetileapp.com/hc/en-us/articles/200591638-Tracking-Moving-Objects-with-Tile (accessed Dec. 8, 2023).

[5] Tile trackers: Up to 40% off, https://www.tile.com/product/black-slim-2-pack (accessed Dec. 8, 2023).

[6] “How does tile work?: How tile trackers work: Bluetooth trackers,” Tile eCommerce, https://www.tile.com/en-us/how-it-works (accessed Dec. 8, 2023).

[7] “Set separation alerts in case you leave an AirTag or item behind in find my on iphone,” Apple Support, https://support.apple.com/guide/iphone/get-notified-if-you-leave-an-item-behind-iph5fe280d90/ios (accessed Dec. 8, 2023).

[8] Chris Coleman, “A practical guide to ble throughput,” Interrupt, https://interrupt.memfault.com/blog/ble-throughput-primer (accessed Dec. 8, 2023).

[9] M5Stack, *M5StickC PLUS Datasheet*.

[10] M5Stack, *M5Core2 Datasheet*.

[11] Using Bluetooth in Location Tracking Devices Bluetooth ranging technology, “Understanding bluetooth range,” Bluetooth® Technology Website, https://www.bluetooth.com/learn-about-bluetooth/key-attributes/range/ (accessed Dec. 8, 2023).

Appendix

Link of complete design package, including circuit design files, program files/source codes, chassis/enclosure design files, etc.

https://github.com/ByronGriggs/Senior-Design-Submission-Byron-Griggs