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Computer Engineering

Technical Report

Fall Guys - a Fall detection and monitoring Embedded Device for the Elderly

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Abstract

This report describes the development of an intelligent monitoring system with the main function of detecting falls of elderly people. Mainly composed of a necklace and an anklet, Fall Detector uses high precision barometric sensors to detect possible falls of the user in order to alert the responsible and avoid more serious consequences. In addition, Fall Detector also provides step data collected on the anklet with a pedometer.

1. Introduction

In this section we will present the problem that our project aims to address and our solution to this problem, as well as the product built for it.

1.1. The Problem

A study carried out in the state of São Paulo pointed out that accidental injury is the sixth leading cause of death for people over 75 years of age. Of these, 70% are falls. It is a major public health problem and the time to first aid has a great impact on reducing sequelae and chances of death.[1]
Approximately 60% of the cases of death occur after 1 month and before 1 year of the fall. This means that the sequelae resulting from the delay in first aid have a strong impact on the chance of survival of the elderly.[2]

In light of these data, dealing with the monitoring and warning of cases of falls in this age group is a problem of interest to today's society.

1.2. The Solution

Our idea is using three high precision barometric sensor to estimate the height using this formula:

$$P = P_b e^{\frac{-gM(h-h_b)}{RT_b}}$$

Where **P** is the pressure, ***g*** is the gravity acceleration, **M** is molar mass of Earth, **R** is the universal gas constant, ***h*** is the height, and P_b, T_b, h_b, are the reference values to pressure, temperature and height.

The two main barometers are one in the neck region through a necklace and one in the ankle region through an anklet. With this we can apply heuristics to determine if the user is standing or in a possible falling situation. The third barometer is on the ground, our solution can differentiate a fall of a moment where the user is sleeping in the bed.

To build this we use three Raspberry Pi Pico, one for each embedded system. In addition, we created a mobile application to receive notifications and a server to store user data.

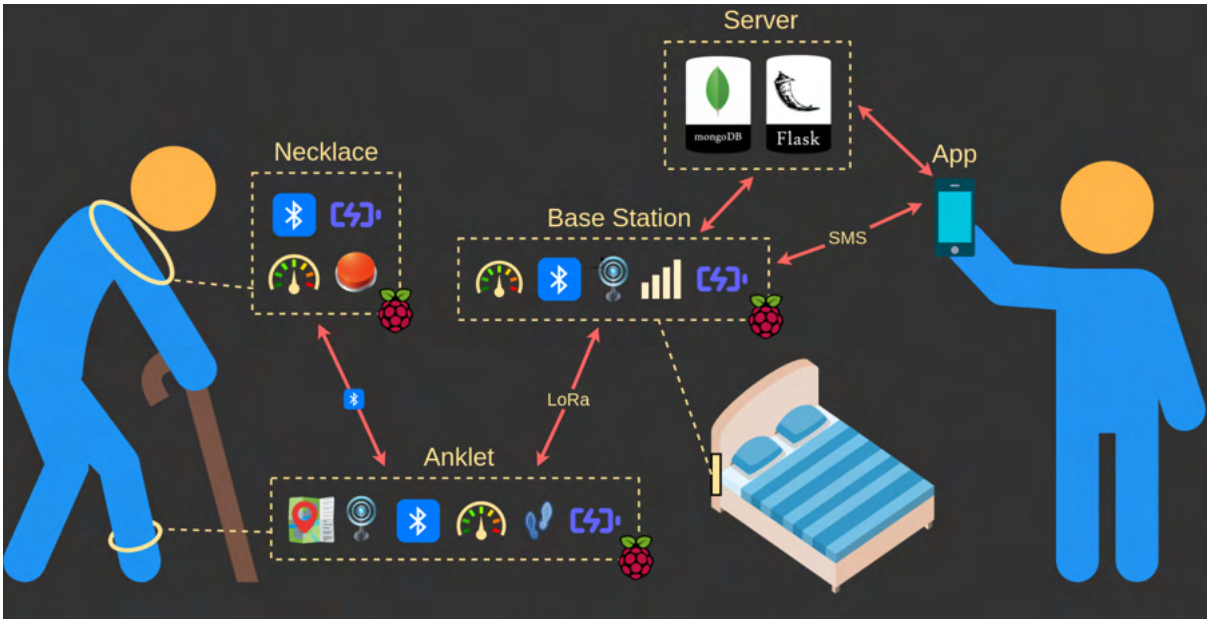


Figure 1. General System

Our project also has other monitoring solutions like a pedometer, GPS and panic button to optimize the life quality of older people.

1.3. Materials and Budget

Here is the list of materials and the expected budget for carrying out the project.

Item	Quantity	Unitary Price	Total Price
Raspberry Pi Pico	3	40	120
GPS sensor VK2828U7G5LF[4]	1	140	140
Barometer MS5611[5]	3	60	180
Battery Switcher	1	64	64
Bluetooth Low Energy module JDY-23[6]	3	33	99
GPRS module Sim800l[7]	1	33	33
Battery 12V BMS + Charger	1	25	25
LoRa communication module	3	58	174
Battery 18650 3,7V	3	18	54
Minor circuit parts	1	50	50
Mechanical parts	1	50	50
Power Bank	1	50	50
Accelerometer Mpu-6050 Gy-521	1	16	16
Total			1055

Table 1. Budget

2. Necklace

In this section we will discuss the necklace, the hardware used to get pressure in chest height. In addition, a panic button that may be pressed by users in panic situations. Both data, panic event and pressure, are sent using bluetooth to the anklet to continue the monitoring process that will be discussed in the nexts sections.

Additionally, the necklace will not be waterproof and will have a battery life of 60 hours.

2.1. Hardware

The Necklace's Hardware is composed by a Raspberry Pi Pico controller, a barometer sensor, battery, bluetooth module and the panic button. Figure 2 shows the schematic diagram, and Figure 3 shows the circuit mounted in a standard board.

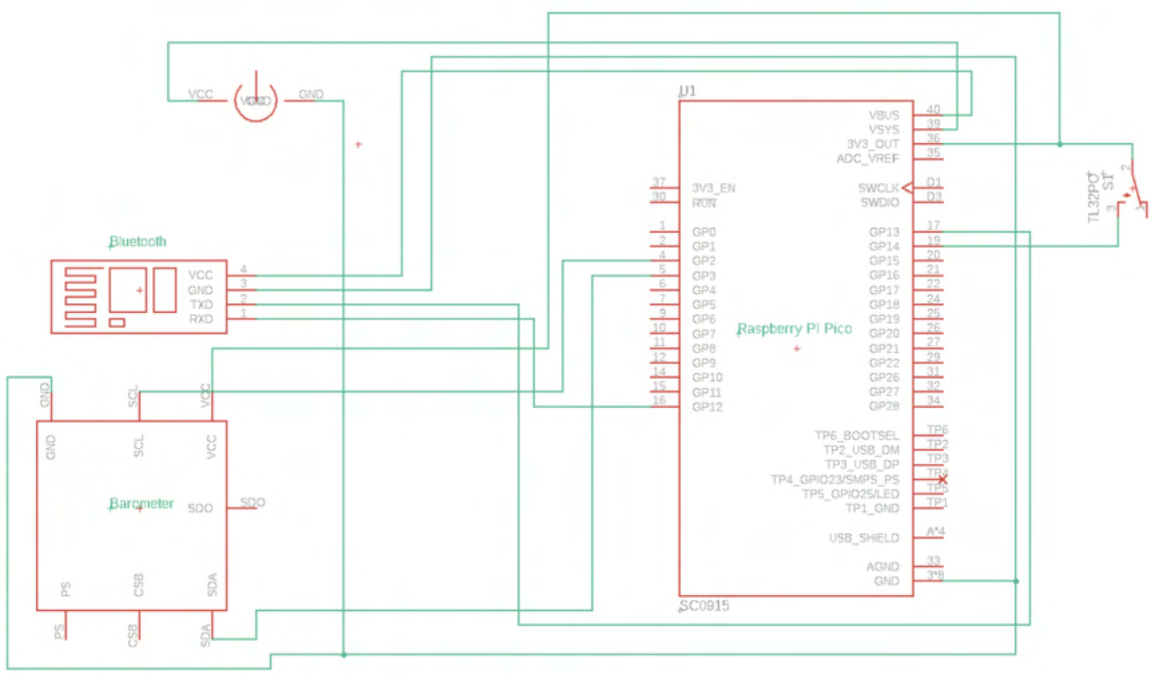


Figure 2. Necklace`s eletronic diagram

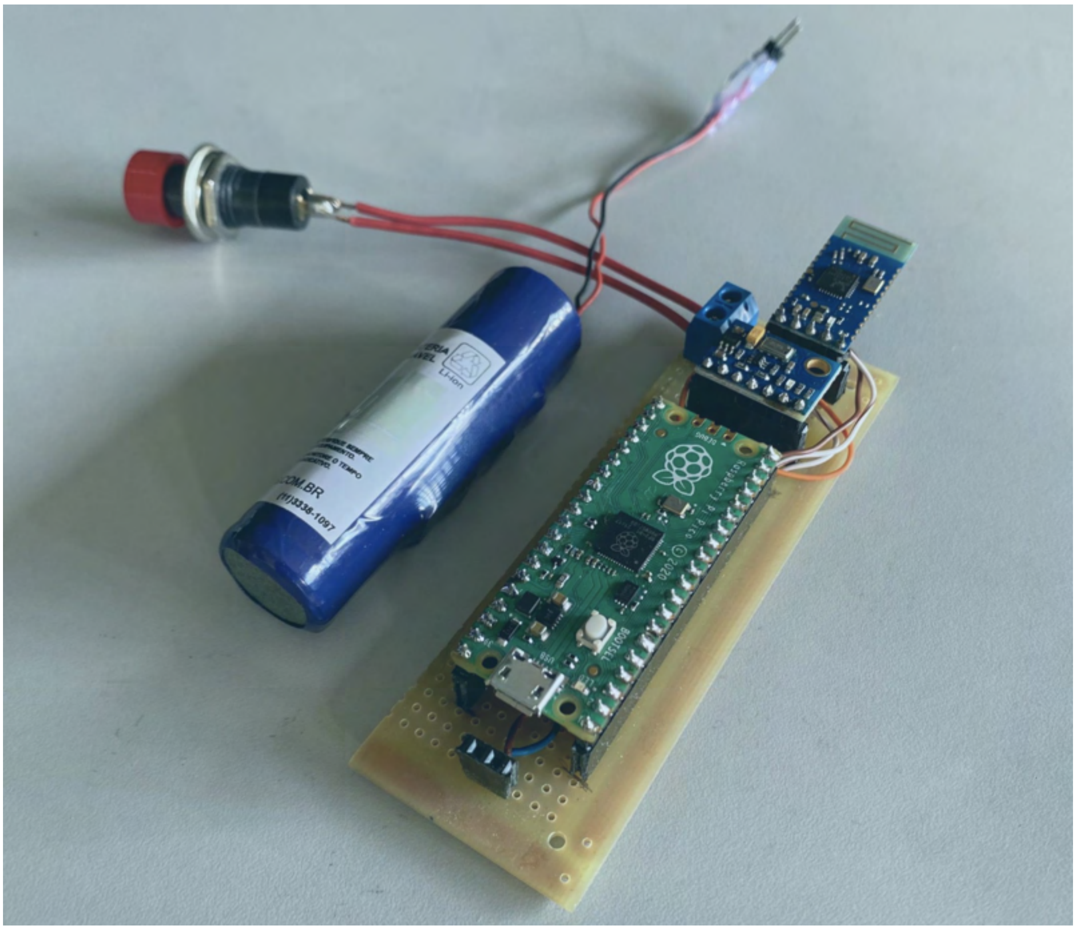


Figure 3. Necklace`s circuit board

2.2. Software

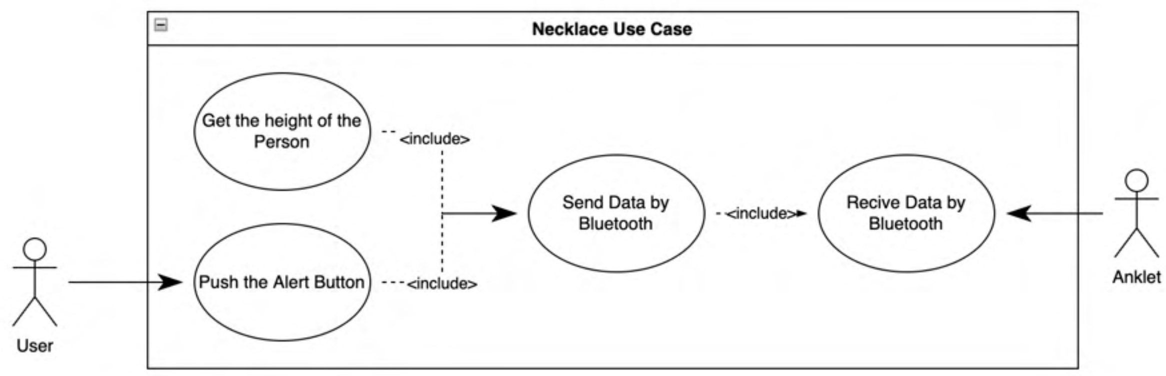


Figure 4. Necklace`s use case diagram

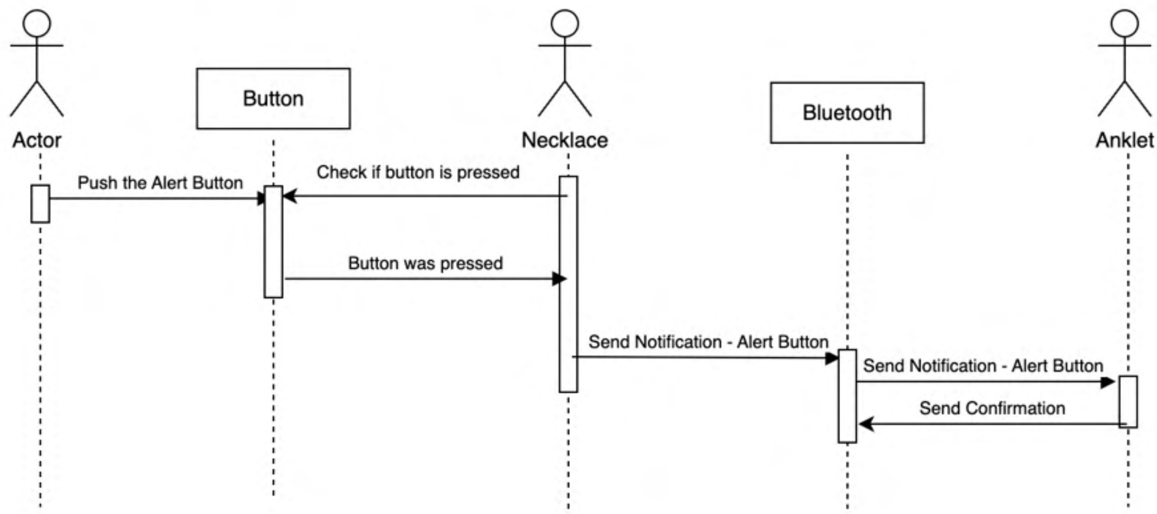


Figure 5. Necklace - Alert Button sequence diagram

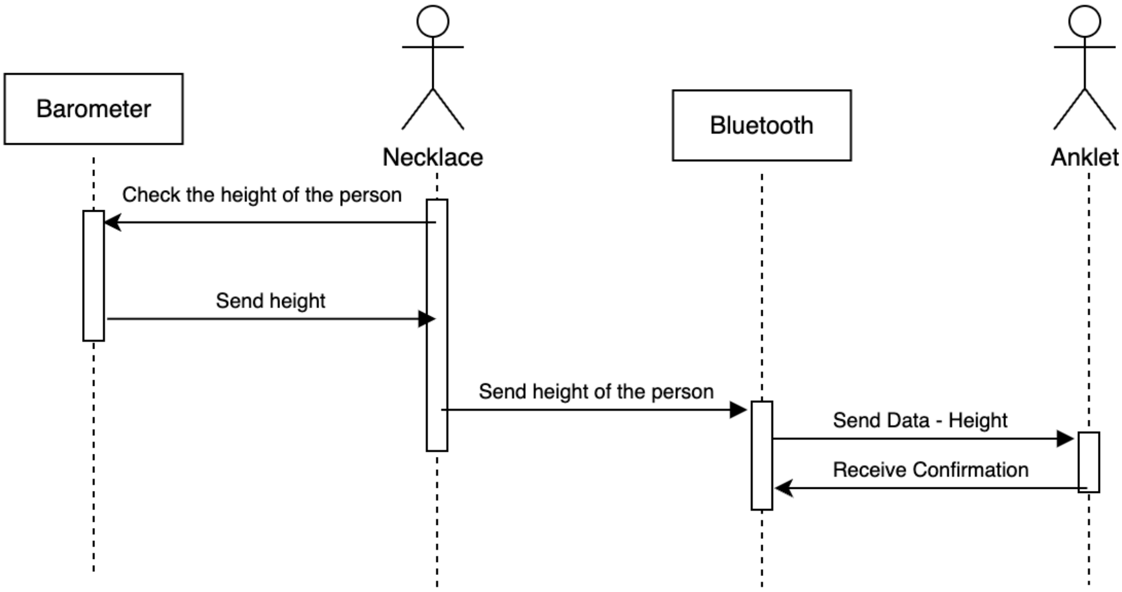


Figure 6. Necklace - Send Barometer data sequence diagram

3. Anklet

The anklet is the embedded device that will be "weared" by the elder user, attached to his/her ankle by stripes.

By comparing the barometer measurements in necklace and anklet, the system can detect if the person is in standing up, sitting, or laying down. Since the base station has another barometer, levelled to the ground, it allows for the inference of a possible fall.

The anklet is also used to collect GPS and pedometer data and receive the necklace data by bluetooth. This data collected and received will be sent using the LoRa module in a range up to 1km, a long range device that implements a radio modulation technique of the same name to send all information to the base station to the conclusion of the monitoring process that will be discussed in the nexts sections.

Additionally, the anklet will not be waterproof, will have a battery life of 60 hours and the user of the Necklace and Anklet must be at least 1.5 meters tall.

3.1. Hardware

The Anklet Hardware is composed by a Raspberry Pi Pico controller, a barometer sensor, battery, bluetooth module, GPS module, LoRa module and the

Accelerometer module. Figure 7 shows the schematic diagram, and Figure 8 shows the circuit mounted in a standard board.

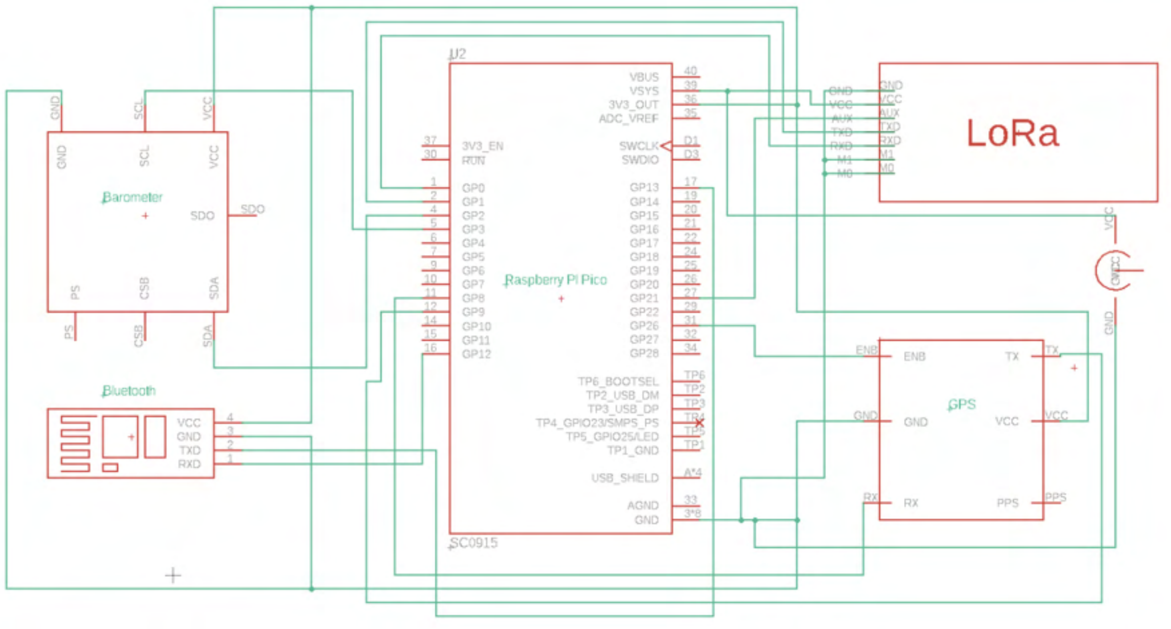


Figure 7. Anklet`s eletronic diagram

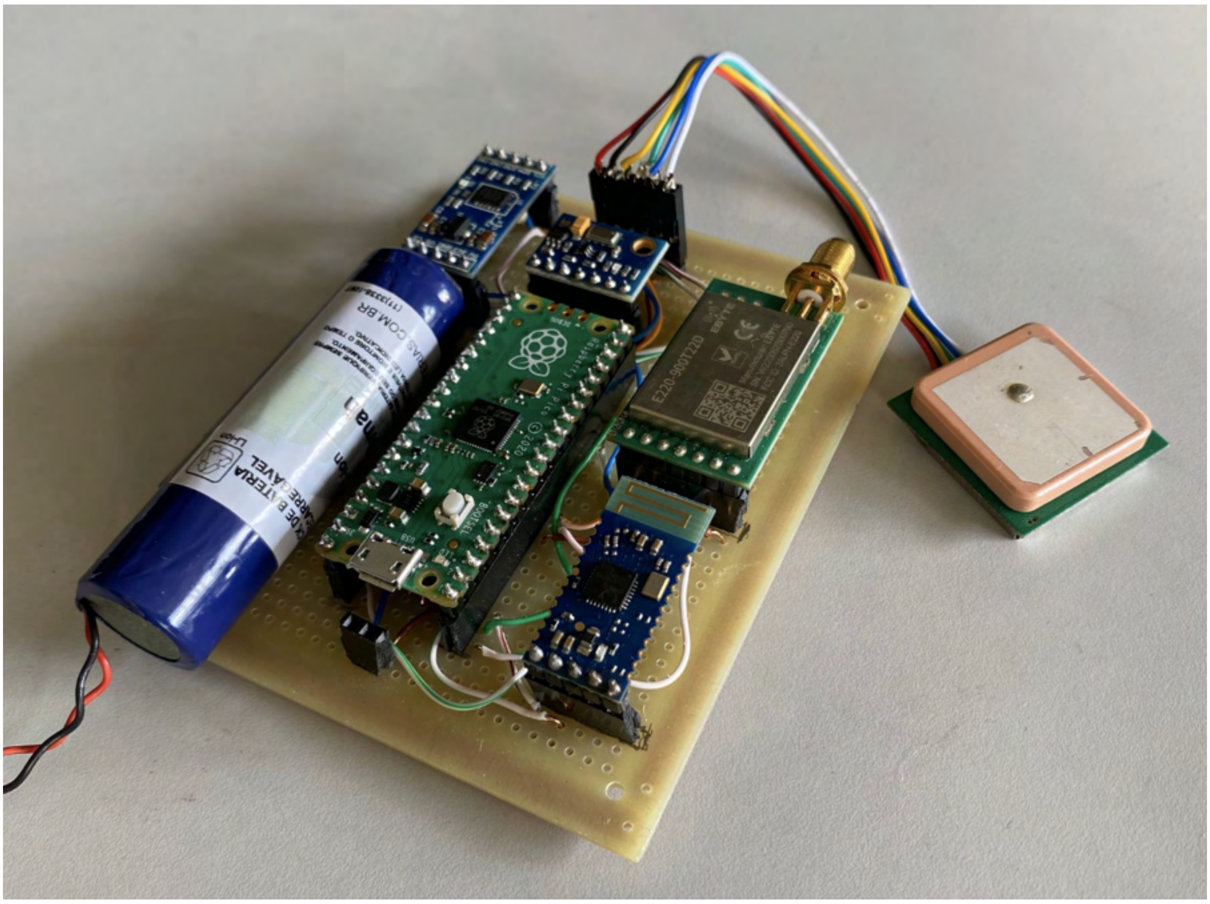


Figure 8. Anklet`s circuit board

3.2. Software

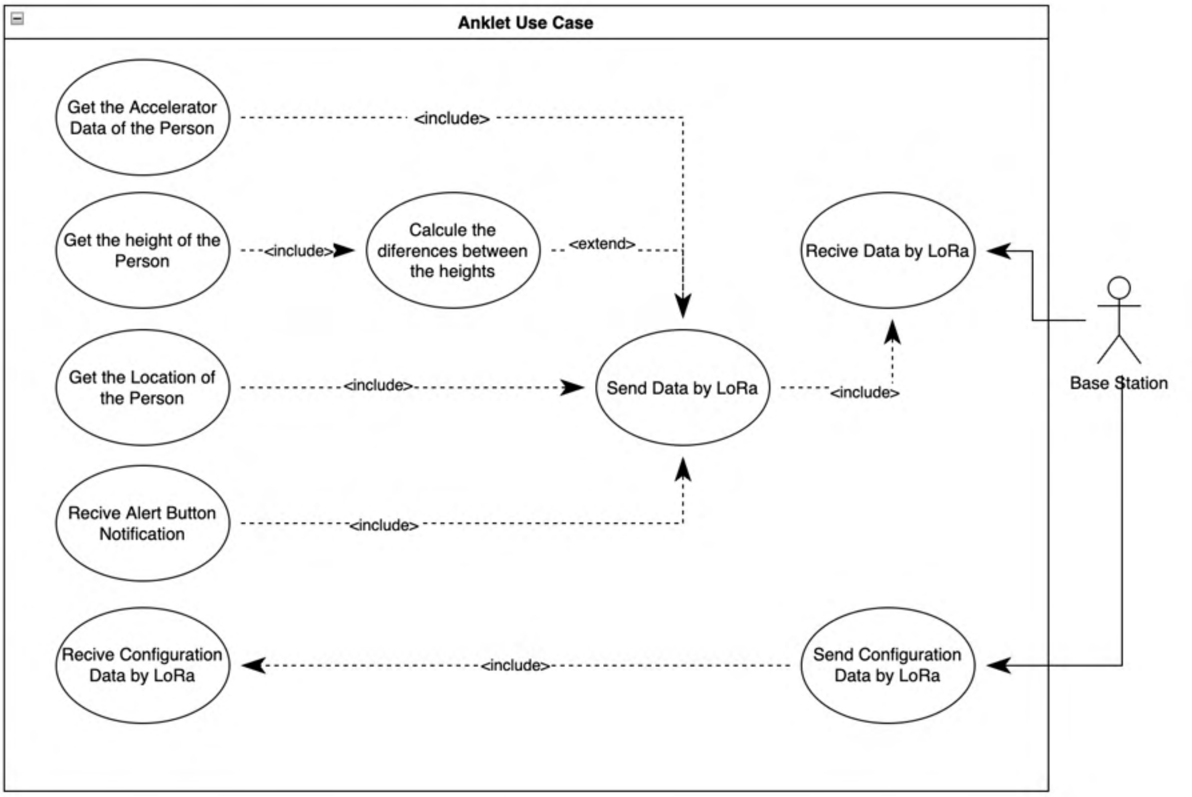


Figure 9. Anklet`s use case diagram

4. Base Station

In this section we will discuss the base station, the hardware used to get pressure in floor height. This embedded device should be installed at the floor level, preferably close to the bedroom, in order to receive all data by LoRa from the Anklet, process all the data applying heuristics to detect fall and send using a GSM module to the server that will store the information.

4.1. Hardware

The Base Station Hardware is composed by a Raspberry Pi Pico, a Barometer module, a Bluetooth module, a LoRa module, a GSM module, a Battery and the system that allows the base be outlet powered. Figure 10 shows the schematic diagram, and Figure 11 shows the circuit mounted in a standard board.

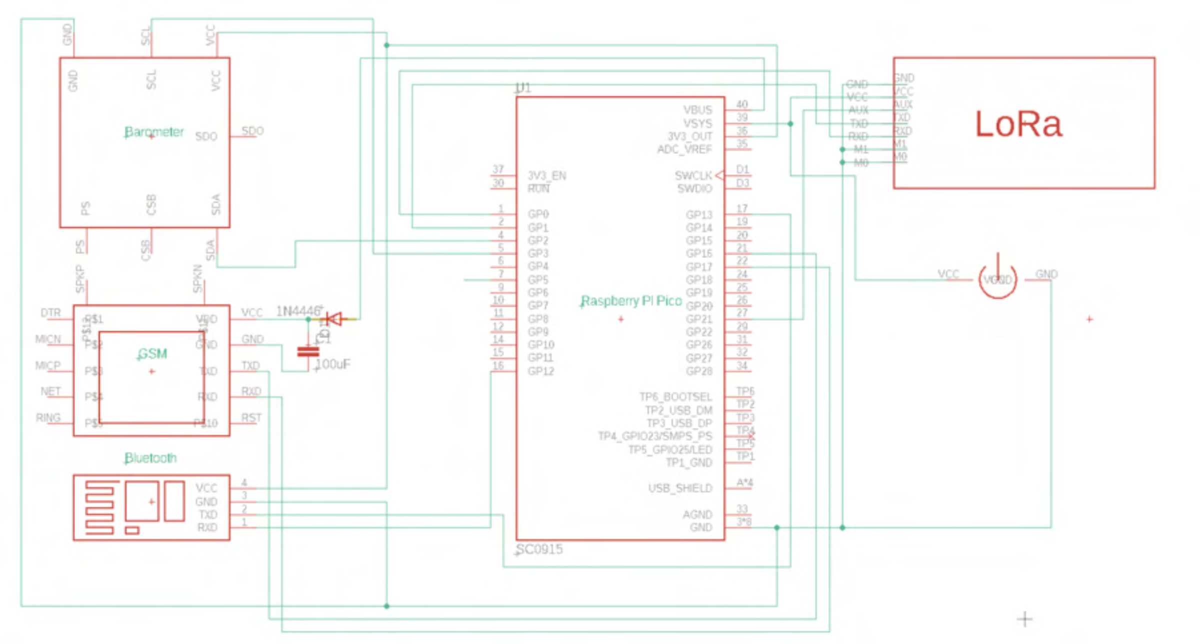


Figure 10. Base Station`s eletronic diagram

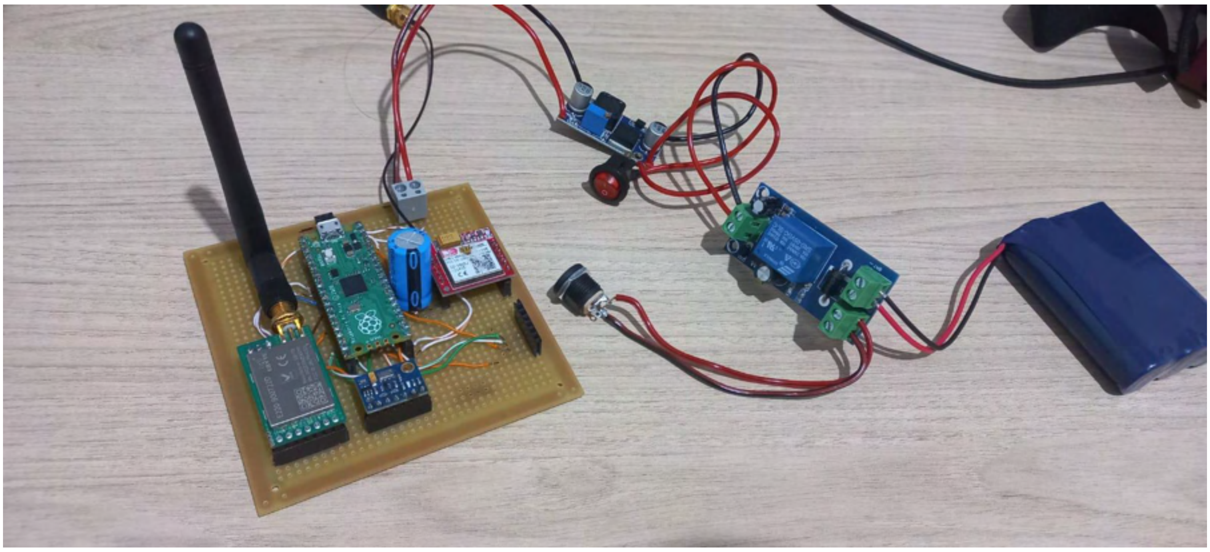


Figure 11. Base Station`s circuit board

4.2. Software

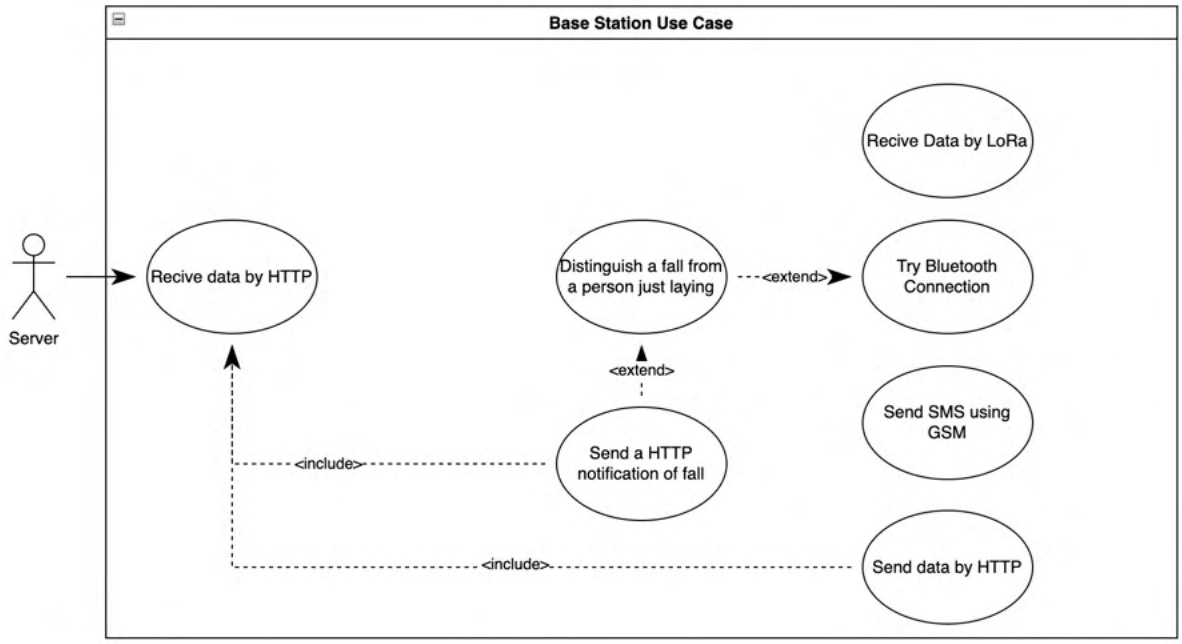


Figure 12. Base Station`s use case diagram

5. Server

In this section we will discuss about the server, an application in the cloud with the responsibility of storing all data created in Anklet-Necklace-Base Station system and the mobile app and provide a way to both parts of the project to access this information. It receives data by HTTP request by GSM module of Base Station and the HTTP library from the android app.

The server is on Cloud (Heroku) and were made using Flask, a Python's microframework.

5.1. Software

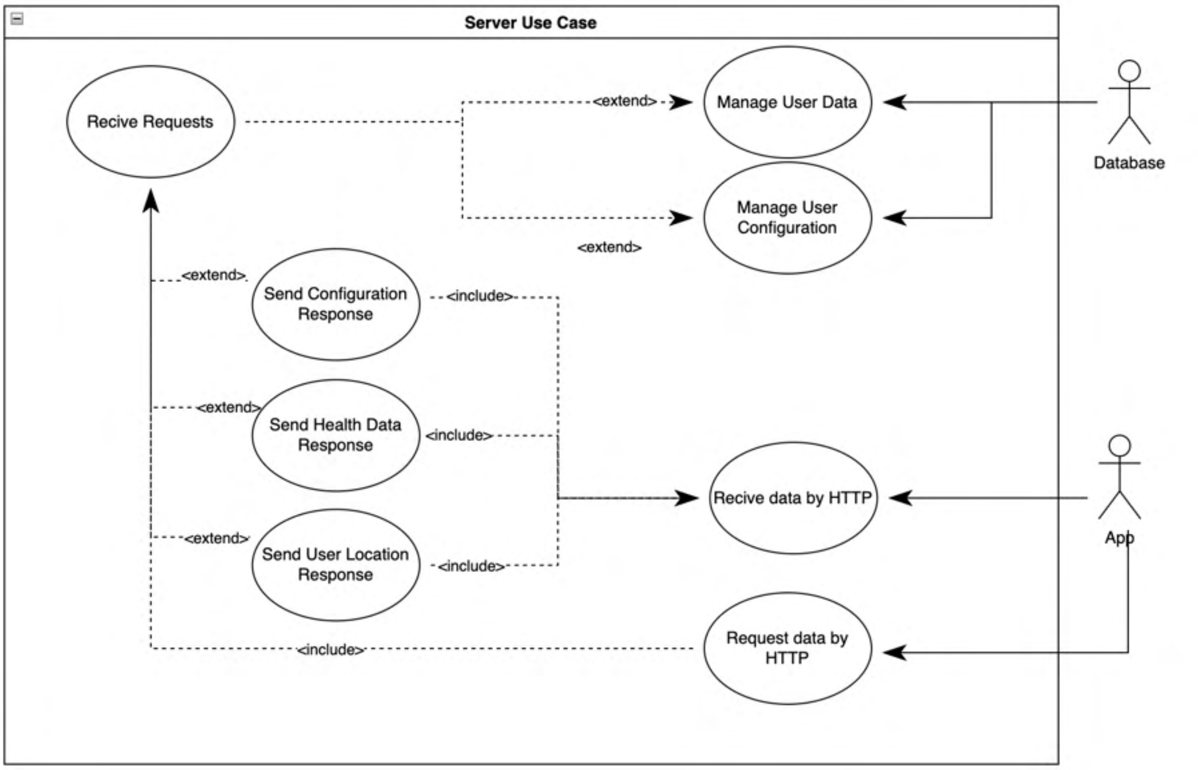


Figure 13. Server`s use case diagram

6. Application

In this section we will discuss the app, a python application for android built in kyvi, a modern cross-platform framework. The app uses the server to get and send health and location data about the user and also the settings. With the app, the user and caregiver can access information about the user to monitor and prevent a fatal fall due to lack of prompt care.

6.1. Software

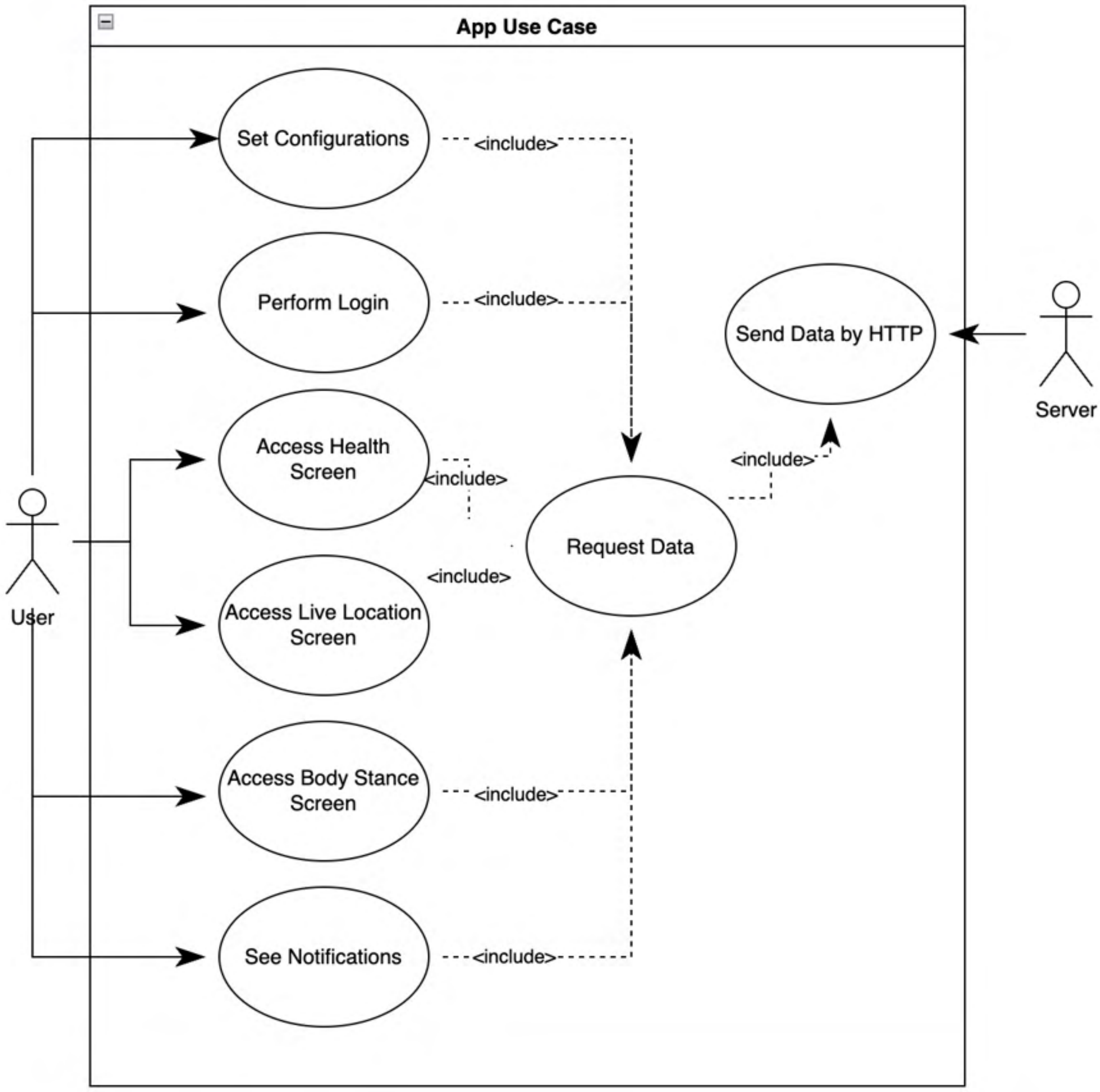


Figure 14. App`s use case diagram

6.2. Print of the Screens:

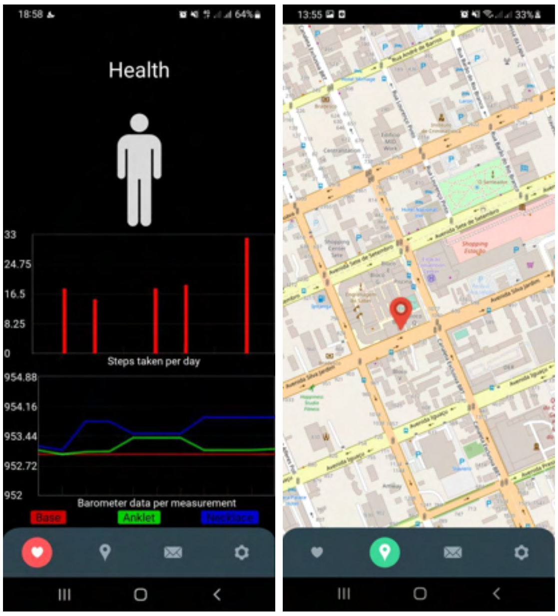


Figure 15. Health and Live Location

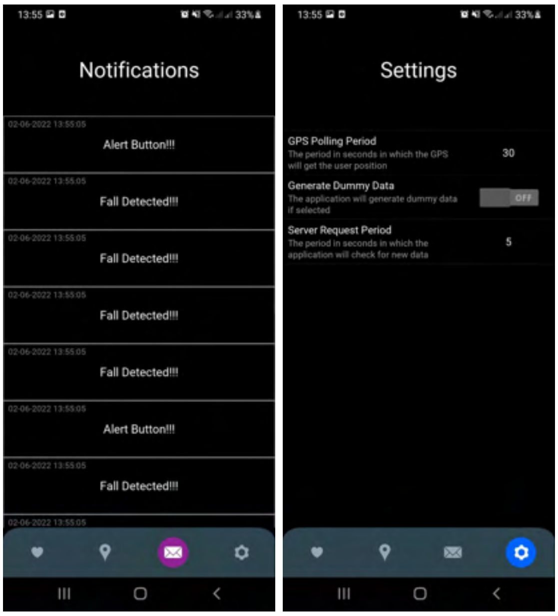


Figure 16. Notifications and Settings

7. Final Product

To keep the components protected, we decided to create boxes printed on a 3D printer. We created the models for the Anklet and the Necklace:

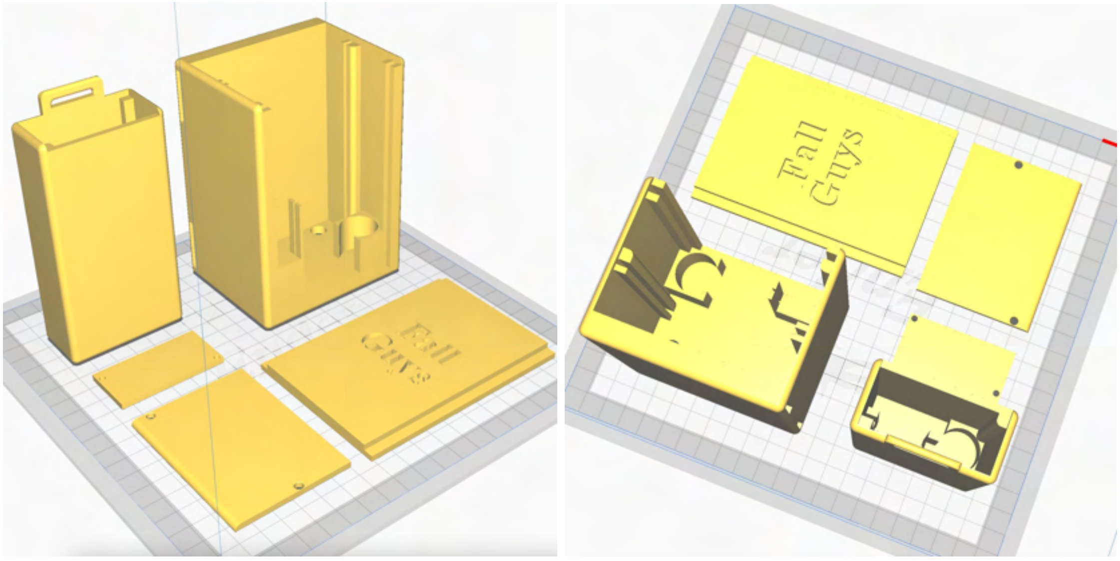


Figure 17. 3D models for the Necklace and Anklet plastic boxes.

We have the space to fit the board and the components. The result are:

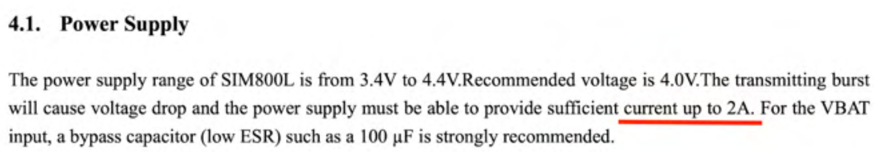
Figure 18. The Anklet's and Necklace's printed box.

8. Difficulties and Challenges

In this section we will discuss about the main problems faced in this project, some predictable and others unexpected.

8.1. GSM Module

Issues on establishing a network connection with the GSM module



4.1. Power Supply

The power supply range of SIM800L is from 3.4V to 4.4V.Recommended voltage is 4.0V.The transmitting burst will cause voltage drop and the power supply must be able to provide sufficient current up to 2A. For the VBAT input, a bypass capacitor (low ESR) such as a 100 µF is strongly recommended.

Because of that, we had to make a thicker weld track.

8.2. Number of UART interfaces

Not enough UART interfaces on Raspberry Pi Pico for the modules that we planned to use on the Anklet and the Base Station.
We found a bug on the Raspberry Pico that not allowed to use more than two UART interface using the Micro Python, and we had 3 modules using the UART on Anklet:

- Bluetooth
- LoRa
- GPS

And on the Base Station:

- Bluetooth
- LoRa
- GSM

In both cases, we were using Bluetooth with UART, and we decided to use it with the I2C interface instead.

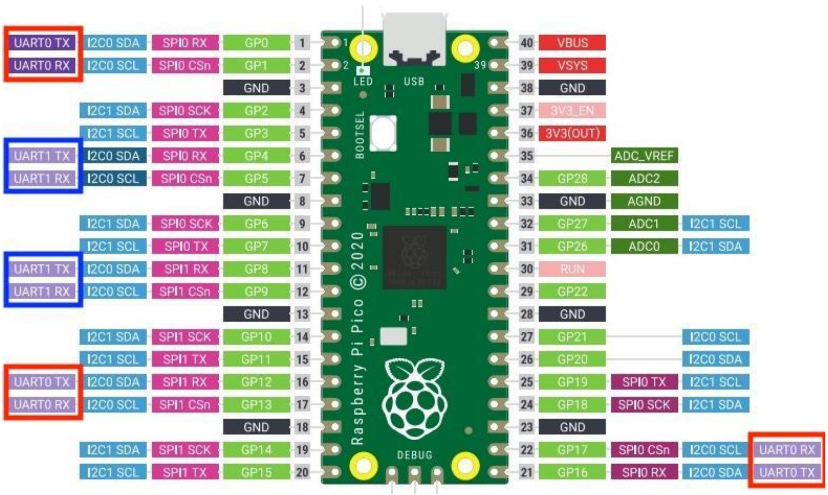


Figure 19. Ports of Raspberry Pi Pico

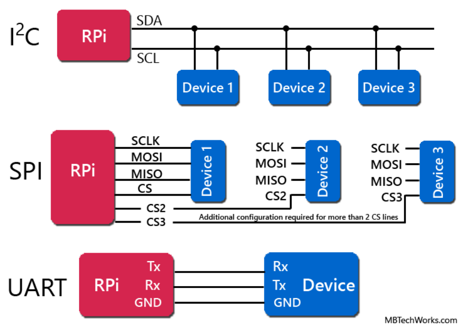


Figure 20. Comparation between I²C and UART.

8.3. Broken LoRa

We had problems with a LoRa module that came broken, as we didn't know how it worked, at first we thought the error was on our side. When we found out it was broken, we bought a new one, and that delayed our schedule a bit.

8.4. Specific antennas for the LoRa module

In the beginning we tried to use the LoRa without any configuration and any change on the antennas, and were only able to communicate by 10 meters. After buying a new antenna, we were able to communicate by 200 meters.

14 Antenna recommendation

The antenna is an important role in the communication process. A good antenna can largely improve the communication system. Therefore, we recommend some antennas for wireless modules with excellent performance and reasonable price.

Model No.	Type	Frequency Hz	Interface	Gain dBi	Height	Cable	Function feature
TX868-XP-100	Sucker antenna	868M	SMA-J	3.5	29cm	100cm	Sucker antenna, High gain
TX868-JK-20	Rubber antenna	868M	SMA-J	3	200mm	-	Flexible &omnidirectional
TX868-JZ-5	Rubber antenna	868M	SMA-J	2	50mm	-	Short straight &omnidirectional
TX915-XP-100	Sucker antenna	915M	SMA-J	3.5	25cm	100cm	Sucker antenna, High gain
TX915-JK-20	Rubber antenna	915M	SMA-J	3	210mm	-	Flexible &omnidirectional
TX915-JK-11	Rubber antenna	915M	SMA-J	2.5	110mm	-	Flexible &omnidirectional
TX915-JZ-5	Rubber antenna	915M	SMA-J	2	50mm	-	Short straight &omnidirectional

Table 1. Antennas recommendation for LoRa

8.5. Power supply for the Anklet

We initially planned using batteries of 3.7v on the Anklet, but after the tests with the completed hardware, we noticed that was not enough to power all the system plus the LoRa. So, we had to put a 5v battery on the Anklet for the LoRa to work.

8.6. SMS blocked

When we were testing the integration system, we sent a lot of SMS messages with the same text. So, it was considered as SPAM by the telephone carrier, and the chip was canceled.

9. Schedule

On the planning schedule, we estimated we would work 490 hours on 8 weeks, and with the margin of 30% we had 637 hours. But we ended working 562 hours on 9 weeks.

On the Chart 1, we have the ammount of hours planned per week and worked per week.

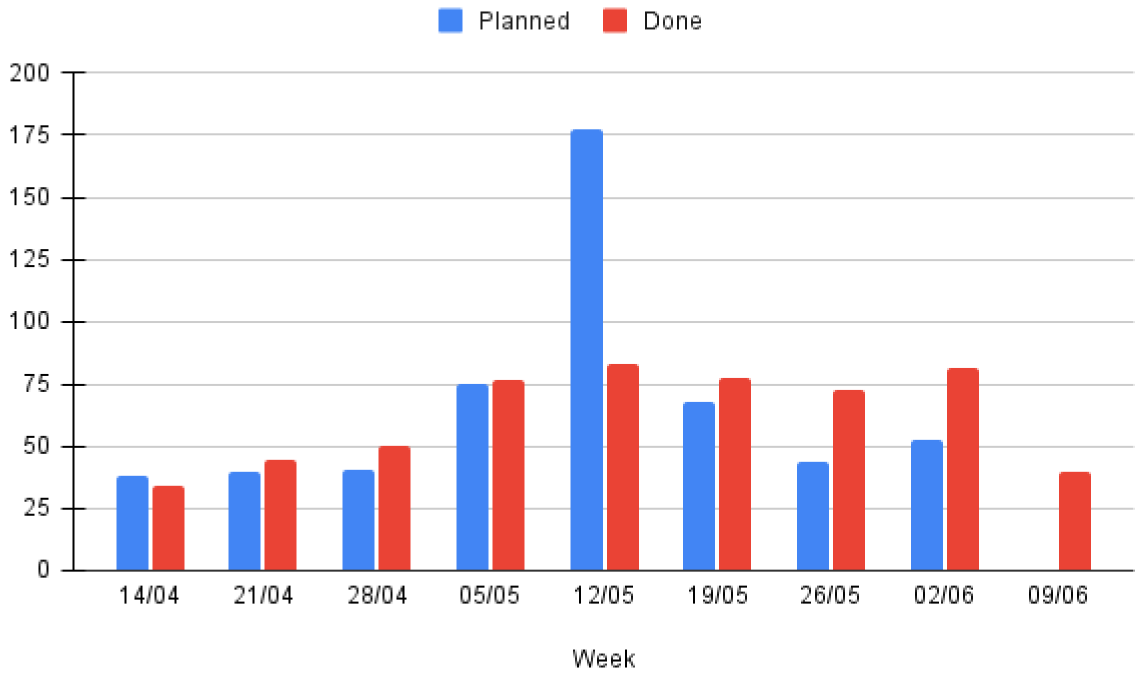


Chart 1. Hours of work per week.

10. Conclusion

Despite the problems faced, our group managed to comply with the pre-established requirements, and the product fulfills its main function very well: detecting falls.

From the tests carried out after the product was ready, we were always able to detect a fall, and we also always received the notification when the panic button was pressed. Of the other proposed features, the project did very well as well.

What we didn't do very well were the size and weight. After using the system for a few minutes, it's clear that it's gotten too clunky, and that it could be a lot smaller, and a lot lighter, even more if we think of an old person wearing these devices.

So, for future improvements, our first goal would be to decrease the size of wearables, and their weight. After that, we would invest time to improve your software and be able to increase your battery life.

11. Acknowledgment

We would like to thank Giovani Andrioni for his knowledge and willingness to cooperate to see a higher quality project.

12. References

[1] Suzele Cristina Coelho Fabrício, Rosalina A Partezani Rodrigues e Moacyr Lobo da Costa Junior. Falls among older adults seen at a São Paulo State public hospital: causes and consequences, 2004.
https://www.scielo.br/j/rsp/a/sHxR7CbcsVqpXvQsrfnWPtJ/.
[2] Débora Regina de Oliveira Moura Abreu, Elisiane Soares Novaes, Rosana Rosseto de Oliveira, Thais Aidar de Freitas Mathias, Sonia Silva Marcon. Fall-related admission and mortality in older adults in Brazil: trend analysis, 2016.
https://www.scielo.br/j/csc/a/3dWRVhXryM7ww95qKLVnLtH/?format=pdf&lang=pt.
[3] Portland State Aerospace Society. A Quick Derivation relating altitude to air pressure, 2004.
https://web.archive.org/web/20110928003908/http://psas.pdx.edu/RocketScience/PressureAltitude_Derived.pdf.
[4] GPS sensor VK2828U7G5LF datasheet.
https://www.openhacks.com/uploadsproductos/vk2828u7g5lf.pdf.
[5] Barometer MS5611 datasheet.
https://www.te.com/commerce/DocumentDelivery/DDEController?Action=showdoc&DocId=Data+Sheet%7FMS5611-01BA03%7FB3%7Fpdf%7FEnglish%7FENG_DS_MS5611-01BA03_B3.pdf%7FCAT-BLPS0036.
[6] Bluetooth Low Energy module JDY-23 datasheet.
https://fcc.report/FCC-ID/2AXM8-JDY-23/4936741.pdf.
[7] GPRS module Sim800l datasheet.
https://www.e-gizmo.net/oc/kits%20documents/SIM800L%20module/SIM800L%20module.pdf.