Instituto Universitário de Lisboa

Department of Information Science and Technology

WearIoT - Wearable IoT Human Emergency System

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A Dissertation presented in partial fulfillment of the Requirements for the Degree of
Master in Telecommunications and Computer Engineering

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ISCTE-IUL

November 2018

Resumo

A área da saúde foi uma das muitas beneficiadas com a evolução tecnológica, dando origem a novos conceitos que visam melhorar ou mesmo prolongar a vida das pessoas. Os sistemas de monitorização vestíveis, juntamente com as comunicações sem fios, são a base de uma classe emergente de redes de sensores. Estas tecnologias de informação permitem a deteção precoce de condições anormais e ajudam na sua prevenção. O objetivo é criar um destes sistemas compostos por uma rede de sensores que é implementada numa peça de roupa através de fios condutores com sensores conectados. Em contato com o corpo humano tem a função de fazer várias leituras, e.g., temperatura corporal, pulsação, entre outras. Outro objetivo é detetar quedas do utilizador. A deteção de quedas é cada vez mais importante para o utilizador, pois é uma situação que pode colocar em risco a sua saúde. Para o desenvolvimento deste conceito, são utilizadas Comunicações Móveis e o Sistema de Posicionamento Global. A primeira é uma tecnologia que permite criar chamadas de emergência em resposta a alarmes do sistema, o segundo indica qual a sua posição geográfica. Para complementar o sistema, existe uma plataforma online que regista a posição do utilizador tal como os seus dados. Tem também uma área de alertas no qual o utilizador pode verificar os seus valores preocupantes. Em caso de emergência o sistema contacta os serviços de emergência ou em casos especiais a ajuda pode ser obtida através de um UAV.

Palavras-chave: Monitorização de Saúde, BAN, Sensores Vestíveis, Deteção de Quedas, Comunicações Móveis, GPS, Serviços de Emergência, UAV

Abstract

The health area was one of the many beneficiaries of technological evolution, giving rise to new concepts that aim to improve or even prolong people's lives. Wearable monitoring systems, along with wireless communications, form the basis of an emerging class of sensor networks. These information technologies enable the early detection of abnormal conditions and help in their prevention. The goal is to create one of these systems composed by a network of sensors that is implemented in a garment through conductive wires with connected sensors. In contact with the human body it has the function of doing several readings, e.g., body temperature, heartbeat, among others. Another goal is to detect user falls. The detection of falls is increasingly important for the user, as it is a situation that can endanger people's health. For the development of this concept, Mobile Communications and the Global Positioning System are used. The first is a technology that allows to create emergency calls in response to system alarms, the second indicates the geographical location. To complement the system there is an online platform that registers the position of the user as well as his data. There is also an alert area in which the user can check his alarming values. In case of emergency the system contacts the emergency services or in special cases help can be obtained through an UAV.

Keywords: Health monitoring, BAN, Wearable Sensor, Fall Detection, Mobile Communications, GPS, Emergency services, UAV

Acknowledgements

First, I would like to thank my mother, Maria de Fátima Batista, for all of her dedication, strength and support, never letting me be discouraged throughout my academic process. This project was developed with a personal inspiration, in the cardiovascular disease that my father suffered, although he is no longer present, he motivated me a lot and helped overcome several difficulties.

I also want to thank my brother, André Baptista, my sister-in-law, Inês Carvalho, and my nephew, Rodrigo Baptista, who were always present and supported me.

I want to give a special thanks to my boyfriend, Rodrigo Cortesão, principally for all the love, support, patience and dedication that has been given me throughout the time.

I would like to thank my counselor, PhD. Pedro Sebastião for the orientation, support, motivation and encouragement given during the development of the dissertation.

To my colleagues and friends of the college, Daniel Fernandes, Catarina Duque, João Monge, António Raimundo, André Marques, André Glória and all the others not so present in this final part but always present throughout the course, I want to thank for the companionship and aid provided.

My childhood friends, Filipa Silvério, Maria Borges, Maria Vala, Catarina Pires, Catarina Oliveira, Inês Farto, Beatriz Leal and Marta Teixeira for the ever present support, trust and friendship.

For the accomplishment of the dissertation several materials were needed, so I want to thank ISCTE-IUL and the Instituto de Telecomunicações for their supply, just like I want to thank Valter Pintéus of La Cravate VP, for the production and supply of the jacket.

Contents

List of Figures

List of Tables

List of Acronyms

I^2C	Inter-Integrated Circuit
1G	First Generation
2.5G	Second and Half Generation
2G	Second Generation
3D	Third Dimension
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
9-DOF	9 Degrees of Freedom
AAA	triple-A battery
ADC	Analog to Digital Converter
BAN	Body Area Network
BLE	Bluetooth Low Energy
CPC	Circuit Playground Classic
CPX	Circuit Playground Express
DC	Direct Current
EDGE	Enhanced Data rates for GSM Evolution
EV-DO	Evolution-Data Optimized
FM	Frequency Modulation
FTP	File Protocol
GPRS	General Packet Radio Services
GPS	Global Positioning Service
GSM	Global System for Mobile Communications
HALE	High Altitude Long Endurance
HSPA	High Speed Packet Access

HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
I/O	Input/Output
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronic Engineers
INForum	National Symposium on Informatics of Coimbra
IoT	Internet of Things
IR	Infrared
JSON	Java Script Object Notation
JST	Japan Solderless Terminal
LED	Light Emitting Diode
LiPo	Lithium Polymer Battery
LoRaWAN	Long Range Wide Area Network
LTE	Long Term Evolution
MALE	Medium Altitude Long Endurance
MAV	Micro Air Vehicle
MEMS	Micro Electro Mechanical Systems
MUAV	Miniature Unmanned Aerial Vehicle
PHP	Hypertext Preprocessor
PIN	Personal Identification Number
PPG	Photoplethysmography
PWM	Pulse Width Modulation
QUATIC	Quality of Information and Communications Technology
RAM	Random Access Memory
RFID	Radio-Frequency Identification
RX/TX	Receive/Transmit
SCG	Seismocardiogram
SIM	Subscriber Identity Module
SMS	Short Message Service
SPI	Serial Peripheral Interface
TUAV	Tactical Unmanned Aerial Vehicle
UAV	Unmanned Aerial Vehicle
UMTS	Universal Mobile Telecommunication System

USB	Universal Serial Bus
W-CDMA	Wide-Band Code Division Multiple Access
WBAN	Wireless Body Area Network
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPA	Wireless Protected Access
WPA2	Wireless Protected Access2
WWBAN	Wearable Wireless Body Area Network

Chapter 1

Introduction

1.1 Motivation and Scope

The evolution of technologies gives rise to new concepts in many areas. Health problems are increasing as the world population. Global aging is increasing as well as care costs are also rising. It is increasingly necessary to improve precocious disease detection and medical intervention. All these problems give rise to a new concept of health care in order to provide monitoring of the vital signs of the user.

Wearable health monitoring systems together with wireless communications are the basis of an emerging class of sensor networks: Wireless Body Area Network (WBAN). This is the information technology that enables early detection of abnormal conditions and helps preventing its consequences. Continuous monitoring could be beneficent for many patients as a part of a diagnostic procedure, supervision of a chronic condition or surgery recovery [1].

For the development of this concept it will be used Mobile Communications, which is used by billions of people all over the world, to create emergency calls in response to system alarms. All of this is possible due to the advancement in communication technology as well as sensor technology leading to the emergence of a new generation of health care systems.

1.2 Objectives

This dissertation aims to create a human emergency system where a network of sensors is created and placed in a piece of clothing created with sustainable fabrics containing conductive wires connected with sensors that in contact with the human body allow to make several readings such as temperature, heart rate, frequency respiratory, among many others. The system also aims to detect user falls.

One of the main goals is to create a jacket with only wearable technology that is comfortable, in which the sensors do not cause discomfort to the user. It is intended that this is a jacket that can be used with and without technology, i.e. it can also be washed.

The system allows 24 hour supervision. It is useful in cases of advanced age that require supervision, for rehabilitation of heart diseases or even for workers or athletes in extreme environmental conditions. This system reduces patient care costs and aims to bring benefits to the user. This monitoring, focused on health services, may have several applications, in the civil or military market, directed to occupations of risk, elderly or child, or directed to athletes or activities that are in situations in which medical supervision is necessary, due to health risks or the extreme conditions in which they occur.

The system has the ability to make various types of alerts, either by Short Message Service (SMS) notification to the user or by calling the emergency services directly. User coordinates are also sent to the same emergency services, so if necessary, an Unmanned Aerial Vehicle (UAV) can be sent to the user where the emergency supplies will be contained.

The data obtained by the sensors will be stored so that they can be consulted later by the user or by the emergency system.

1.3 Contributions

In the development of this project the results obtained resulted in a functional low cost and easy to use prototype. A scientific paper was published at the national computer science symposium, with contributions to the scientific community, a poster presentation for an event of the Instituto de Telecomunicações and a presentation for an European project:

- M.Batista, P. Sebastião and A. Glória, "Sistema Inteligente de Emergência Humano", at the 10th National Symposium on Informatics of Coimbra (INForum) and 11th International Conference on the Quality of Information and Communications Technology (QUATIC), presented in September 2018;
- M.Batista and P. Sebastião, "WearIoT - Wearable IoT Human Emergency System", on "Visit of International Evaluation Panel" event at Instituto de Telecomunicações, Aveiro, Portugal, on 8th November 2018.
- M.Batista and P. Sebastião, "WearIoT - From Science to a Business Product", (to be presented) in Lisboa meeting EULA-GTEC, international European Project, Lisboa, Portugal, on 13th December 2018.

For the development of the project a partnership was made with Valter Pintéus, creator of a new style of ties, La Cravate VP, based in Switzerland and patented in 31 countries, that made the development of the jacket for the system.

1.4 Thesis Organization

After this introductory chapter, Chapter 2 addresses the state of the art, introducing project related themes such as Internet of Things (IoT), Body Area Network (BAN), Wearable Hardware, Communications Protocols, types of Unmanned Aerial Vehicles and finally some papers related. In Chapter 3, the description of the system is made speaking about the prototype scheme created, the chosen hardware components, in how they are sewn in the jacket, in the UAV used and in the final consumption of the system. Chapter 4 covers all the software part of the system, the server used, the use of the database and Hypertext Preprocessor (PHP) scripts. It also addresses the use of the Arduino Integrated Development Environment (IDE) application for the system development and finally introduces the implementation of the developed website. In Chapter 5, the results are presented and there is an analysis of system results. Finally, in chapter 6, the general conclusions of the dissertation are presented, focusing on aspects to be improved and future work.

Chapter 2

State of the Art

This chapter deals with the literature review on the most important aspects related to the work developed. It is divided as follows: section 2.1, introduces the theme involving the present, the IoT and its main components are described. Section 2.2, is about the system network, where initially it is described the main one that is the BAN and also about two of its constituents, which are Wireless Body Area Network and Wearable Wireless Body Area Network (WWBAN). In section 2.3, Hardware Wearable sensors and actuators are introduced, where the former are responsible for generating data and the latter for processing and analyzing the data collected. Section 2.4 discusses the entire communication part of the system. In section 2.5. the types of UAVs are introduced. Finally, related work is presented in section 2.6.

2.1 Internet of Things

The term Internet of Things (IoT) describes a scenario in which numerous objects from our everyday life are connected to the Internet and communicating with each other. As specified in [2], the title Internet of Things was given by a British entrepreneur, Kevin Ashton, in 1999. He said, IoT refers to a global network of objects connected to Radio-Frequency Identification (RFID).

Currently each house, company, school and hospital are connected to each other via the Internet. More specifically, each individual nowadays is connected to the world through the Internet. The full potential of this connectivity nowadays is explored interconnecting not only individuals, but also devices.

Internet of Things, as the name reveals, is a paradigm that is an aggregate of things, physical objects, and more specifically smart things [2].

According to [2], and depicted in Figure 2.1, the major IoT components are:

- **Things** - The things that make up the Internet of Things are not simple things, they are smart things. These are objects or devices that are equipped with electronics and communication interfaces and therefore are called Smart Things. These things can be controlled remotely through Internet communication interfaces;

- **Sensors** - A sensor forms an essential interface for the IoT implementation and therefore referred as the front end of the IoT environment. In an IoT environment, every sensor has to generate data, which will be implemented by a complex program code for appropriate and accurate data collection. The sensors related to IoT are also identified as a proximity sensor, touch sensor, humidity sensor, temperature sensor, pressure sensor, accelerometer, and gyroscope;

- **Actuators** - An actuator is a device that transforms electrical signals into functional and useful energy. Sensors collect data, the next issue is to process and analyze the collected data. This issue is solved by the usage of actuators. Sensors are present in a much larger number than actuators. Actuators are classified on the basis of their energy source that they need and use to cause the movement;

- **Storage Component** - IoT is a combination of a big number of devices, applications and services which are communicating with each other. The generated, processed data must be stored in appropriate storage devices, for processing and analysis the appropriate actions. The solution for data storage in IoT is cloud based storage because in this cases data is big and heterogeneous. The traditional modes of storage are not enough.

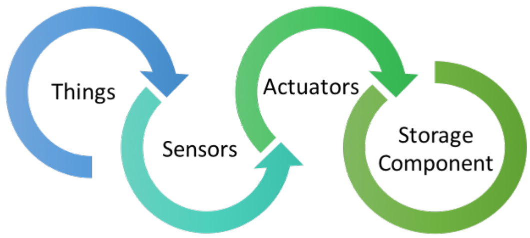


Figure 2.1: IoT Components

2.2 Body Area Network

BAN is a field of networking in which communication takes place between different sensors or network elements in or around the human body.

The movement of data or packets between nodes is mainly wireless, originating the Wireless Body Area Network (WBAN). In recent times, the breakthrough in the area of the Body Area Network has been in the development of lighter and smaller sensors, ultra-low power and intelligent, and wireless technologies for their communication. This recent advances in electronics have enabled the development of bio-medical sensors which can be worn on or implanted in the human body [3].

This type of network is restricted within the body called intra-BAN, this is a type of BAN in which sensors or electronic wearable equipment are embedded on to the body at the nodes of the Body Area Network. These sensors or electronic wearable equipment at the nodes are interconnected using wireless technologies and are called the intra-body communication links. This network can also be used to unite with other BAN's called inter-BAN. The basic idea is to allow secured interconnection of sensors and another electronic equipment and regulate communication between them [4].

The Body Area Network has some possible applications, such as, in health care, assisted living, entertainment and sports. These applications allow to obtain some advantages for the human being like the early detection of chronic diseases, for military use, for security purposes and even to assist a continuous communications between individual and people.

A Body Area Network may be a Wireless Body Area Network as previously stated but may also be a WWBAN, as shown in Figure 2.2.

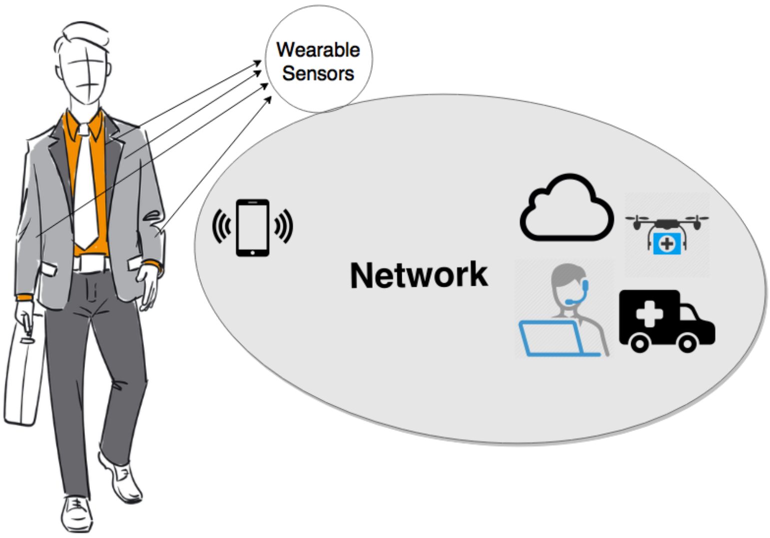


FIGURE 2.2: Wearable Wireless Body Area Network

2.3 Wearable Hardware

Wearable Sensors are a type of sensors that are a part of wearable technology, which are electronics that can be worn on the body. This technology might be used as an accessory or even as part of the material used to make the clothing itself. There are various types but some of the most popular devices are activity trackers and smart watches. The ability to make a connection to the Internet is one of the major features of wearable technology, enabling data to be exchanged between a network and the device. This ability to both send and receive data has pushed wearable technology to the forefront of the Internet of Things.

2.3.1 Sensors

As shown in section 2.1, sensors are one of the components of IoT. There are many sensors and from several manufacturers. For the choice of sensors in this dissertation the cheaper ones prevail because the main characteristics are identical between them. The purpose of these sensors is to measure vital signs and other physiological measures, such as the following:

- **Pulse**

  Heart rate, also named pulse sensor, can detect the heart pulse that is the speed of the heartbeat measured by the number of contractions of the heart per minute. This measurement is non-invasively with the Photoplethysmography (PPG) technique, where a pair of infrared light emitter and detector capture the variations of the reflected light by the body surface [5];

- **Temperature**

  This sensor allows measuring the temperature of the human body. The common body temperature is 37.0°C (98.6°F). In healthy adults, body temperature fluctuates throughout the day, as the body's needs and activities change. Other circumstances such as the time of day also affects the body's temperature. This temperature change above and below the critical level lead to fever, hyperthermia or hypothermia [6];

- **Accelerometer/Gyroscope**

  This sensor is used to monitor and recognize body posture. The accelerometer-based posture monitoring for BAN's typically consists of 3-axis accelerometers which is placed on some strategical location on the body of the user. Gyroscopes can be used together with accelerometers for physical movement monitoring. This sensor has the purpose of detecting any fall by the user [7];

- **Respiration**

  Number of movements indicative of inspiration and expiration per unit time (breathing rate). Respiration is an important physiologic function that is associated with the kinematics of the chest, which brings changes of the thoracic volume. The inductive plethysmography method is the gold standard for unobtrusive respiratory monitoring and has been used widely in clinical and research settings [8].

  The Seismocardiogram (SCG) is a measure of chest vibrations caused by heart beats. SCG signals can be measured using a miniature accelerometer attached to the chest to extract respiratory information [9].

2.3.2 Wearable Electronic Platforms

2.3.2.1 Arduino

Arduino project started early 2000s at the Interaction Design Institute Ivrea in Ivrea, Italy. Arduino is an open source computer hardware and software company, that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects with the physical world [10].

- **Arduino Gemma**

  The Arduino Gemma is a miniature wearable microcontroller board based on ATtiny85 [11]. Contains everything needed to support the microcontroller but needs a power supply, such as a computer or battery.

  This board (Figure 2.3) was taken from Arduino's website. Other wearable boards have been developed by the brand that will be addressed in the next section [12].

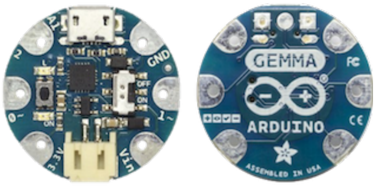


FIGURE 2.3: Arduino Gemma [12]

LilyPad Arduino Family

The LilyPad Arduino is designed for e-textiles and wearable projects. These were designed and developed by Leah Buechley and SparkFun Electronics. It can be sewn to fabric and connected to power supplies, sensors and actuators with conductive thread. Several input, output, power and sensor boards were also developed. Almost all LilyPad Arduino technology can be washed [13].

- **LilyPad Arduino Simple**

  The LilyPad Arduino Simple Board is a microcontroller board controlled by an ATmega328 [14] and has 9 pins for Input/Output (I/O), a Japan Solderless Terminal (JST) connector and a built in charging circuit for Lithium

Polymer Battery (LiPo). It has a built in power supply socket, and an on/off switch. The Simple board (Figure 2.4) was designed to streamline and give more space to work and eliminate the need to sew a power supply [15];

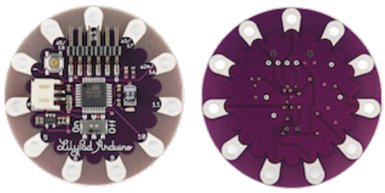


FIGURE 2.4: LilyPad Arduino Simple [15]

- **LilyPad Arduino SimpleSnap**

  The LilyPad Arduino SimpleSnap (Figure 2.5) is a microcontroller board based on the ATmega328 [14] and has 9 pins for I/O. It is similar to the LilyPad Arduino Simple, except that it has a built in rechargeable LiPo, and instead of through-holes, it has female snap connectors. By using matching snaps it is possible to connect this board to the SimpleSnap Protoboard so that the board is removable from clothes for washing [16];

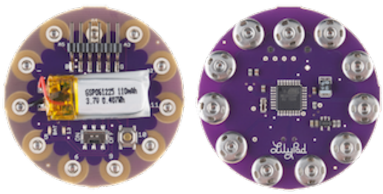


FIGURE 2.5: LilyPad Arduino SimpleSnap [16]

- **LilyPad Arduino SimpleSnap Protoboard**

  The SimpleSnap Protoboard (Figure 2.6) was developed to connect to the SimpleSnap board. It was made with the purpose of washing clothes. The Protoboard works by placing the ring of male snap connectors on the SimpleSnap Protoboard mate directly to the LilyPad SimpleSnap main board [17];

FIGURE 2.6: LilyPad Arduino SimpleSnap Protoboard [17]

- **LilyPad Arduino USB**

  The LilyPad Arduino Universal Serial Bus (USB) board (Figure 2.7) is controlled by an ATmega32U4 [18] with the Arduino bootloader. It has 9 digital I/O pins, a micro USB connection, a built in power supply socket, an on/off switch and a reset button. To program the LilyPad USB it is only needed a micro-USB cable to connect it to the computer. The LiPo can be plugged to the board, these batteries are rechargeable through the board, therefore there are no more special external chargers required [19];

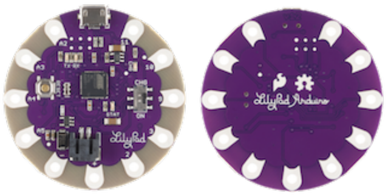


FIGURE 2.7: LilyPad Arduino USB [19]

- **LilyPad Arduino Main Board**

  The LilyPad Arduino Main Board (Figure 2.8) is a microcontroller based on the ATmega168V [20] or on the ATmega328P [14] with the Arduino bootloader. This board will run from 2V to 5V and it has several pin-out holes that make it easy to sew and connect to the other components. This board is the most complete because it aims to have a minimum number of external components, making it as small and simple as possible [21];

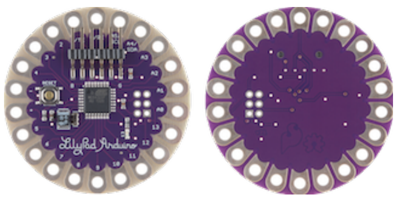


FIGURE 2.8: LilyPad Arduino Main Board [21]

- **LilyPad Arduino Simblee**

  The LilyPad Simblee Board (Figure 2.9) is a wearable development board that allows to add mobile application functionality via Bluetooth Low Energy (BLE) to e-textile. The Simblee RFD77101 [22] module equipped to this board, is intended to make embedded devices using Bluetooth Low Energy connections easier [23];

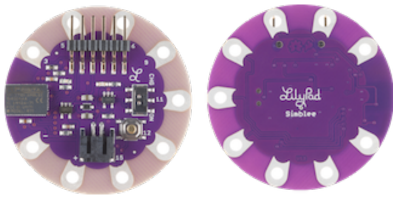


FIGURE 2.9: LilyPad Arduino Simblee [23]

In the table 2.1 some of the characteristics of the 5 types of Arduino LilyPad presented previously are described. This table serves as the basis for the choice of the microcontroller that best suits the system to be developed [15, 16, 19, 21, 23].

TABLE 2.1: Types of LilyPad Arduino

Parameter	**Simple**	**SimpleSanp**	**USB**	**Main Board**	**Simblee**
Microcontroller	ATmega328	ATmega328	ATmega32U4	ATmega328	Simblee RFD77101
Programming Language	C/C++	C/C++	C/C++	C/C++	C/C++
Analog Input Pins	4	4	4	6	3
Digital I/O Pins	9	9	9	14	7
PWM	5	5	4	6	4
I^2C	1	1	0	1	1
Flash Memory [kB]	32	32	32	16	128
RAM [kB]	2	2	2.5	2	24
Clock Speed [MHz]	8	8	8	8	16
Operating Voltage[V]	2-5	2-5	3.3	2-5	3.3
LiPo Charger	yes	yes	yes	no	yes
Diameter [mm]	50	50	50	50	45
Price ≈€	18	26	22	18	22

2.3.2.2 Adafruit

Adafruit Industries is an open-source hardware company based in New York City. It was founded by Limor Fried in 2005. This company designs and manufactures a number of electronics products, such as the following Adafruit boards: Flora and Gemma, Circuit Playground Classic and Express [24].

Flora

Flora is one of Adafruit's wearable electronics platform and uses the Atmega32U4 [18] microcontroller, which has built-in USB support. To program it is only needed a micro-USB cable to connect it to the computer, as it works both on Windows and Mac. The Flora depicted in Figure 2.10 is small and has a small but easy to use on board reset button to reboot the system. There are 14 sewing tap pads for attachment and electrical connections. The power supply is designed to be flexible and easy to use. There is an on board polarized 2 JST battery connector with protection schottky diode for use with external battery packs from 3.5V to 9V Direct Current (DC) [25].

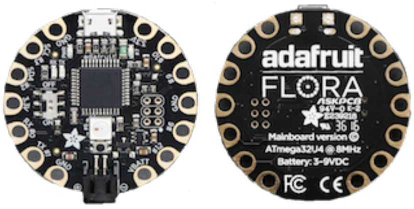


FIGURE 2.10: Flora [25]

Gemma

Gemma is a tiny wearable platform board (Figure 2.11) powered by an ATtiny85 [11] and programmable with an Arduino IDE, it is only needed a micro-USB cable to connect it to the computer. The ATtiny85 [11] is small, but it has 8K of flash memory, and 5 I/O pins, including analog inputs and Pulse Width Modulation (PWM) analog outputs. It has ultra low power, draws only 9mA while running. Gemma works like a mini-Flora [26].

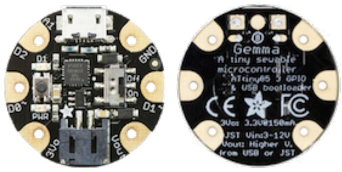


FIGURE 2.11: Gemma [26]

Circuit Playground

- **Classic**: This is the Classic version of Circuit Playground (Figure 2.12), which comes with an ATmega32U4 [18] processor, running at 3.3V and 8MHz. This is an all-in-one board that has sensors and LEDs built in. It is designed to be used with Arduino IDE. Circuit Playground Classic (CPC) has built-in USB support so it can be powered from USB, an triple-A battery (AAA) battery pack, or with a lipoly battery [27].

  In Figure 2.13 it can be observed that the Circuit Playground Classic has a large number of sensor inputs, such as:

  - Light Sensor

- Temperature Sensor
- Accelerometer
- Microphone Audio Sensor

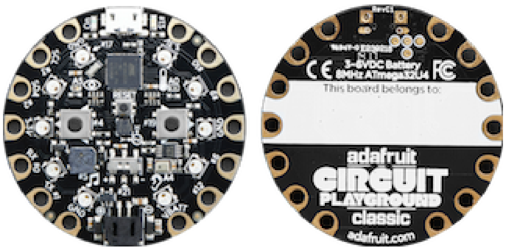


FIGURE 2.12: Circuit Playground Classic [27]

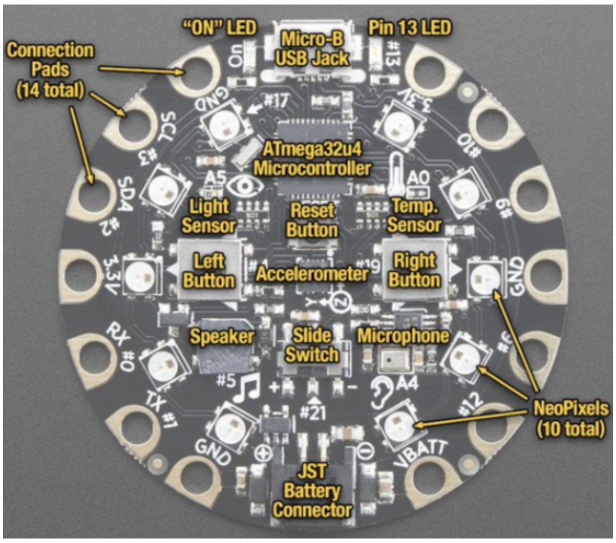


FIGURE 2.13: Components of Circuit Playground Classic [28]

- **Express**: The Circuit Playground Express (CPX) (Figure 2.14) was an evolution of the classic model, this one has a microcontroller ATSAMD21G18 [29] to Cortex M0 which is much better than the ATmega32U4 [18]. In the Circuit Playground Express there is also a new storage chip, called Serial Peripheral Interface (SPI) Flash and also Infrared (IR) was added to receive and transmit. This innovation allows to communicate with televisions and other devices such as other Circuit Playground Express [30].

  In Figure 2.15, as in the Circuit Playground Classic it can be observed that it has a large number of sensor inputs but in the Express version there are also others components such as:

  - Infrared Transmitter (IR Out)

- Infrared Receiver (IR In)
- Flash Memory
- Analog output

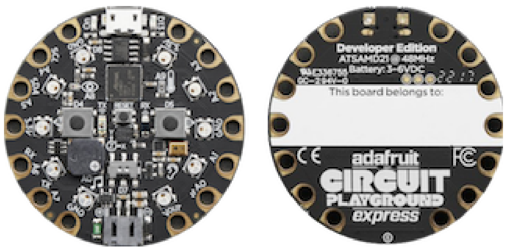


FIGURE 2.14: Circuit Playground Express [30]

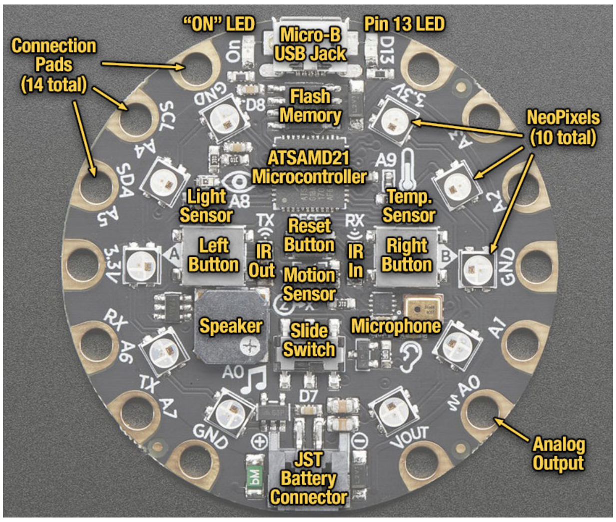


FIGURE 2.15: Components of Circuit Playground Express [31]

In the table 2.2 there are 4 types of Adafruit Wearable [25, 26, 27, 30].

TABLE 2.2: Types of Adafruit Wearable

Parameter	**Flora**	**Gemma**	**CPC**	**CPX**
Microcontroller	ATmega32U4	ATtiny85	ATmega32U4	ATSAMD21G18
Programming Language	C/C++	C/C++	C/C++	C/C++
Analog Input Pins	3	1	8	8
PWM	5	2	4	4
Flash Memory [kB]	32	8	32	256
Operating Voltage [V]	3.3	3.3	3.3	3.3
Diameter [mm]	45	28	50.6	50.6
Price ≈€	13	8	17	22

2.3.2.3 Wearable Platforms Comparison

After observing and comparing all the existing microcontrollers, it was possible to conclude that from Arduino, the Simblee is an asset because its price is in account and has the smallest size. In addition it is the one that has bigger flash memory, clock speed and Random Access Memory (RAM). It is built with Bluetooth Low Energy (BLE) which allows the use of a mobile application for system control. Regarding the adafruit models, the Circuit Playground Express is the most suitable because several sensors are already incorporated that in others would be used separately. Although the price is higher, it is the chosen for this project because it already has the sensors incorporated.

2.4 Communication Protocols

As discussed earlier, communication is one of the components of IoT, since the need to exchange data is crucial to the efficiency of an IoT project.

In this section, various communication protocols are detailed, the main characteristics of each and the comparison of various communication hardware.

2.4.1 Wireless Communication

Wireless communications are a fast growing technology that allow people to access networks and services without cables. One example of implementation is a single user connecting various devices to the same wireless network.

Based in [32], the wireless approach shows many advantages but also has some disadvantages as can be seen in Table 2.3.

Table 2.3: Advantages and Disadvantages of Wireless Communication

Advantages	**Disadvantages**
mobility	lower reliability
dynamic use	higher power consumption
	security threats

2.4.1.1 Bluetooth

Bluetooth, also known as the IEEE 802.15.1 standard, is based on a wireless radio system designed for short range, in other words, bluetooth is mainly oriented toward connections between closely connected devices as a substitute for data transfer cables [32].

2.4.1.2 Wi-Fi

Wireless Fidelity (Wi-Fi), a standard which conforms to IEEE 802.11, is a bidirectional radio frequency wireless protocol with the aim to provide wireless connectivity to devices that require quick installation, such as portable computers, or generally mobile devices inside a Wireless Local Area Network (WLAN) [32].

2.4.1.3 LoRaWAN

Long Range Wide Area Network (LoRaWAN) is a bi-directional communication protocol that uses the LoRa physical layer to provide low-power, long-range communications. This technology is a two-way wireless radio frequency platform designed specifically for IoT [33].

The table 2.4 presents some of the main characteristics of wireless communication protocols [32, 33].

TABLE 2.4: Typical System Parameters of the Wireless Protocols

Parameter	**Bluetooth**	**Wi-Fi**	**LoRa**
Standard	IEEE 802.15.1	IEEE 802.11	IEEE 802.15.4
Frequency Band [GHz]	2.4	2.4	0.867-0.869
Based Data [Mbps]	1	11	0.11
Range [m]	10	1-100	20000
Nodes	7	32	-
Power Consumption [mA]	1-35	100-350	1-10
Complexity	Medium	High	Medium
Channel Efficiency	Constant	Decreasing with offered traffic	-
Security	128 bits	WPA/WPA2	128 bits

2.4.2 Evolution of Mobile Communications from 1G to 5G

The First Generation (1G) mobile voice communication systems was introduced in 1980. These types of systems allowed the transfer of data (voice only) through waves whose shape varied continuously. This type of systems had great limitations because they are analog systems and the sound quality is poor and the transfer speed is around 9.6kbps [34].

The Second Generation (2G) systems appeared around 1990 to address the limitations of First Generation mobile communications systems. These systems are completely digital and their main features are security, reliability, efficient spectrum use and support for low-speed data transmission services. The most popular 2G mobile technology is GSM. The Second and Half Generation (2.5G) mobile technology served as a transition between second generation systems and third generation systems. In the 2.5G systems, some services have been introduced, which are very popular today, such as SMS, General Packet Radio Services (GPRS), Enhanced Data rates for GSM Evolution (EDGE) [34].

The 3G mobile technology aims to support a wide range of services, ranging from multimedia applications (video, audio, data) to access to various services available on the Internet. There are a number of technologies that fit into 3G systems, including Universal Mobile Telecommunication System (UMTS), Wide-Band Code Division Multiple Access (W-CDMA), Evolution-Data Optimized (EV-DO) and High Speed Packet Access (HSPA) [34].

The Fourth Generation (4G) has improved the 3G systems and is associated with a set of advantages that equip the experience of using the mobile services to the fixed fiber communications giving greater speed, greater bandwidth, better coverage and higher network quality. Through 4G, greater data transfer rates are achieved, as well as greater efficiency and performance in accessing services available on the Internet. Technologies such as Worldwide Interoperability for Microwave Access (WiMAX) or Long Term Evolution (LTE) were introduced to the market in 2006, and due to their evolution, have been "tagged" 4G technologies [34].

The Fifth Generation (5G) is the next generation of mobile networking technology following 4G. Much like every generation before it, 5G aims to make mobile communication faster and more reliable [34].

In Figure 2.16 can be observed the evolution of transmission rate for each technology.

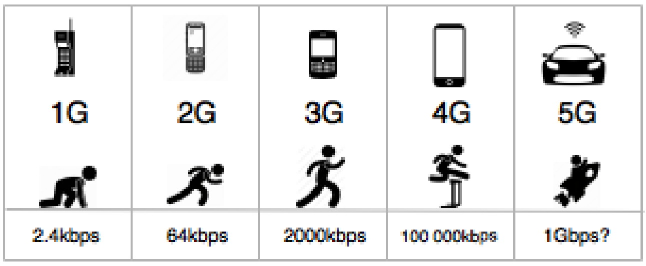
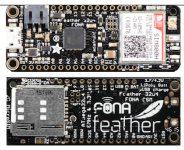
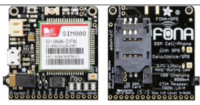
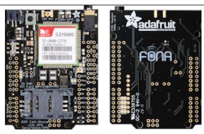
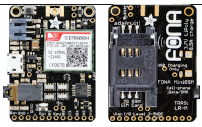
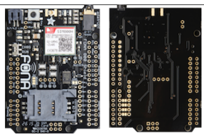
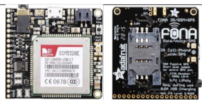
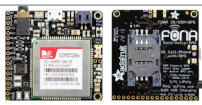


FIGURE 2.16: The Evolution of Mobile Technologies

2.4.3 Communications Hardware

There are several communication modules developed by Adafruit, in the table 2.5 their main features are detailed.

TABLE 2.5: Main Features of Adafruit FONA Hardware

Model	Dimension [mm]	SIM	SMS	Voice	FM Radio	GSM/GPRS	GPS	3G	Price [€]
FONA Feather 32u4  [35]	61 x 23 x 7	SIM800H[36]	✓	✓	✓	✓	No	No	39
FONA 808  [37]	44 x 43 x 8	SIM808[38]	✓	✓	No	✓	✓	No	43
FONA 808 Shield  [39]	69 x 54 x 4	SIM808[38]	✓	✓	No	✓	✓	No	43
FONA 800  [40]	45 x 32 x 2	SIM800H[36]	✓	✓	✓	✓	No	No	43
FONA 800 Shield  [41]	53 x 69 x 7	SIM800H[36]	✓	✓	✓	✓	No	No	35
FONA 3G European Version  [42]	50 x 46 x 7	SIM5320E[43]	✓	✓	No	✓	✓	✓	69
FONA 3G American Version  [44]	50 x 46 x 7	SIM5320A[43]	✓	✓	No	✓	✓	✓	69

The module chosen for the development of the system is the model FONA 808, as it is one of the latest versions developed by Adafruit and incorporates everything the system needs, GSM/GPRS, SMS, Voice and Global Positioning Service (GPS). The FONA 3G, was also taken into account, although, due to its higher price and that there are two different models, the European and the American, which only allow communications in the specified regions, FONA 808 was chosen, as it can be used anywhere. The FONA 3G was discarded, also because the Adafruit's library for this component is not yet fully developed [45].

2.5 Unmanned Aerial Vehicle

An Unmanned Aerial Vehicle or drone, is a controlled aircraft on all 3 axes and does not require a current pilot at the vehicle.

There are several types of UAVs such as High Altitude Long Endurance (HALE) that fly at high altitudes (15 km) and have long autonomy (24 hours flight). Medium Altitude Long Endurance (MALE) that is similar to HALE, but operates at short distances and fly at lower altitudes (5 km - 15 km).

Tactical UAVs or Tactical Unmanned Aerial Vehicle (TUAV) that are simpler and smaller than HALE and MALE and operate at shorter distances (100 km - 300 km). Mini UAVs or Miniature Unmanned Aerial Vehicle (MUAV) that are smaller than TUAVs, these UAVs are lightweight (maximum weight of 20 kg) and have even smaller range (30 km).

The Micro UAVs, also called Micro Air Vehicle (MAV), are smaller and lighter than the previous ones and can perform actions that no other UAV can perform. They require a slow flight with slow steering movements. These UAVs are commonly used for civil purposes because they are accessible, easily controllable and can perform simple actions [46].

In this dissertation, the MUAVs of the Multi-rotor type will be the type used.

2.6 Related Work

Over the years many projects have emerged in wearable context, these had several objectives such as monitoring human health or even monitoring a specific health problem.

In 2008, in Portugal, a project called Vital Jacket® (see Figure 2.17) was developed whose final product was commercialized. It was developed by the University of Aveiro and Biodevices S.A. after several years of laboratory development. Its objective is to be a vital signs monitoring system that joins fabrics with microelectronics and has the main focus the area of cardiology and sport [47].

FIGURE 2.17: Vital Jacket® [47]

The paper [48], addresses the development of wearable sensor-based systems for health monitoring. In this article it is possible to take notice of much work developed in the area, some of these works are detailed below.

In [6], the aim was to develop a generic clothing technology that successfully integrated biosensors into a shirt as shown in Figure 2.18. Therefore they developed an ambulatory device which enables the measurement of heart rate, electro dermal activity, and skin temperature with non-invasive sensors. Since they had combining parameters such as body temperature and galvanic skin resistance, they had to know about the patient's integral condition. One of the key features of their system is fall detection, which mainly arises from the complication of heart attack during which body's vitals signs changes and patient tends to collapse. This system gives a warning to prevent such complications.

FIGURE 2.18: Sugathan System [6]

Ziyu Lv in [49], described a mobile health monitoring system called iCare for the elderly. They used wireless body sensors and smart phones to monitor the wellbeing of the elderly. When detecting an emergency, the smart phone will automatically alert people's family and friends, and call the ambulance of the emergency center. It also acts as a personal health information system and a medical guide which offers one communication platform and the medical knowledge database so that the family and friends of the served people can cooperate with doctors to take care of him/her.

MyHeart is an Integrated Project of the European Union aiming to develop intelligent systems for the prevention and monitoring of cardiovascular diseases. The project develops smart electronic of textile systems and appropriate services that empower the users to take control of their own health status [50].

In 2017, a project was proposed with the objective of developing a wearable glove system to detect real-time driver stress events as shown in Figure 2.19. The driver's stress is estimated by the use of physiological signals and steering wheel motion analysis. The steering wheel motion is analyzed by the driver's hand moving characteristic. Principally, the sensors on the glove gathered the PPG signal via fingertip, and hand motion signal via inertial motion unit. The sensor module readings are transmitted to an end terminal application via a Bluetooth low energy transmission module to compute the driver stress index [51, 52].

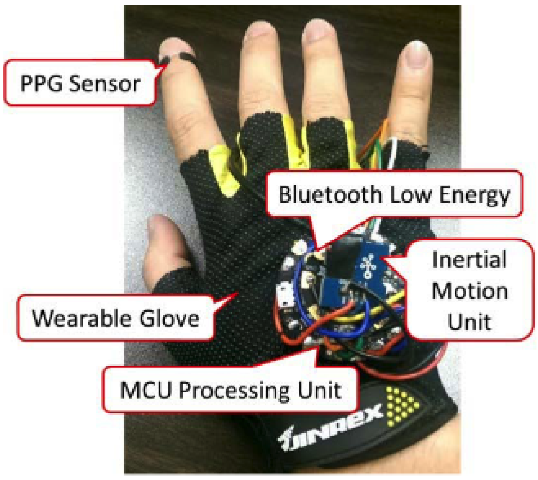


FIGURE 2.19: Lee Glove System [52]

Projects related to the detection of user failures have been developed over the years. In 2005, the Ivy Project was developed with small non-invasive sensors, Micro Electro Mechanical Systems (MEMS) accelerometers. These were placed on the waist of the user and in their home environment in order to detect the failure and thus provide a pathway to a more independent life for the elderly [53]. In 2014, a prototype of fall detection system was developed using an accelerometer and a gyroscope based on a smartphone. The accelerometer and gyroscope sensors were built into the smartphone to get the most accurate fall detection result. An automatic call is made as an alert and is sent to family members if the person using this application is in fatal condition and needs help [54].

More recently in 2017, much research was done in the area to develop a fall detection system. In this study, the pre-fall detection system that detects human falls is detected in approximately 250 ms before it occurs. The designed system monitors the user's balanced and unbalanced state. Once the imbalance state is detected, it means a fall have occurred, thus giving milliseconds of time to trigger the safety devices, such as the wearable airbag used by the subject. In case of failure, the system sends an emergency notification to the attendant using Internet of Things or Bluetooth Low Energy [55].

Related to the project under development there are also systems such as the system developed by Libelium, which has been under study for several years, comes from the evolution of an initial model called eHealth sensor platform. It was launched in the market in 2016 and is called MySignals, as in Figure 2.20 [56].

FIGURE 2.20: Evolution of eHealth System [56]

This system is very complete as can be seen in Figure 2.21, allowing to make more than 15 different measurements of biomedical parameters [56].

The data can be viewed in real time on the device or Android/iOS applications developed. Later they are sent to the cloud so that they can be consulted later [56].

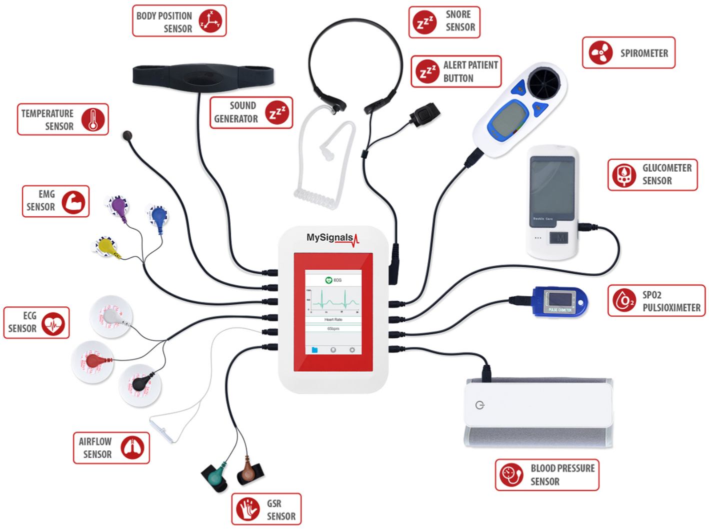


FIGURE 2.21: MySignals [56]

Known brands such as Apple, Samsung, LG and most sports brands over the past few years have developed wearable products such as smartwatches or activity trackers shown in Figure 2.22 which are basically watches with various functionalities. These, increasingly, have very high capacities in the area of health allowing to monitor the physical activity of the user and in addition also allow to obtain values of pulse, oxygen in the blood, daily step numbers, GPS position, among others. Largely, these devices have an application developed for the user's smartphone, that is, they can be connected to the smartphone and in addition the user can have access to his phone through the clock. So when connected to the mobile phone, the clock can be very useful because in case of emergency it is possible to ask for help through it. One advantage of these watches is that the battery life is very high and is easy to charge.

FIGURE 2.22: Smartwatches [57]

This dissertation stands out from other studies because it is a set of several projects in one and aims to develop a 24 hour emergency system. The system is applied to a jacket with only wearable technology with the possibility that it is removed for washing. The system, in addition to obtaining some vital data from the user, has an algorithm for the detection of falls of the same and that in case of emergency comes in contact with the user or in a more serious case contact the emergency services. There is also an online platform, which houses the data collected from the sensors that can be accessed by the user and the emergency services in real time on a server. In addition, it is possible to use an innovative feature that involves the aid of an UAV in chaotic situations, like when the ambulance is having difficulty arriving at the place or just to deliver to the user some medicine faster.

About the use of Unmanned Aerial Vehicle in the development of the dissertation, a study was carried out and some projects were found, in which cases similar to the one proposed have already been tested. In 2017, a project aimed at drones to be designed to provide some jobs with benefits, as medical drones that save lives and provide medical help. The interest in using the drones is in part because it might be faster to locate wounded in crucial areas and provide essential supplies to the incident before the medical staff arrives.

In Africa, drones are being used in hospital distribution centers. In emergency cases, doctors may order by app and wait for medical supplies to drop from the sky. The drones are characterized by Zipline's and are being operated in East Africa [58].

Recently in Portugal, during the bathing season of 2018, a life-saving drone was available. Rescue situations have been tested, in which the drone's function is to move to the person and throw a yellow packet which upon touching the water inflates in a few seconds and becomes a buoy for the castaway. The buoy serves as a helper to the person while the swimmer reaches the latter. So the swimmer's task becomes easier and calmer [59].

Chapter 3

System Description

The system presents two phases as can be seen in the Figure 3.1, the information phase that is composed by the sensors applied to the jacket and the intervention phase that is made by the emergency services.

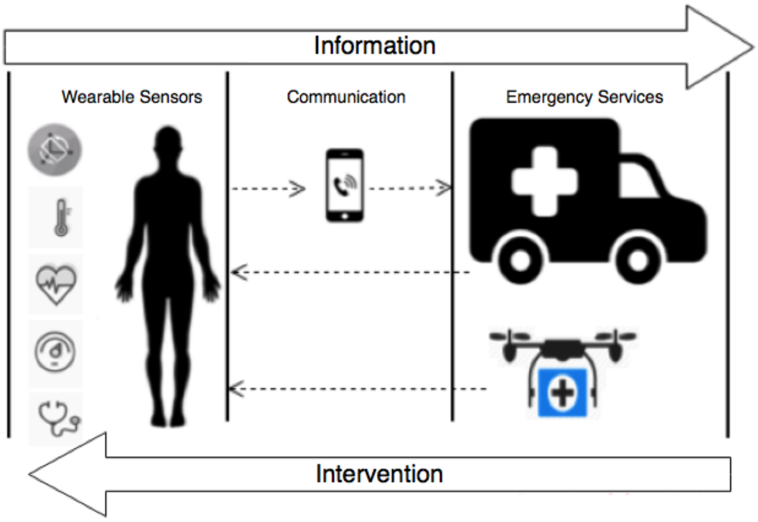


FIGURE 3.1: Information/Intervention Diagram

The first is designed through a set of sensors that make the various measurements necessary for the operation of the system, according to the proposed objective. These sensors are implemented in the jacket in a non-invasive manner, also taking into account the comfort of the user. Therefore, a conducting line is used that interconnects all these components. The intervention phase is intended to make a direct connection between the user and the emergency services, which is only activated if strictly necessary, i.e. if there are results of the sensors that exceed the limits.

The architecture of the system has four blocks as can be seen in the Figure 3.2. At the first block is represented the human or user, in which the Wearable Sensors were placed, on the jacket.

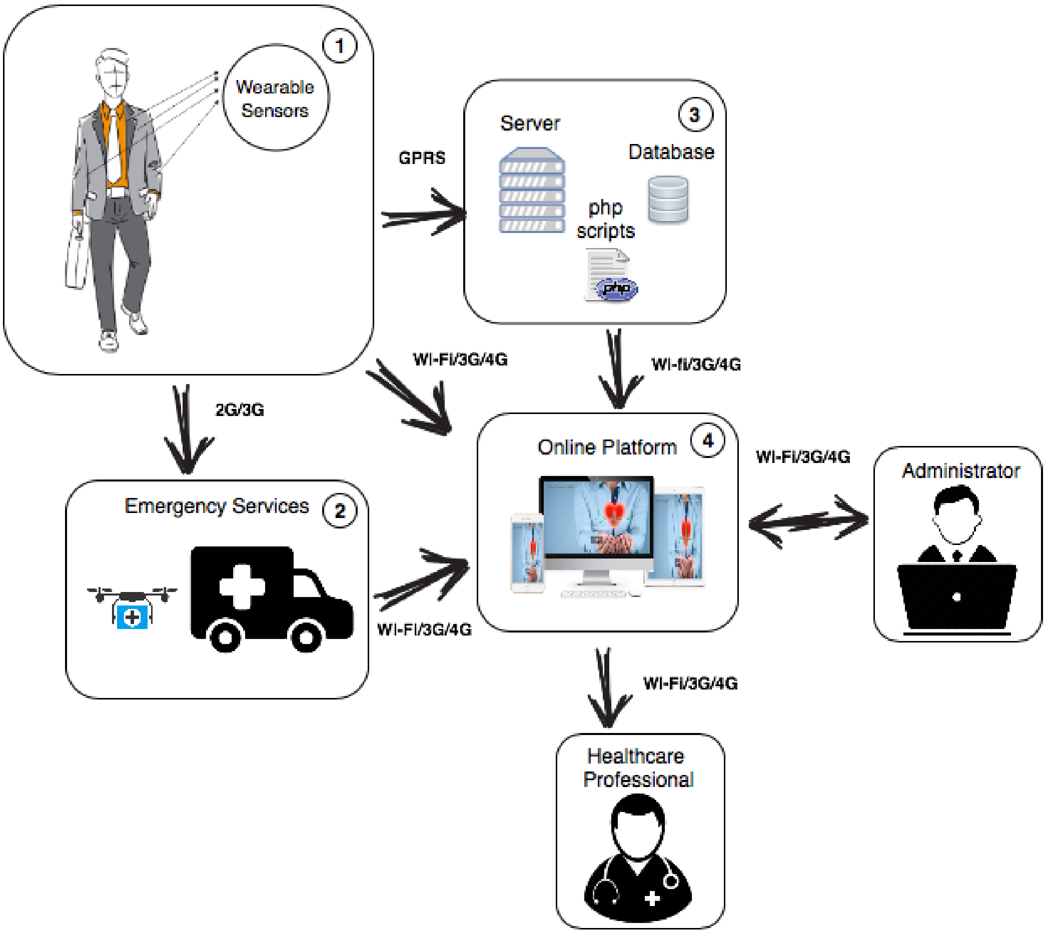


FIGURE 3.2: System Architecture

The microcontroller ATSAMD21G18 [29] contained in Circuit Playground Express, has the responsibility of obtaining data from the sensors. These will do the acquisition and processing, where the data is checked. If data is abnormal the system sends an alarm and contacts the second block, that is, the emergency services, ambulance or UAV. These will meet the user in the event of an alarm.

The third block is the server (cloud), which receives and stores the information in the database so that it can be accessed later. The software technologies used on the server side are PHP and MySQL. This allows the communication between applications.

The fourth block, represents an online platform that accesses the information in the cloud that can be viewed by the user, their health care professional and the administrator.

3.1 Hardware Components

The system hardware is responsible for the acquisitions, processing and sending of data to the server. In the system, those are pulse sensor, temperature sensor, LSM9DS0 accelerometer, microcontroller CPX and FONA, module responsible for the communication.

3.1.1 Pulse Sensor

The pulse sensor shown in Figure 3.3 can detect heart rate, which is heart rate velocity measured by the number of heart contractions per minute. This measure is non-invasive with the Photoplethysmography technique, in which a pair of emitter and Infrared light detector captures the variations of light reflected by the surface of the body.

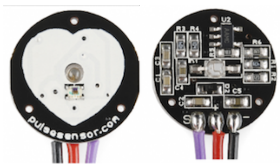


FIGURE 3.3: Pulse Sensor [60]

This sensor is called the Pulse Sensor Amped, as it is an evolution of an earlier model. The schematic of the sensor is shown in [61]. It is an open source hardware design by Joel Murphy and Yury Gitman that contains an Avago Ambient Light Sensor (APDS-9008) [62] and a Super Bright Kingbright Reverse Mounting Green Light Emitting Diode (LED) (AM2520ZGC09) [63] [60].

The heart pulse signal that comes out of a PPG is an analog fluctuation in voltage, and it has a predictable wave shape as shown in Figure 3.4. The depiction of the pulse wave is called a Photoplethysmography. Pulse Sensor Amped responds to relative changes in light intensity.

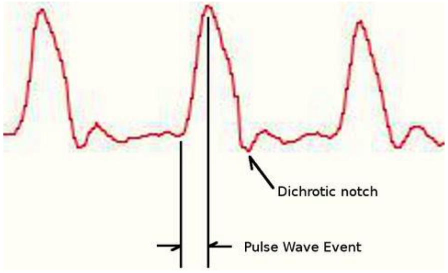


FIGURE 3.4: Predictable Wave Shape of a Heart Pulse Signal [60]

In Figure 3.5 can be seen the functioning of the sensor, through the reflection of the green light and the Photodetector.

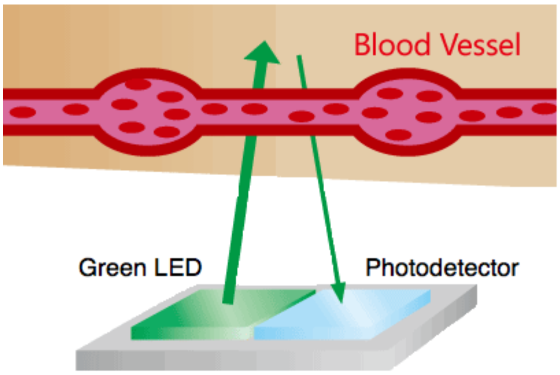


FIGURE 3.5: Pulse Detection Scheme

To obtain heart rate values, this sensor was positioned on the wrist of the jacket (see Figure 3.6) so that it can be adjusted and be in contact with the radial artery.

FIGURE 3.6: Pulse Sensor on the Wrist of the Test Jacket

In Table 3.1 the values obtained in the various possible situations, normal values, Bradycardia and Tachycardia are presented. These values are used as the basis for creating the system alarms.

Table 3.1: Pulse Values [64, 65]

	for adults:	**for children:**	**for babies:**
Normal values:	60 to 100 pulses/minute	80 to 120 pulses/minute	100 to 160 pulses/minute
Bradycardia:	less than 60 pulses/minute (< 60)		
Tachycardia:	greater than 100 pulses/minute (> 100)		

3.1.2 Temperature Sensor

This temperature sensor of Figure 3.7 is one of the Arduino LilyPad family. It is called LilyPad Temperature Sensor and consists of an MCP9700 [66] chip. The schematic of the sensor is shown in [67].

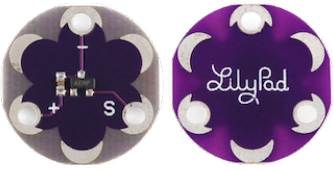


Figure 3.7: LilyPad Temperature Sensor [68]

This sensor allows to detect the ambient temperature and the temperature of the human body [68]. To obtain temperature values of human body, the sensor was positioned near the left axillary zone of the jacket as shown in Figure 3.8.

Figure 3.8: Temperature Sensor on Axillary Zone of the Test Jacket

The output of this sensor is 0.5V at 0°C and 0.75V at 25°C. With these values it is possible to convert this signal from analog to digital and the temperature value through the following formulas:

The rawTemp value is the analog value read from the sensor pin (TemperaturePin).

$$rawTemp = analogRead(TemperaturePin) \tag{3.1}$$

The voltage is obtained by the read analog value multiplied by the maximum voltage value (3.3) to be divided by the maximum Analog to Digital Converter (ADC) value (1023.0).

$$voltage = rawTemp \times \frac{3.3}{1023.0} \tag{3.2}$$

The voltage output of the sensor is linearly proportional to the Celsius temperature.

$$Celsius = (voltage - 0.5) \times 100 \tag{3.3}$$

To convert this reading to Fahrenheit, use this formula:

$$Fahrenheit = \frac{Celsius \times 9.0}{5.0} + 32.0 \tag{3.4}$$

In Table 3.2 the values obtained in the various possible situations, normal values, fever and other clinical data are presented. These values are used as the basis for creating the system alarms.

TABLE 3.2: Temperature Values [64, 65]

	for adults, children and babies:
Normal values:	36.3°C to 37.4°C
Hypothermia:	less than 36.2°C (< 36.2°C)
Fever:	37.5°C to 38.9°C
Hyperpyrexia:	greater than 39°C (> 39°C)

3.1.3 Flora LSM9DS0

The Flora LSM9DS0 shown in Figure 3.9 with LSM9DS0 [69] chip has high precision 9 Degrees of Freedom (9-DOF) sensors. The schematic of the sensor is shown in [70].

FIGURE 3.9: Flora LSM9DS0 [71]

It consists of three sensors, as shown in Figure 3.10, a classic 3-axis accelerometer, which can tell in which direction the user is towards Earth or the acceleration of the plate in Third Dimension (3D) space. Another is a 3-axis magnetometer that can detect where the strongest magnetic force is coming from, commonly used to detect magnetic north. The third is a 3-axis gyroscope that has the function of measuring the velocity [71].

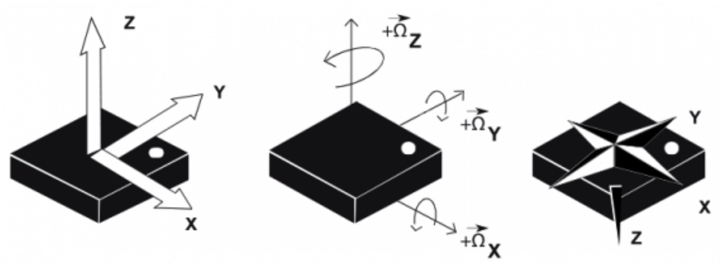


FIGURE 3.10: 3-Axis Accelerometer, Gyroscope and Magnetometer [72]

To obtain respiration values, three accelerometers were positioned to form a triangle near the diaphragm zone. The plan was to use a technique to take advantage of an existing study based on the seismocardiogram, which is a non-invasive measure of the chest vibrations caused by the heartbeat [9]. Due to the jacket not being fair to the body, by the use of accelerometers it was not possible to obtain satisfactory values of respiration. In the human body the respiration movement is almost unnoticed and less more with the rest of body's natural movement. As the accelerometers return many different values it is not possible to clearly distinct the respiration movement from the rest, as it is so small and unnoticed. To develop the seismocardiogram technique it would require much more investigation time and equipment. In this way, this would be a possible future work development.

The Flora LSM9DS0 was used in the algorithm for detecting user falls in combination with the Circuit Playground Express. The LSM9DS0 is used to predict very fast speed changes towards the Earth. They were placed in the middle of the jacket next to the area of the closure buttons of the jacket as shown in Figure 3.11.

FIGURE 3.11: LSM9DS0 in Test Jacket

3.1.4 Circuit Playground Express

This microcontroller included many sensors, such as 10 mini NeoPixels, a motion sensor (LIS3DH accelerometer), a light sensor (phototransistor), a temperature sensor (thermistor), a sound sensor (MEMS microphone), a mini speaker , two buttons, a switch, among others [30]. The schematic of the sensor is shown in [73].

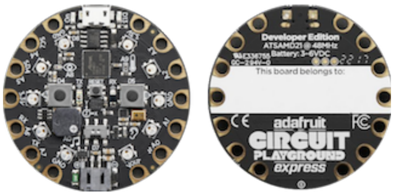


FIGURE 3.12: Circuit Playground Express [30]

This microcontroller is the main of the system, in which it has several functions, as it is responsible for obtaining the information of the sensors and processing them. It is placed in the chest area on the left side of the front of the jacket, as shown in Figure 3.13. It is placed on the outside of the jacket because it is important that the NeoPixels are visible as they are used in the event of an alarm.

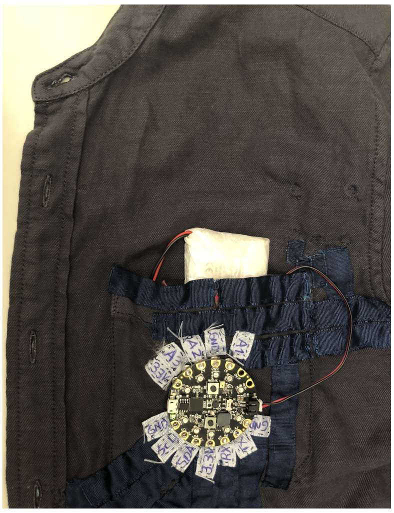


FIGURE 3.13: CPX in Test Jacket

In the processing phase it checks if the values obtained in the sensors are within the ideal values, otherwise in some situations it activates the alarm by placing the NeoPixels in flash, Figure 3.15, and uses the FONA module to send an alert message. An emergency call is made when necessary and user location is sent too.

An algorithm was developed to detect user falls through the internal accelerometer of the Circuit Playground Express and a LSM9DS0 accelerometer. As Figure 3.14 shows, the accelerometer is at the center of the microcontroller. If the user falls, the ten NeoPixels microcontrollers shown in Figure 3.15 start flashing and emit an alert sound through the microcontroller's built-in speaker, Figure 3.16, to try to ask for help from someone nearby. If the user reaches the ground without changing after a few minutes, a message is sent to the mobile phone with indication of pressing the alert buttons. If they are not pressed an emergency call is started.

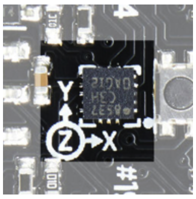


FIGURE 3.14: LIS3DH 3-axis XYZ Accelerometer [74]

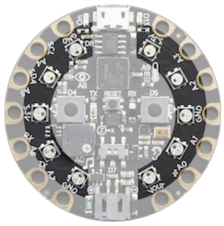


FIGURE 3.15: neoPixels [75]

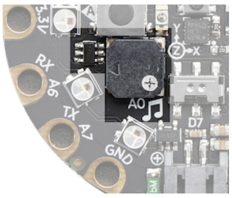


FIGURE 3.16: Speaker [76]

3.1.5 FONA 808

In Figure 3.17 it is presented a small module, which is FONA 808. At the center is a GSM cellular module (SIM808)[38] that allows connection to any global GSM network with any Subscriber Identity Module (SIM). It is possible to make and receive calls using a headset or a speaker, and also send and receive text messages, such as sending and receiving data via GPRS [37]. The schematic of the sensor is shown in [77].

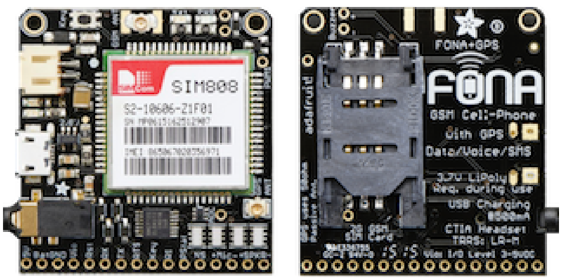


FIGURE 3.17: FONA 808 [37]

To operate the module it is needed a LiPoly battery - 500mAh or more, a GPS antenna and a GSM antenna, which are respectively found in Figure 3.18, Figure 3.19 and Figure 3.20.

Figure 3.18: GPS Antenna [78]

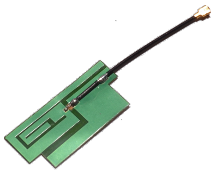


Figure 3.19: GSM Antenna [79]

Figure 3.20: Lithium Ion Polymer Battery 3.7v 1200mAh [80]

To make voice calls, a loudspeaker and a microphone have been added as shown in the figures, respectively 3.21 and 3.22. These were sewn into the collar area of the jacket.

Figure 3.21: Mini Metal Speaker [81]

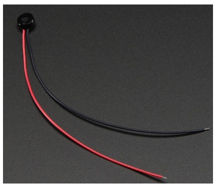


Figure 3.22: Wired Miniature Microphone [82]

The FONA module is placed in the inside of the jacket just below the CPX microcontroller (see Figure 3.23).

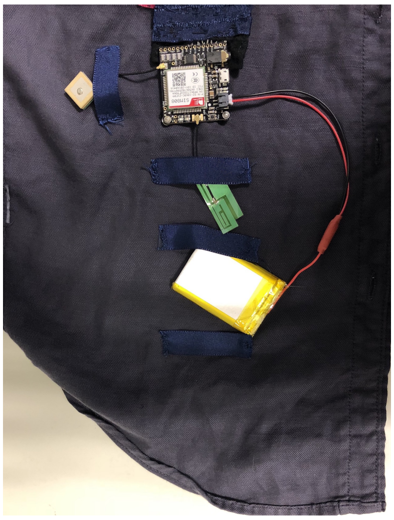


Figure 3.23: FONA 808 in test jacket.

3.2 Prototype

The system, consisting of several elements, has as its final objective the develop of a prototype of a jacket with applicability in the civil and military market, being able to have various styles and specificities, e.g., casual, etc.

The prototype scheme that was developed is presented in Figure 3.24.

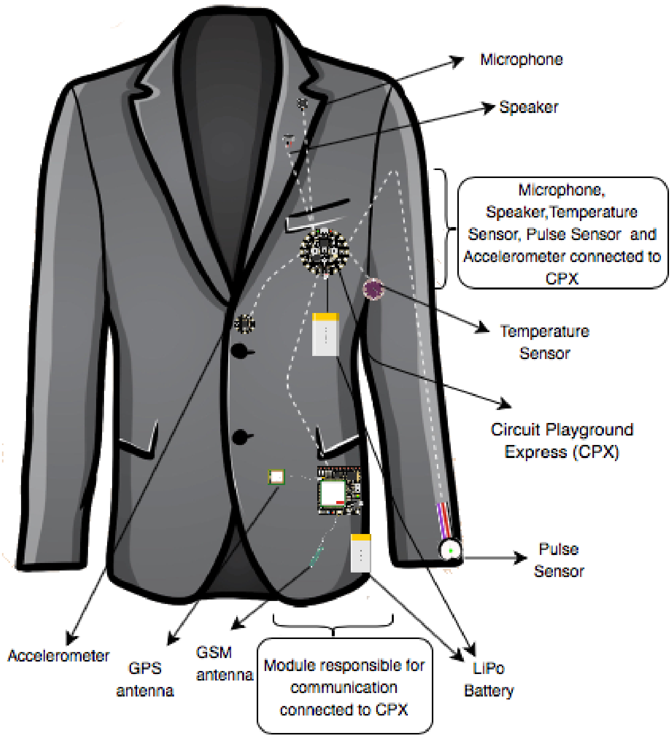


FIGURE 3.24: Prototype Scheme

Care was taken to have the electronics placed near the pockets of the jacket, so that the batteries, the antennas, and the FONA could be hidden. Since the CPX has to stay in sight so that the alarms can be seen through the NeoPixels, all other electronics can be hidden. The pulse sensor lies inside the jacket sleeve to the wrist, the temperature sensor is in the armpit zone inside the jacket and the accelerometer is also placed in the position described in the picture, but inside the jacket.

As can be seen from the legend shown in Figure 3.24, the CPX microcontroller is connected to FONA by Receive/Transmit (RX/TX), i.e. basically by a RX/TX based communication protocol.

The CPX is the microcontroller responsible for obtaining sensor data. The connection with the FONA module allows data to be sent to the server as well as to the emergency systems are, if necessary, alerted i.e., the FONA module is the microcontroller responsible for the part of communication, connection and sending of data to the server. It is also responsible for obtaining and submitting the user location. The data obtained are temperature and pulse. An algorithm was developed in the CPX for position detection and for the detection of user falls.

3.3 Conductive Thread and Sewable Snaps

For the connection of all the hardware it is used a conductive line, Figure 3.25, and sewing snaps, Figure 3.26.

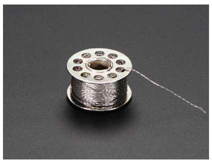


FIGURE 3.25: Conductive Thread [83]

FIGURE 3.26: Sewable Snaps [84]

The conductive line is from Adafruit and is type 2 ply stainless thin thread. This line is strong and made entirely of stainless steel. Stainless steel fibers do not oxidize like silver, i.e. the project can be washed and does not run the risk of ceasing to function [85]. For this project it has been chosen the type of 2 ply because the system will be sewn by hand, and this is most the indicated as the other line types are equal to and greater than 3 ply.

The use of the snaps allows to remove all the electronics from the jacket, Figure 3.27, making it washable. If any component fails, it is also easier to replace.

FIGURE 3.27: CPX with Snaps in Jacket

3.4 Miniature UAV (MUAV)

A Miniature UAV, also called SUAS, was used to simulate a situation of emergency. This type of drones weight less than 25 kg. The drone used can be seen in Figure 3.28.

FIGURE 3.28: MUAV

The UAV is composed by various components, as can be seen in Figure 3.29, the main structure contains the battery, a Raspberry Pi, Ublox and a ArduPilot Mega 2.6 (Firmware: ArduCopter).

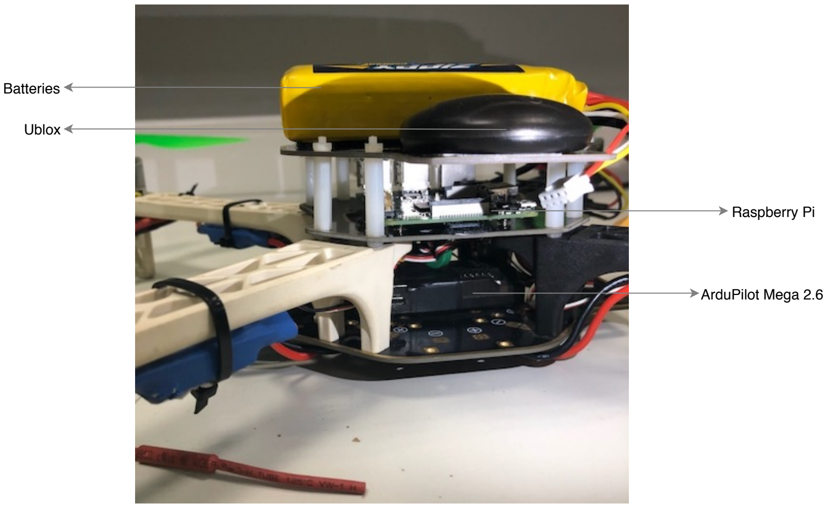


FIGURE 3.29: MUAV Components

For the system operation the drone main goal is to move towards the user, allowing medical care to act faster. The drone has a Raspberry Pi with connection to the server in order to get the coordinates of the user. The Ublox used in the drone has the function of making the drone move to the user using the last coordinates on the server.

3.5 System Consumption

In the Table 3.3 it is possible to observe some characteristics of the sensors, such as dimensions, voltage, consumption and approximate price. These sensors were chosen mainly because of their small size and competitive price.

TABLE 3.3: Main Features of the Hardware

Model	Dimension [mm]	Voltage [V]	Consumption [mA]	Price [€]
Pulse Sensor	15.88	3-5	4	21
LilyPad Temperature	20	3-5	10	3
Flora LSM9DS0	16	3	10	17
CPX	50.6	3.3	200	22
FONA 808	44 x 43 x 8	3-5	200	43

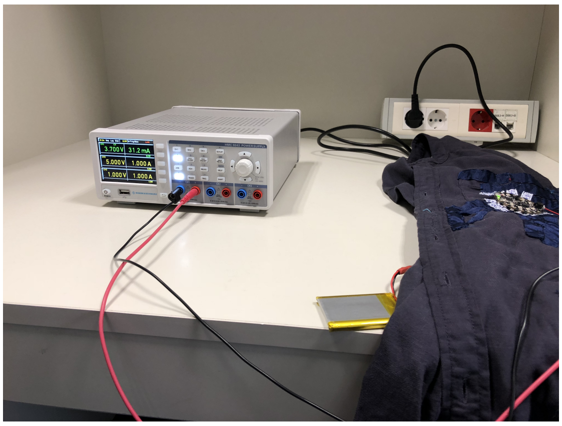


FIGURE 3.30: System Consumption Analysis

To determine the system consumption, calculations were made based on formula 3.5, where the *Duration* is in hours (h), the *Capacity* in mAh and the *Electric Current* in mA:

$$Duration = \frac{Capacity}{ElectricCurrent} \tag{3.5}$$

CPX has a battery of 1800 mAh and the estimated electric consumption during approximately one hour of test was approximately of 31 mA, so, in the system this battery has a maximum duration of 58 hours 3 minutes and 36 seconds.

$$Duration = \frac{1800}{31} = 58.06 \text{ h} \tag{3.6}$$

FONA has a battery of 2000 mAh and the estimated electric consumption during approximately one hour of test was approximately of 42 mA, that is, this battery has a maximum duration of 47 hours 37 minutes 12 seconds.

$$Duration = \frac{2000}{42} = 47.62 \text{ h} \tag{3.7}$$

Assuming that the user wears the jacket from 9am to midnight, and therefore, for 15 hours, it is estimated how many days the user could use the jacket without charging the batteries.

For 15 hours, CPX battery consumes:

$$15 = \frac{Capacity}{31} \Leftrightarrow Capacity = 465 \text{ mAh} \tag{3.8}$$

In the case of the FONA battery, for 15h, it would consume:

$$15 = \frac{Capacity}{42} \Leftrightarrow Capacity = 630 \text{ mAh} \tag{3.9}$$

In sum, the battery of the CPX when spending 465 mAh for 15h use, to discharge the whole battery of 1800 mAh, it would be necessary 3.8 days, that is, 3 days, 20 hours and 52 minutes. In the case of the FONA that consumes 630 mAh for 15h to discharge the battery of 2000 mAh it would take 3.17 days, that is, 3 days 4 hours and 5 minutes.

Chapter 4

Software

This chapter describes the server side and how communications are performed between the server and existing applications (Arduino and Online Platform). Also described is the software developed in Arduino. Finally, it describes the application, which is a website, and the types of users.

4.1 Server Side

4.1.1 Remote Server

The server available for the development of the dissertation is a remote server. The server is of type LAMP, as shown in Figure 4.1 and means:

FIGURE 4.1: LAMP

- **L**inux - Operation System;
- **A**pache - Apache HyperText Transfer Protocol (HTTP) Server;
- **M**ySQL - Database Server;
- **P**HP - Programming Languages;

The server is responsible for storing all patient data, the account created on the online platform as well as the vital data received through the software developed in Arduino. This way it is possible to access and analyze this information in the future through the online platform.

In order to communicate between the software developed in Arduino and the server, a Web service called Representational State Transfer (REST) is required. This Web service aims to respond to requests made by the client, i.e., accept and respond to HTTP requests, Apache is the server responsible. Content sent by the Web server in response to a HTTP request can have two types:

- **Static** pages, where the content comes directly from an existing file on the server and will always be the same.
- **Dynamic** pages, where content is created dynamically by a program or script called by the server.

In this work the dynamic pages are used to process the customer's request, access the database and send the information through scripts. These are performed in PHP language which is a language developed on the server side for Web development purpose.

After custom applied, a File Protocol (FTP) session is required to upload PHP scripts. This is done by using a FTP client called FileZilla, which allows connection with remote server. In Figure 4.2 it is shown the work folders on the server.

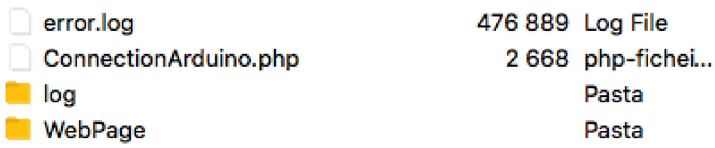


FIGURE 4.2: Folder Organization in Server

- **PHP File ConnectionArduino:** It is the PHP file that receives the data by the POST of the software developed in Arduino, treats it and sends it to the database on the server. It is the only file that connects the entire system with the server, Arduino, database and online platform.
- **Folder log:** This folder (see Figure 4.3) contains a text file containing the data obtained from the software developed in Arduino.

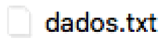


FIGURE 4.3: Content of Log Folder

- **Folder WebPage:** This folder contains PHP files dedicated to the online platform. These PHP files are separated by folders (see Figure 4.4).

FIGURE 4.4: Content of WebPage Folder

4.1.2 Database

Initially a system analysis was performed to find out what kind of data the database should hold. The database was developed in MySQL using the phpMyAdmin tool. In Figure 4.5 the diagram of the database is represented.

The diagram consists on four tables:

- **Utilizador:** This table stores user account data. The user personal information, such as nome, apelido, idade, genero, email, numero. The codigo and password fields are present in the table because they serve as the credentials for the user login. The code in the table corresponds to the code inside the jacket, which is unique. The primary key is codigo.

- **Dados:** It is in this table that the data corresponding to the temperature, breath and pulse of the user are stored. The id_dados, data and hora fields are also present in the table because in each data message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the data belongs. The primary key is id_dados.

- **Quedas:** It is in this table that the data corresponding to the user falls is stored. The id_quedas, time, and date fields are also present in the table because in each fall message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the data corresponds. The primary key is id_quedas.

- **Localizacao:** It is in this table that the latitude, longitude and altitude data corresponding to the user's location are stored. The id_localizacao, date, and time fields are also present in the table because in each location message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the location belongs. The primary key is id_localizacao.

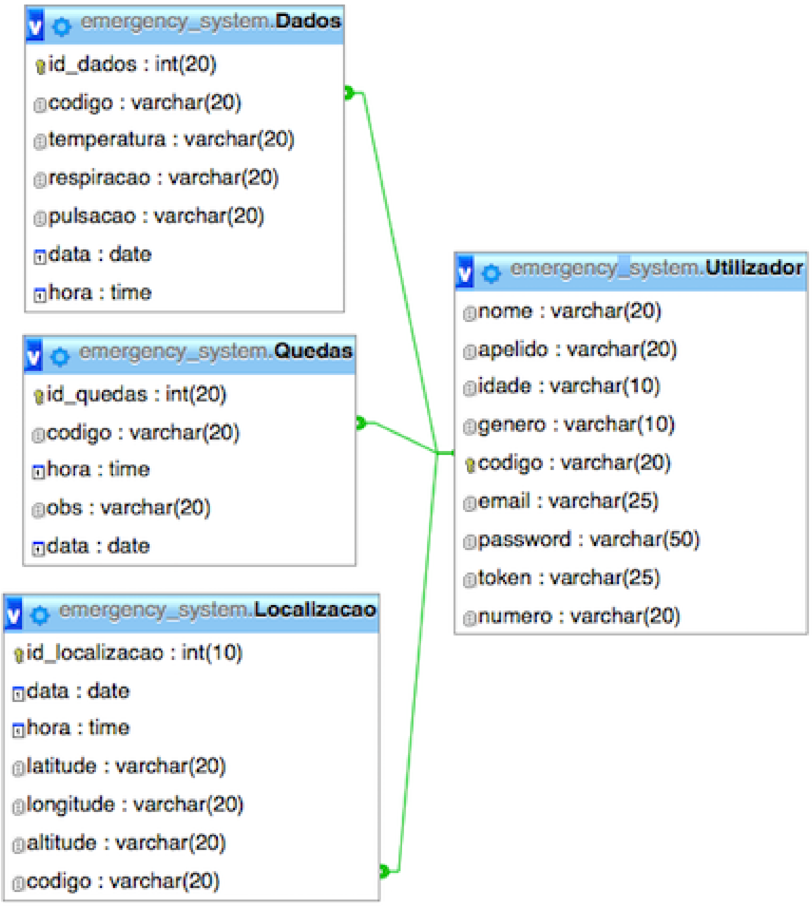


FIGURE 4.5: Diagram of Database

4.1.3 PHP Scripts

PHP is an open source scripting language, especially suitable for web development and can be placed inside HyperText Markup Language (HTML). PHP scripts are required to perform communication between the software developed on Arduino, the server and the online platform. These scripts are hosted on the server.

The use of scripts occurs when there is communication between the client and the server, where the communication protocol called HyperText Transfer Protocol (HTTP) is used.

HTTP functions as a request-response protocol in the client-server computational model, as shown in Figure 4.6.

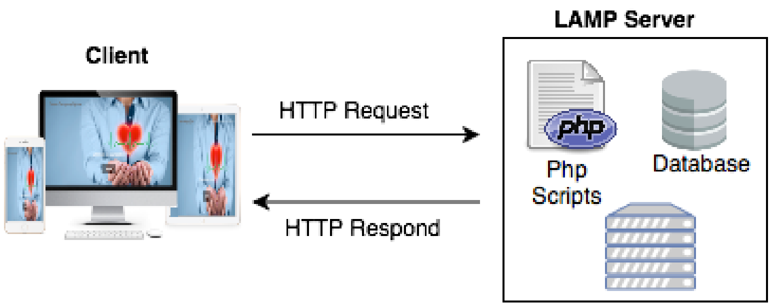


FIGURE 4.6: HTTP Request/Respond

For this project several PHP scripts were developed. For the communication between the software developed in Arduino and the server the following script is used:

- **ConnectionArduino.php:** This script is responsible for sending sensor data to the server. Through this script, the data is stored directly in the database so that it can be consulted on the online platform.

In the case of the online platform, the following developed scripts are the most important for the application goal:

- **db.php:** This is the script responsible for connecting to the database. All PHP files that need access to the database require this script.
- **db_login.php:** This script checks the login, that is, it checks if any filled fields are incorrect or if the user is in the database.
- **dados.php:** Upon successful login, the user is redirected to his data page, created through the data collected from the sensors. This script is responsible for displaying a daily chart of data such as showing the last data message stored in the database.

- **localizacao.php:** This script returns a list of user positions throughout the day. In each location message listed it is possible to observe through a Google Maps API the exact location of the user on the map.
- **alertas.php:** The data obtained from the sensors is processed through this script. In case of irregular values, the data is listed in a table for the user to consult.
- **historico.php:** Through this script it is possible to list and obtain the graphic of the daily data of a certain day that exists in the database.
- **index.php:** This file, which is inside the WebPage folder, is the central script of the entire website. This is responsible for the interconnection of all the scripts that are inside the WebPage folder, that is, all the previously spoken files and others.

In Figures 4.7, 4.8, 4.9, 4.10 and 4.11 is the developed ConnectionArduino.php file divided into five parts to make it simpler to explain its content. This file has been chosen because it is responsible for the interconnection of the software developed in Arduino, the database and the website.

Initially a PHP file is opened and the script is waiting for a POST request. When the POST arrives it is called the deliver_response function that receives the data in JSON format. The data is printed to a text file called data.txt that is placed in the folder called log (see Figure 4.7).

```php
<?php
if(isset($_POST)) {
 deliver_response(200, "success", $_POST);
}
function deliver_response($status, $status_message, $data) {
 header("HTTP/1.1 $status $status_message");
 $response['status'] = $status;
 $response['status_message'] = $status_message;
 $response['data'] = $data;

 $post_data = file_get_contents("php://input");
 $json = json_decode($post_data, true);
 echo $post_data;
 $uplink = $json['DevEUI_uplink'];

 $filename = 'dados.txt';
 file_put_contents('log/' . $filename, print_r($post_data, true));

}
```

FIGURE 4.7: ConnectionArduino.php File Part1

The connection to the database is made with all the necessary fields. Then all variables for processing the data are started, including the day and the time of arrival of the POST request. The file dados.txt is opened for reading and the size of the file is checked because when the first reading is made the contents of the file are erased, thus avoiding null data being sent to the database. Data is separated by commas, so the data is read and processed for the given variables (see Figure 4.8).

```
$conn = new mysqli(            ,         ,              ,                  );
if ($conn->connect_error) {
  die("Connection failed: " . $conn->connect_error);
}

$data; $hora; $latitude; $longitude; $altitude; $codigo; $today = date("Y-m-d");
$time = date("H:i:s", time()+1*3600); $temperatura; $pulsacao; $respiracao;
$arquivo= fopen("./log/dados.txt", "r");
$fsize = filesize("./log/dados.txt");
$id = " ";

if($fsize == 0){
}else{
   while(($linha = fgets($arquivo))!== false){
      $valores = preg_split("[,]",$linha);
      $data = $today;
      $hora = $time;
      $latitude=$valores[0];
      $longitude=$valores[1];
      $altitude=$valores[2];
      $codigo=$valores[3];
      $temperatura=$valores[4];
      $respiracao=$valores[5];
      $pulsacao=$valores[6];
      $obs=$valores[7];
   }
```

FIGURE 4.8: ConnectionArduino.php File Part2

In the case that the user falls before any pulse or temperature values are measured, those values are zero. There is a check to verify if this values are null. The code, date, and time data for the Data table are checked if they are already in the table so that there are no duplicates. If they do not already exist, the new temperature, pulse, breath and respective code, date and time data are added. The id that is in the table is automatically added by the database because it is the identifier of the new element that was added to the table (see Figure 4.9).

```
if($temperatura == "0" || $pulsacao == "0"){
 }else{
  $stmt = $conn->prepare('SELECT * FROM Dados WHERE codigo=? AND data=? AND hora=?');
  $stmt->bind_param('sss',$codigo,$data,$hora);
  $stmt->execute();
  $stmt->store_result();
  $stmt->bind_result($db_id,$db_codigo,$db_temperatura,$db_respiracao,$db_pulsacao,
  $db_data, $db_hora);
  $row = $stmt->fetch();
  if($stmt->num_rows==1){
  }else{
     $sql = "INSERT INTO Dados VALUES ('$id','$codigo','$temperatura','$respiracao',
     '$pulsacao','$data','$hora')";
     if ($conn->query($sql) === TRUE) {
     } else{
         echo "Error: " . $sql . "<br>" . $conn->error;
     }
  }
 }
```

FIGURE 4.9: ConnectionArduino.php File Part3

The latitude and longitude data may come empty from the Arduino because there are some cases where it is not possible to obtain GPS signal, then this verification is made. When data is available, it is checked if it already exists in the table so that no repeated data occurs. If they do not exist, the data, date, time, latitude, longitude, altitude and code data are added to the table. The id that is in the table is automatically added by the database because it is the identifier of the new element added to the table (see Figure 4.10).

```
if($latitude == "" && $longitude == ""){
 }else{
  $stmt = $conn->prepare('SELECT * FROM Localizacao WHERE codigo=? AND data=?
   AND hora=?');
  $stmt->bind_param('sss',$codigo,$data,$hora);
  $stmt->execute();
  $stmt->store_result();
  $stmt->bind_result($db_id,$db_data,$db_hora,$db_latitude,$db_longitude,
  $db_altitude, $db_codigo);
  $row = $stmt->fetch();
  if($stmt->num_rows==1){
  } else{
     $sql = "INSERT INTO Localizacao VALUES ('$id','$data','$hora','$latitude',
     '$longitude','$altitude','$codigo')";
     if ($conn->query($sql) === TRUE) {
     } else{
         echo "Error: " . $sql . "<br>" . $conn->error;
     }
  }
 }
```

FIGURE 4.10: ConnectionArduino.php File Part4

Obs, that is, observations data refers to user falls situations. This situation does not always occur so the field may come empty from the Arduino. When data occurs, it is checked if it already exists in the table so that repeated data does not occur. If it does not exist, code, time, obs, and date data will be added to the table. The id that is in the table is automatically added by the database because it is the identifier of the new element added to the table.

Finally, the file is read, the connection to the database and the PHP file are closed (see Figure 4.11).

```
     if($obs == ""){
      }else{
       $stmt = $conn->prepare('SELECT * FROM Quedas WHERE codigo=? AND data=? AND hora=?');
       $stmt->bind_param('sss',$codigo,$hora,$data);
       $stmt->execute();
       $stmt->store_result();
       $stmt->bind_result($db_id,$db_codigo,$db_hora,$db_obs,$db_data);
       $row = $stmt->fetch();
       if($stmt->num_rows==1){
       }else{
          $sql = "INSERT INTO Quedas VALUES ('$id','$codigo','$hora','$obs','$data')";
          if ($conn->query($sql) === TRUE) {
          }else{
            echo "Error: " . $sql . "<br>" . $conn->error;
          }
       }
    }
  }
  fclose($arquivo);
  $conn->close();
?>
```

FIGURE 4.11: ConnectionArduino.php File Part5

4.2 Arduino IDE

The chosen hardware is compatible with the Arduino IDE software, so this was the software chosen for the development of the system. The developed code is in C/C++ and the libraries of each component are used.

4.2.1 Implementation

The diagram shown in Figure 4.12 illustrates the initialization phase of all components.

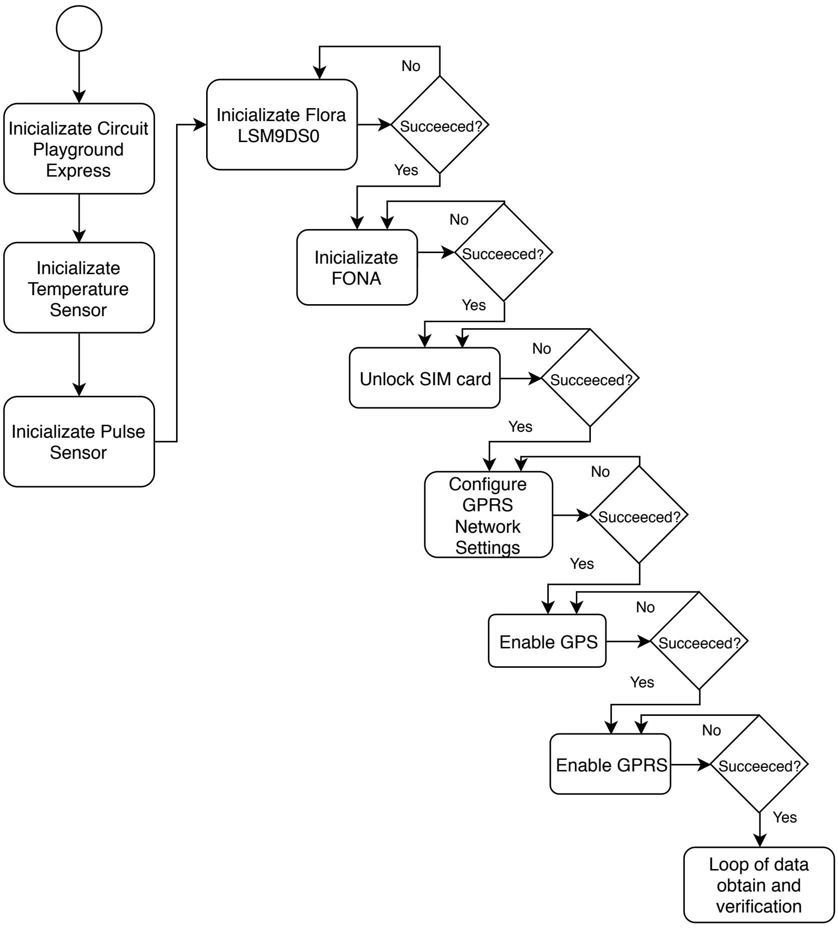


FIGURE 4.12: Arduino Activity Diagram

Initially, components that do not require configuration are started, the Circuit Playground Express, temperature and pulse sensor. Flora LSM9DS0 and the FONA module must be successful at startup. The LSM9DS0 is connected by SDA/SCL to the Circuit Playground Express, i.e., it is necessary to establish communication between them. In relation to the second, it necessarily requires a GSM antenna and a 3.7 V battery connected to it and therefore checks before starting.

The Flora LSM9DS0 requires setting the accelerometer range between $\pm 2, 4, 6, 8$, or 16 g, using 2 g. It is also necessary to set the gain of the magnifier between $\pm 2, 4, 8$, or 12 gauss, using 2 gauss. Finally it is necessary to choose the gyroscope scale between 245 or 500 DPS, using the 245 DPS. The FONA module needs to unlock the SIM card with its Personal Identification Number (PIN) code. It is also necessary to configure the network for the SIM card operator. Next GPS and GPRS are enabled.

Finally the system enters the loop to get the data and verify it.

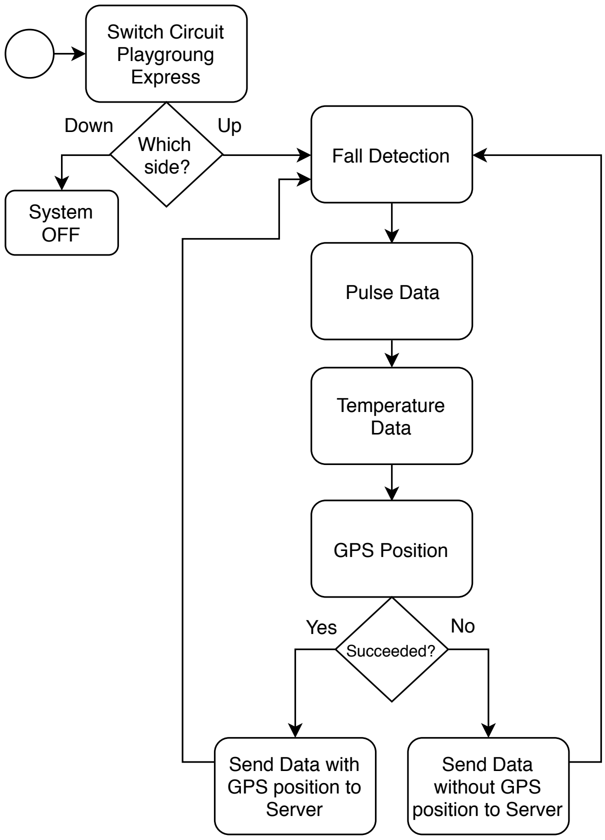


FIGURE 4.13: Arduino Activity Diagram

The diagram shown in Figure 4.13 illustrates the last process, obtaining data and verifying values loop, exemplified in the diagram of Figure 4.12.

When putting on the jacket the person has to check the position of the CPX switch. The switch position down means the system is off. That is, for the system to be in operation the user has to put the switch up. When the user does this the system starts. Data is fetched and sent to the server in intervals of about ten minutes. When the system is started, it starts by checking the body position of the user, this check is done by the second, interleaving with the acquisition of the sensor data.

The fall detection algorithm works through the analysis and interconnection of the data obtained by the CPX internal accelerometer and by an LSM9DS0. From the CPX of accelerometer, values are taken for the x, y, and z axes while in LSM9DS0 only gyro values of the x axis was required.

TABLE 4.1: CPX and Gyroscope Fall Values Range

	X	**Y**	**Z**
CPX	≤ 1	-	-
Gyroscope	$\leq$ -200 or $\geq$ 200	-	-

According to table 4.1, for CPX and LSM9DS0 when values of x are within those values the system assumes that the person has fallen. It is given a time of approximately 20 seconds to detect if the person has really fallen. If the values are according to the table 4.2 the person fell back, and if they are according to the table 4.3 the person fell forward.

TABLE 4.2: Range of CPX Values for Back Fall

	X	**Y**	**Z**
CPX	-	-	$\leq$ 10 and $\geq$ 8

TABLE 4.3: Range of CPX Values for Front Fall

	X	**Y**	**Z**
CPX	-	-	$\geq$ -10 and $\leq$ -8

If the X values of the CPX remain for 1 minute within the values of the table 4.4, the system assumes that the person remains on the ground and during that time the CPX has the 10 neopixels flashing and emits an alert sound. At the end of this time without changing the position of the user a text message is sent to the user's personal cell phone asking him to press the CPX buttons until the neopixels are cleared, there is two minutes after sending the message to do so. If the user clicks the buttons the system assumes that everything is fine and continues the cycle normally. If the user does not press the buttons, the system assumes that it is necessary to act and create an emergency call. The user can communicate with the emergency services because the jacket has a loudspeaker and a microphone near the user's face. The user's coordinates are sent by text message to the emergency services.

TABLE 4.4: CPX Values Range for Fall Detection Confirmation

	X	**Y**	**Z**
CPX	≤ 5	-	-

The temperature is withdrawn five times, i.e., it is withdrawn more or less every two minutes. After obtaining the temperature data, it is checked whether the value is inside or outside the acceptable values. If the values are out of acceptable range, the user is notified of the status of the values, as can be seen an example in Figure 4.14.

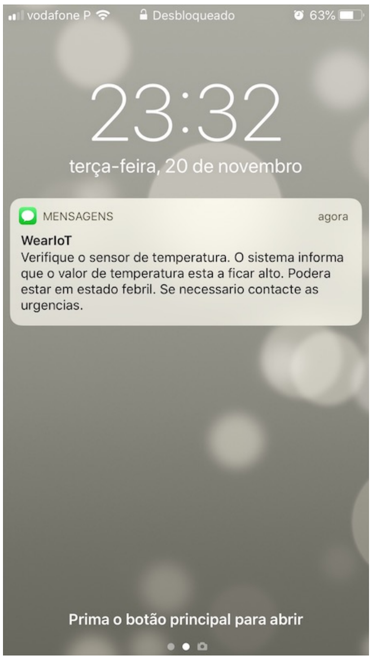


FIGURE 4.14: User SMS Notification

If the values are either too high or too low from the acceptable values an emergency call is created. The same situation applies to the pulse sensor. In relation to GPS, sometimes it is not possible to obtain results in closed places.

When the timer reaches 10 minutes, the data is sent to the server. If there are no GPS position values, the data is sent without position to the server. After that, the beginning of the cycle is returned as shown in Figure 4.13.

4.2.2 Alarms

The alarms developed serve as a warning to the user. There are two types of alarms, via SMS and via call. The purpose of the SMS is to alert the user that something may not be correct, one example of that is asking the user to check his jacket because some sensor may be misplaced. The call is created for emergency services that come in direct contact with the user. The system is responsible for sending a SMS to the emergencies with the user's GPS location. In this way, emergency services can move to the user.

These alarms are made through the software developed in Arduino. But they are also done on the server side. After accessing user data in the database, notifications are also made and displayed on the alerts page. Having as a basis Table 3.2 and Table 3.1, alarms are made according to Table 4.5 and Table 4.6.

TABLE 4.5: Alarms Temperature Values

State	**Range of Values [°C]**	**Form of Action**
Critical Zone	≤ 29	Call
Hypothermia	≥ 30 and ≤ 36	SMS
Feverish State	≥ 37.5 and ≤ 38	SMS
Fever	≥ 38.1 and ≤ 39.9	SMS
Hyperthermia	≥ 40 and ≤ 42.5	SMS
Critical Zone	≥ 42.6	Call

The temperature values presented in table 4.5 have six different alarms. The alarms made per call are when the user is in a critical, worrying situation, therefore the emergency services are contacted immediately. The messages serve as a notification to the user, for him to have knowledge that some value is not correct. Therefore, the system advises that, if the user finds it necessary, to contact the emergency department.

TABLE 4.6: Alarms Pulse Values

State	**Range of Values [bpm/minute]**	**Form of Action**
Critical Zone	≤ 55	Call
Bradycardia	≥ 56 and ≤ 60	SMS
Tachycardia	≥ 111 and ≤ 179	SMS
Critical Zone	≥ 180	Call

Pulse values shown in table 4.6 have four alarms. Two of them are made via call because they are when the user is in the critical zone and may need help. The other two are via SMS and serve as notification to the user to know that something may not be correct at the moment.

As there may be cases where the user has pulse rate values higher than those in the table 3.1 (for example in physical activity sometimes up to around 200 beats per minute) an adjustment was necessary so that false alarms do not occur.

Fall alarms have been addressed previously. In case of fall, the user is notified initially by SMS so that the system notices the severity of the fall. If the user responds to the system by pressing the indicated buttons, the alarm is deactivated. Otherwise the system creates an emergency call.

4.3 Website

The application developed for the system is a site and it will be discussed below what are its main functions for the user, how it was implemented and what resources it uses. It is also important to discuss the users of this site.

The website developed is available on the following link:

https://sandbox.skyverse.pt/miriam/WebPage/

To access the main functionalities available on the website, the access data below can be used:

Código do Casaco: **64825**

Password: **WearIoT18**

4.3.1 Implementation

The homepage of the website as can be seen in Figure 4.15, just like the whole platform was designed to be user friendly and attractive.

The website was developed as a working tool to allow the user to monitor his temperature, heartbeat and breathing data throughout the day. The choice of a website platform is because it is possible to access on any device, for example iOS, Android or Windows and there is no problem being on computer, tablet or mobile phone, it is compatible with all, being easier to access by anyone. In order to use the site, the device must have access to the Internet, that is, it is needed a mobile or Wi-Fi network to access it.

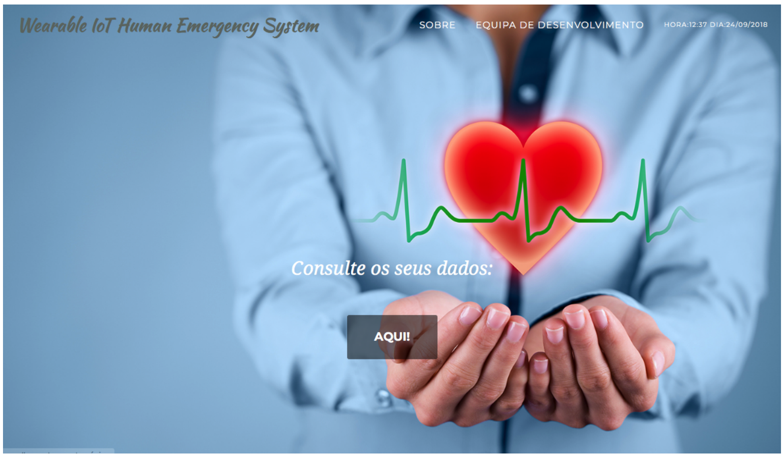


Figure 4.15: Homepage

It does not require pre-installation, initially it is only necessary to create an account, as seen in Figure 4.16, with the user's personal data and the code that is inside the jacket. In Figure 4.17 an example sketch of the code inside the jacket is represented.

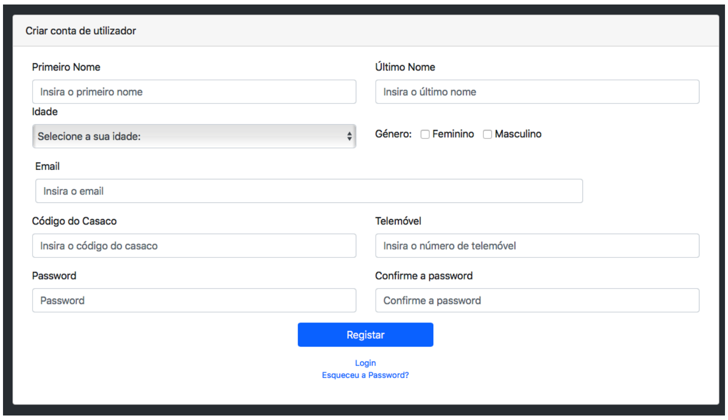


Figure 4.16: Create an Account

Figure 4.17: Sample Sketch of the Code Inside the Jacket

Then it is only needed to login, (Figure 4.18), with the jacket code and password chosen to be able to access the user's data.

FIGURE 4.18: Login

When the user logs in he is redirected to his data page which is shown in Figure 4.19. This data is shown by using a graph that is updated as new data is collected from the sensors.

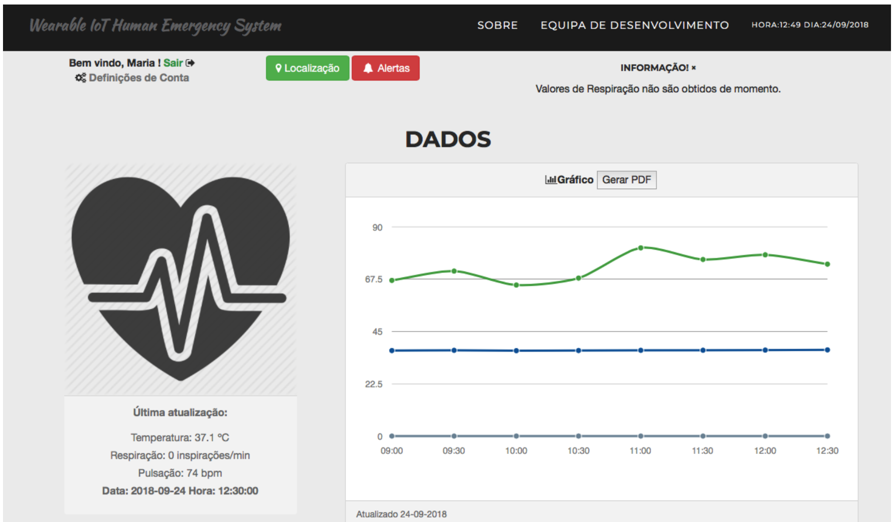


FIGURE 4.19: User Data

On this page it is possible to change the user settings. It is also possible to access the location and alerts page.

By clicking the heart icon, it is possible to check the data history for another day.

The location of the user is also queried through the platform (Figure 4.20). There is a list with the coordinates of the user throughout the day with the user's last location shown on the map to the side. By clicking the times available in the list, it is also possible to check the location where the user was at that specific time.

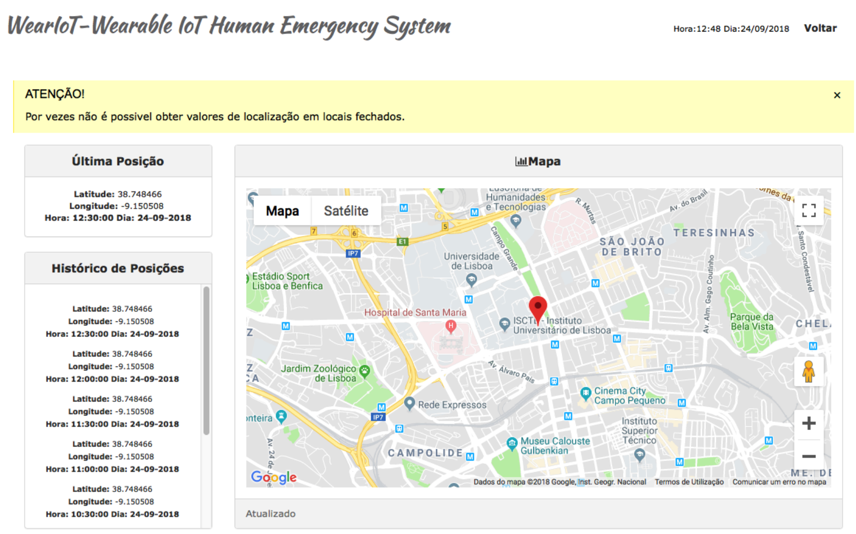


FIGURE 4.20: User Location

In the alerts page (Figure 4.21) only the alarming data is recorded. These data is outside the stipulated limits. The user can query the data through notifications that occur or through a table. The table only shows more severe values. It is also possible to know the daily log of user falls which is recorded in a table with the respective time to which it occurs.

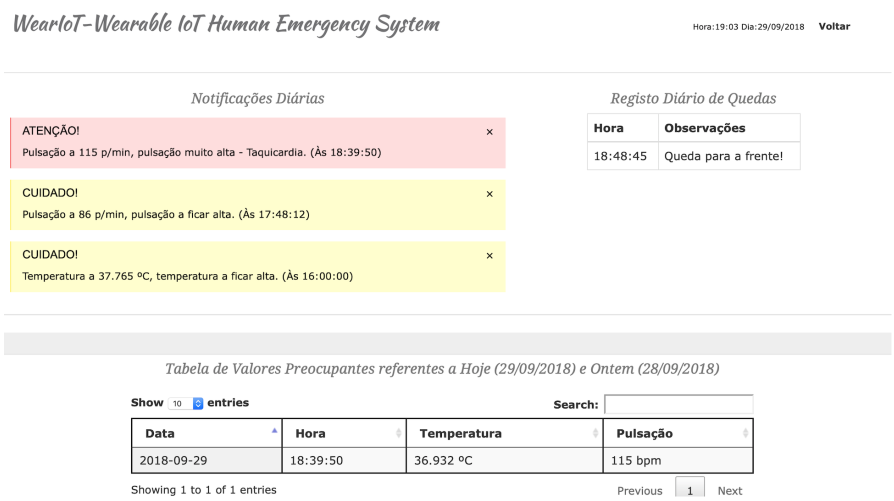


FIGURE 4.21: Alerts Page

4.3.2 Website Activity

The site was developed primarily for personal use. When there are reasons for the emergency services intervention, those are notified by an alarm message. These message contains data, such as the user location and access to the user account.

The access to the user account can also be given to a health professional, who will go along with the user and can also inform the emergency services if in his professional opinion it is necessary. In this way, and thinking in a faster intervention, it is possible to access the user location and send a UAV with the necessary medical care.

The diagram shown in Figure 4.22 illustrates what is possible for the user to do and view using the online platform.

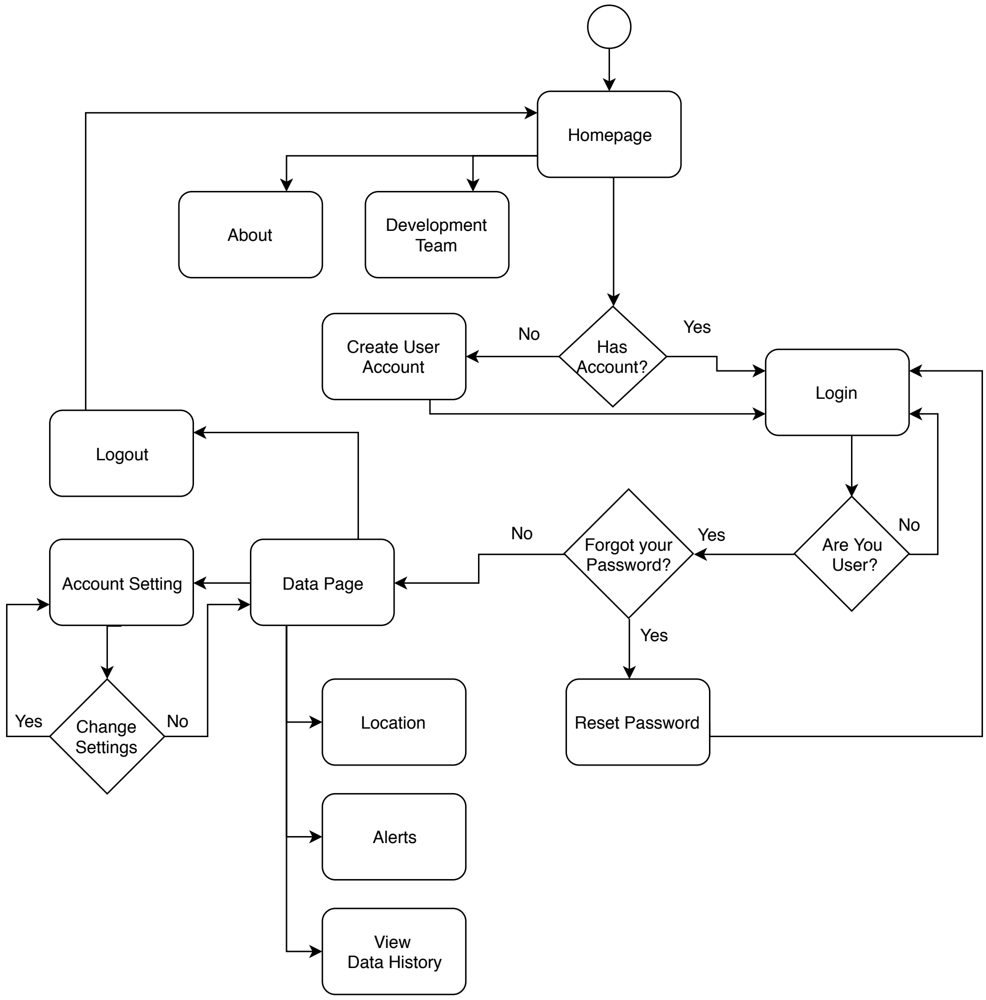


FIGURE 4.22: Website Activity Diagram

4.3.3 Users

The system has only one user, who is the patient wearing the jacket. But there may be more actors, the administrator and health professionals.

The administrator/technician has the function to correct problems that may occur in the developed platform.

The health professional who is providing medical follow-up to the user as access to the user data. There is also the possibility that, if needed, the emergency services have access to this same data.

Chapter 5

Results

This chapter deals with the results obtained from the prototype developed in the ambit of this project. To be able to obtain results, first the prototype had to be finalized, so there will be a description of it, then which tests were made, why they were made and how. A detailed analysis of the results is also realized, as a simulation of an emergency with an UAV.

5.1 Prototype

The jacket used to develop the prototype was produced by La Cravate VP, a company based on Switzerland, patented on 31 countries. This jacket has as it main component, pineapple bark fibers, which is a sustainable and environmentally friendly material that aims to replace leather.

FIGURE 5.1: Jacket Before Hardware Implementation

FIGURE 5.2: Jacket After Hardware Implementation

In Figure 5.1 it is presented the original jacket, without any hardware implementation.

The already implemented jacket is presented in Figure 5.2 and in Figure 5.3 it is possible to see the user wearing the final jacket.

This implementation was hand made because it requires acknowledge about each one of the electronics and the touch of any of the conductive thread with each other could cause short circuit, causing the system to fail and maybe get unutilized.

FIGURE 5.3: User with Final Jacket

In this prototype the inside of the jacket (lining) is made of cotton, however, in a future production it would be used hemp, also with the aim of sustainability.

In Figure 5.4 it is possible to see the electronics in the jacket with a legend of each.

Initially, the weight of the jacket without electronics is 1,31 kg. In the final product the weight is 1,45 kg, so the electronic components only weigh approximately 140 grams.

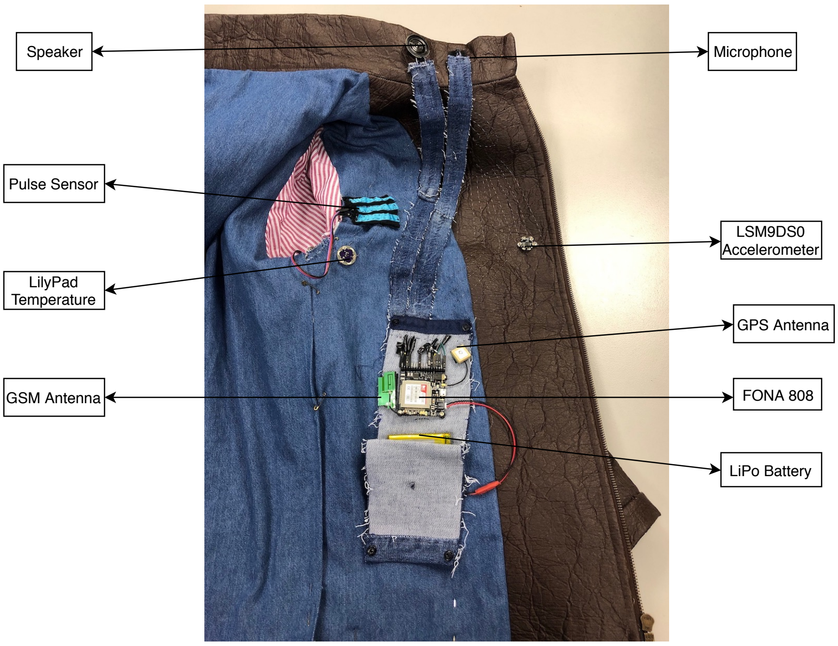


FIGURE 5.4: Jacket with Electronics

5.2 Tests

In order to obtain results, tests need to be performed. All the components of the prototype were tested individually and in the final product.

With the purpose of having a trustworthy set of results, the prototype was tested in three different people, of different age and different gender. This way it is possible to cover not only different physiognomies, but also distinct daily routines.

The first test is the body temperature. With the goal of covering several situations that might occur, the prototype is tested with the user in a set of different activities: resting position (seated) and moving. In order to verify if the temperature values are correct, the user is under monitoring, making use of a digital thermometer.

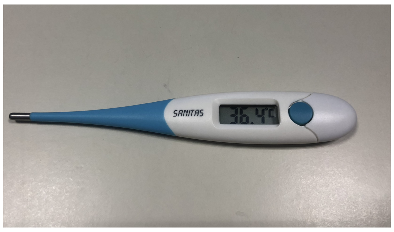


FIGURE 5.5: Digital Thermometer

Then, the pulse of the user is tested. In this test, the user uses a pulse oximeter machine, as shown in Figure 5.6, to check his pulse rate. This machine is professional, so the results are accurate.

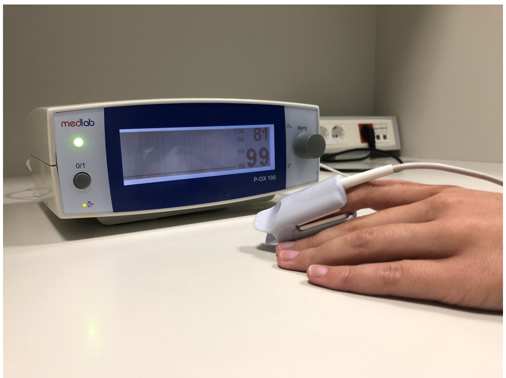


FIGURE 5.6: Pulse Oximeter Medical Machine

The fall test is performed, which consists on detecting if the user has fallen and if there are false positives. False positives happen when the user has not fallen but the system detects a fall. This test is performed while the user is on its daily activity, in order to detect any false positives that might happen. After the conclusion of this test, it is safe to assume that there are no false positives on this system. To detect a fall, the user has to move fast towards the ground and stay in an horizontal position for a few time, this way, even if the user lays down on a bed, a fall is not detected. If the user stumbles, it detects the high speed towards the ground but if the user stands up immediately, there is no fall detected. If, in fact, the user falls and stays in the ground, a fall is detected.

Finally, the GPS position of the user is tested at the same time the tests described above are being performed. The user position can be viewed on the online platform with the help of a Google Maps API. To check if the user is in the position given by the system, a comparison is constantly made with the Apple Maps app.

5.2.1 Analysis of Results

This tests were performed with the help of three subjects. The first subject, Subject A, is 23 years old male. The second subject, Subject B, is a 22 years old female. At last, Subject C, is a 59 years old female. Subject A practices sport regularly and Subject B does not. Although Subject C does not practice sports, has a very busy day-to-day life.

The graphs presented in the figures show two lines, referring to two different tests. The first test, represented by the blue line, refers to the test in which the user was in a seated position. The second test, represented by the green line, refers to the test in which the user was moving.

5.2.1.1 Temperature Test

Figure 5.7 shows the temperature test results obtained for Subject A. This test was 50 minutes long.

The outside temperature at which the resting test was performed was approximately 33°C. In the walking test the outside temperature was lower, 26°C.

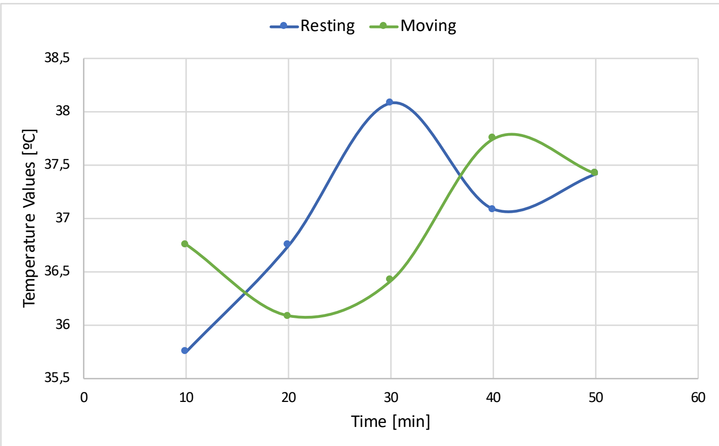


FIGURE 5.7: Temperature Values of Subject A

Analyzing the results, it is possible to understand that the values are generally in the ideal range. In the walking test, the first value obtained is relatively low. This happens because the user just wore the jacket seconds before the test started, and in the few minutes where data is obtained, the sensor temperature is not yet the user's body temperature.

As it is possible to observe, the body temperature of the subject A is greater when he is sitting than when he is walking. This is easily explained for two reasons. The first are the meteorological factors, because the day the first test took place, the temperature was 6°C higher than the day of the second test. Second, when the subject is seated, the arms are closer to the body, as opposed to walking, which allows a better reading of the temperature values.

Figure 5.8 shows the temperature test results obtained for Subject B. This test was also 50 minutes long.

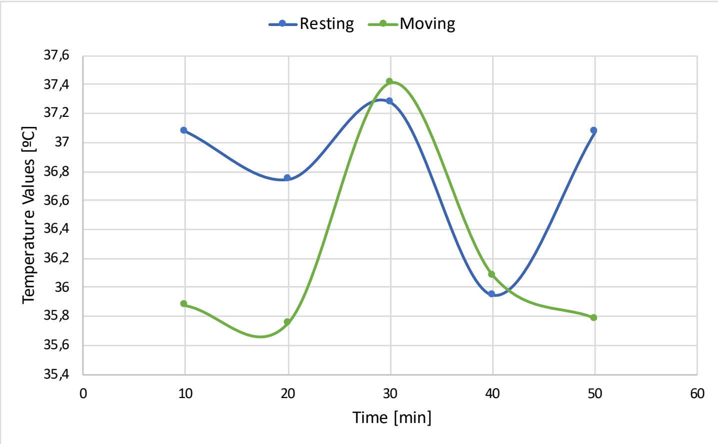


FIGURE 5.8: Temperature Values of Subject B

The external temperatures are the same as the tests presented in subject A, since these tests were performed on the same days.

The values obtained for subject B are consistent with those obtained for A. For the test where the subject is sitting, the initial value of the temperature is already acceptable, since the jacket was dressed by subject B immediately after the test was performed on subject A, in this way, the sensor was no longer at outside temperature. As in the test to the previous subject, there are some higher temperature values for when the user is sitting than walking. This is due to the same facts already presented: outside temperature and body posture.

Figure 5.9 shows the temperature test results obtained for Subject C. This test was also 50 minutes long.

For Subject C, the results are as expected. Temperature in both tests, resting and walking, starts lower and then has a peak, although on the moving test the temperature gets higher, which is normal because it involves physical activity. As on the other subjects sometimes temperature is higher during the resting test than the walking test, once again, it is due to the facts already stated.

Since all subjects are healthy, no unexpected variations in temperature were expected. In this way, it is possible to affirm that the test was successful.

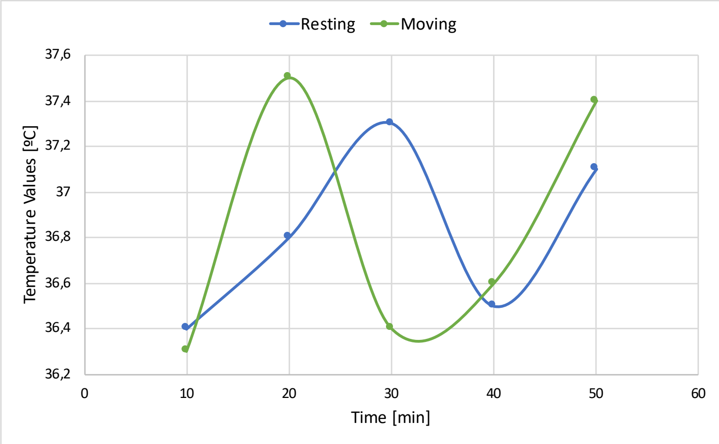


FIGURE 5.9: Temperature Values of Subject C

5.2.1.2 Pulse Test

Figure 5.10 shows the pulse test results obtained for Subject A. This test was 50 minutes long.

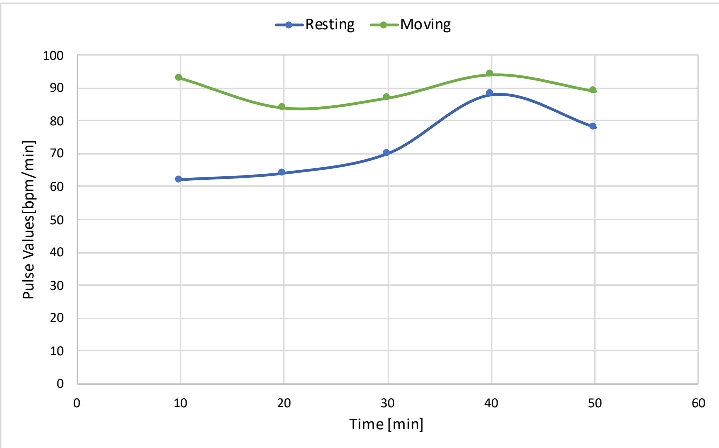


FIGURE 5.10: Pulse Values of Subject A

In this test, subject A presents two different situations. When seated the values of pulsation are lower. As can be seen, when subject A is sitting, there is a small change in the values in the fourth measure. The pulse sensor, when pressed harder against the body, usually increases its values, and this change may be due to this fact. When walking, the subject has his pulse values increased, which is normal due to physical activity.

Figure 5.11 shows the pulse test results obtained for Subject B. This test was also 50 minutes long.

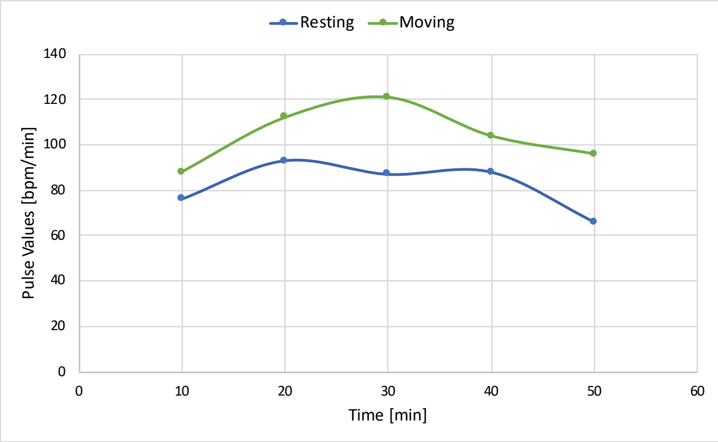


FIGURE 5.11: Pulse Values of Subject B

Subject B, shows the same type of results of subject A. When sitting in a resting position, pulse rate is lower than when walking, this is, having physical activity.

Figure 5.12 shows the pulse test results obtained for Subject C. This test was also 50 minutes long.

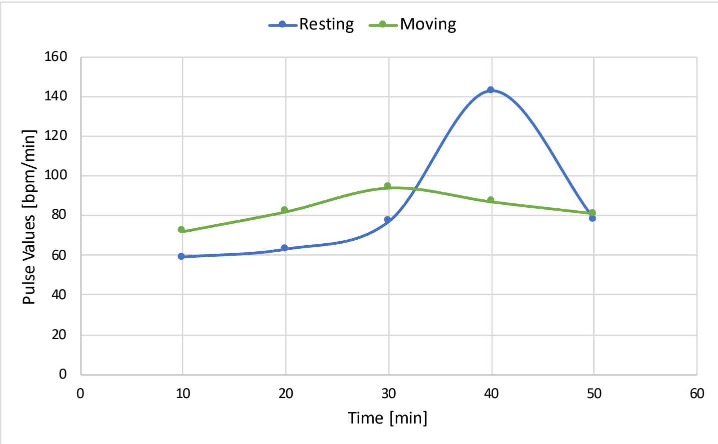


FIGURE 5.12: Pulse Values of Subject C

When testing Subject C, it was possible to detect that a wrong read might happen with pulse sensor, as it is possible to see on the resting test. For this reason, when there is a high read on this sensor, the user receives a text message to verify if the sensor is on its correct position or, if necessary, contact the emergency services. As the sensor is located on the user's pulse, it must be in the correct position to get the correct values.

After analyzing the results of the three subjects, it is possible to state that this test was successful.

5.2.1.3 Fall Test

To perform the fall test, a mattress was used. To take the test, Subject A was asked to fall into the mattress in various ways. In the case referred to here, Subject A fell on his back on the mattress, and the system detected that same fall and sent the fall data to the server, such as his GPS location.

FIGURE 5.13: Initial Position of Fall Test

Twenty seconds after the fall, the CPX's LEDs turn on and a "Please help" alarm sounds through the CPX's loudspeaker. The visual part of this situation can be seen in Figure 5.14.

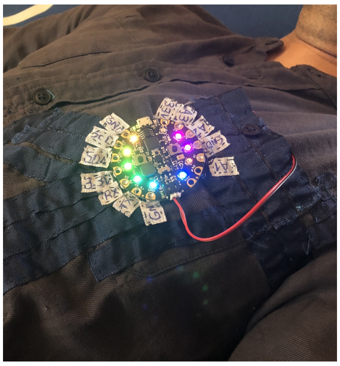


FIGURE 5.14: Detect Fall Alarm with NeoPixel

In the first scenario, the subject remained motionless on the mattress. In this situation, after one minute, the user receives a text message, Figure 5.15, requesting that in a space of two minutes, continuously press the CPX buttons until the LEDs are no longer on. In this test the user presses the buttons and the system exits the alarm of falls assuming that the user is well.

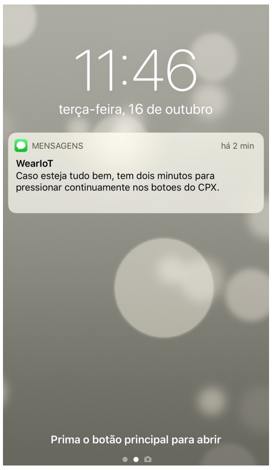


Figure 5.15: WearIoT System Informs User with SMS Notification

Figure 5.16: WearIoT System Create an Emergency Call

In the second scenario, the whole first scene is repeated, however, the subject does not press the buttons. In this situation, after two minutes, the system creates a call to the emergency services (Figure 5.16). It is important to note that in the tests, no emergencies contact was ever used.

5.2.1.4 GPS Test

In Figure 5.17 it is possible to observe the obtained position of the user through the developed online platform.

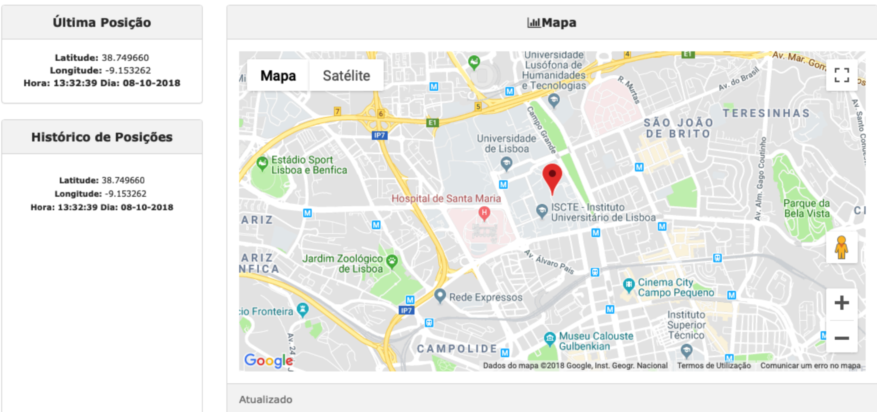


Figure 5.17: Coordinates Obtained in WearIoT Platform

To understand if the position obtained by the system is correct, the coordinates on the online platform are compared, just after being obtained, to the position of the user, obtained automatically by the Apple Maps app.

As can be seen in Figure 5.18, the user position obtained through the system, pinpointed on the map, is in the radius of the user location obtained in the Apple Maps app. This way it is possible to verify that the GPS position obtained through the developed system is correct and precise.

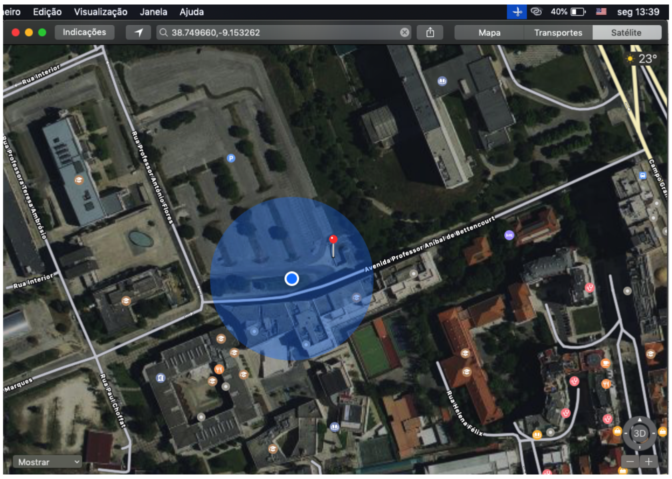


FIGURE 5.18: Checking the Coordinates in the Apple Maps Application

5.2.2 Simulate an Emergency with UAV

For this test, an emergency simulation with a UAV was developed. In Figure 5.19 it is possible to observe the UAV that was used.

FIGURE 5.19: UAV

In order to carry out this simulation, the coordinates used are the ones corresponding to the user position, that is, the last ones that are in the server. Through Raspberry Pi, which is connected to the server, it is possible to obtain these coordinates. There is an application that has been previously developed by other master student from ISCTE [86], installed directly in Raspberry Pi. This application is responsible for translating the received messages from the server to perform actions on the drone, specifically the pre-programmed mission from the initial drone position to the user.

Figure 5.20: Scenario of Simulation Test with Drone Arriving

In Figure 5.20, the UAV is observed closer to the user, to where it has moved completely autonomously.

Chapter 6

Main Conclusions and Future Work

This chapter deals with the main conclusions and possible future work.

6.1 Conclusions

The developed system goes according to the proposed objectives, except to obtain breathing data. The results are good, as it is possible to obtain values of pulsation, temperature, GPS, detection of falls and realize alarms.

The CPX is a great choice for the system as it works perfectly and has a great storage for the whole process and data processing.

It was possible to draw some conclusions about the sensors. In relation to the temperature sensor is reliable and the output values are as expected.

There is only one thing to note that can occur with this sensor because the jacket temperature is lower before being used by the user so that the first data obtained can vary. Therefore, if the outside temperature is too low, the first reading of the user's temperature may be lower, although this only happens at first reading and is not problematic. An important aspect is that the jacket must have the correct size of the wearer, otherwise it may be wider and therefore the sensor is not in contact with the user's armpit.

The pulse sensor is the least reliable sensor, meaning it does not always work properly, as peaks of values might happen. After the tests, it was possible to understand that when pressed, the sensor increases its output value. Therefore, it is important that the sensor is not placed too tightly on the user's wrist. The ideal zone for the sensor to be placed is the finger, but as one of the objectives of the system is that the user has no obligation to put something directly into his body, in this system it is placed on the wrist so that it can be adjusted.

The LSM9DS0 accelerometer used in conjunction with CPX has created a more complex user fall detection algorithm that works correctly. This accelerometer, LSM9DS0, was designed to be used in conjunction with two others to make breath measurements, but these breath measurements were not obtained. To get breath values, the user's body would have to have sensors and the product could not be a jacket but something fairer to the body. As the concept of wearable is not invasive, it was not possible to obtain breath values.

The FONA module allows to obtain GPS data from the user and is almost 100% accurate, since the coordinates obtained for the user correspond to the position of the user. As it is normal, this sensor does not always allows results in enclosed places, but it has the advantage that if the user moves from outside to inside a closed site, building, it maintains the coordinates and updates them whenever requested. The FONA module also allows to create calls and send SMS and get and send data to the server through HTTP requests.

It is important that the system does not cause false alarms. The user is notified whenever their data is out of the normal values. Only in situations considered critical the emergency alarms are issued. The notifications made to the user are via text message. The user is also notified in situations where the values are getting high or low and are asked via SMS to check the position of the sensor or if needed go to a hospital or contact the emergency services.

The UAV test worked correctly, being possible to conclude that it can carry contents to the user, such as supplements or medication. In any future application of this system it is necessary to take into account the existing regulations that may limit the drone's action.

After all the tests, it is possible to conclude that the material used in the system, more precisely the electronics used for development, are reliable.

In general the system works correctly and was in accordance with the proposed objective. The product/idea is great, innovative and original and may have a future commercial application.

As a result of this project it is also concluded that there is the possibility of applying the same technology to various types of garments, such as normal or sporty t-shirts or even pajamas. This is possible because the system has been optimized so that it is easy to implement and therefore allow adaptation to various pieces of clothing.

6.2 Future Work

To improve and optimize the system, some future work can be developed, for example:

- **New Physiological Sensors** - Implementation of New Sensors that allow new physiological measurements to be added, such as implementation of respiratory measurements. The pulse sensor used should be replaced by a more precise sensor to avoid the strange oscillation that sometimes happens. One possible sensor that allows to obtain this data is the ECG, this was initially discarded from this project because this is a wearable concept and the ECG would require the user to stick sensors directly into his body, since it requires that three electrodes be placed in the user chest. Sensors to measure blood pressure, pulse oximeter, glucometer or others can be added to the system. With the addition of these sensors, the system would be much more complete and functional;
- **New Garments** - Implementation of the system in new garments with different applications;
- **Photovoltaic Solar Cells for Textile** - Solar Panel Cells can be added for a longer battery life of the system. This allows the batteries to be charged at the same time they are being used [87];
- **Mobile Application** - To complete the already developed site, it would be interesting to develop a mobile application to complement the system. This application can have different functions that allow the system to interact

more with the user. It could thus bring the doctor or health care provider closer to the user, creating a chat directly through the application, allowing the technician/physician to access the user's data directly and communicating with the user whenever possible.

Appendices

Appendix A

Publications

The article submitted at the national computer science symposium and a poster presentation is presented in this appendix.

Sistema Inteligente de Emergência Humano

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Resumo A evolução tecnológica deu origem a novos conceitos em muitas áreas, aplicada à saúde trouxe benefícios e visa melhorar ou mesmo prolongar a vida das pessoas. Os sistemas de monitorização vestíveis, juntamente com as comunicações sem fio, são a base de uma classe emergente de redes de sensores. Estas tecnologias de informação permitem a deteção precoce de condições anormais e ajudam a prevenir as suas consequências. O objetivo é criar um destes sistemas, composto por uma rede de sensores que é implementada numa peça de roupa criada com tecidos inteligentes. Esta, contém fios condutores com sensores conectados, que em contato com o corpo humano tem a função de fazer várias leituras, e.g., temperatura corporal, pulsação, respiração, entre outras. Para a realização de algumas destas leituras, será utilizada uma técnica que aproveita um estudo já existente baseado no seismocardiograma, que é uma medida não invasiva das vibrações do tórax causadas pelo batimento cardíaco. Para o desenvolvimento deste conceito, a parte de comunicação já foi desenvolvida e utiliza o Sistema Global de Comunicações Móveis e o Sistema de Posicionamento Global. O primeiro é uma tecnologia que permite criar chamadas de emergência em resposta a alarmes do sistema, o segundo indica qual a sua posição geográfica. O trabalho desenvolvido integra uma plataforma que regista em tempo real a posição do utilizador. Futuramente registará os seus dados vitais e terá uma área de alertas que em caso de alarme contacta os serviços de emergência.

Palavras-chave: Monitorização de Saúde, Tecnologias Vestíveis, GPS, GSM, Sistema de Emergência,UAV.

1 Introdução

Este artigo descreve um sistema de emergência humano com o objetivo de fornecer a monitorização dos sinais vitais do utilizador.

Com o aumento do envelhecimento global e dos problemas de saúde, os custos de tratamento também são cada vez mais elevados. Portanto, é necessário agir e melhorar a deteção precoce de doenças e intervenção médica. Com as tecnologias hoje em dia tudo isso é possível, o avanço da tecnologia de comunicação, bem como da tecnologia de sensores, originou uma nova geração de sistemas de saúde. A Rede de Área de Corpo sem Fios (Wireless Wearable Body Area Network -

WWBAN) [1], como retrata a Figura 1 é uma tecnologia para a monitorização de saúde, composta por uma rede de comunicação entre seres humanos e tecnologia através de dispositivos vestíveis. Estes dispositivos são integrados na roupa dos utilizadores usando Redes de Área de Corpo (Body Area Network - BAN) [2]. A monitorização contínua pode ser benéfica para muitos pacientes como parte de um procedimento diagnóstico, supervisão de uma condição crônica ou recuperação cirúrgica. É também útil em casos de idade avançada que necessitam de supervisão, para reabilitação de doenças cardíacas ou mesmo para trabalhadores ou atletas em condições ambientais extremas [3]. O sistema desenvolvido reduz os custos de atendimento e tratamento ao paciente e visa trazer benefícios para o dia-a-dia do mesmo.

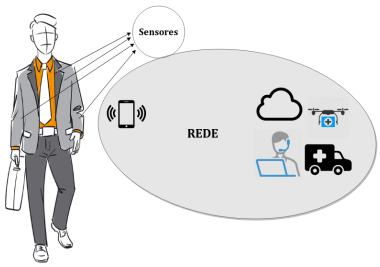

Figura 1. Rede de Área de Corpo sem Fios (WWBAN).

Para este desenvolvimento foi utilizado o Sistema Global de Comunicações Móveis (Global System for Mobile Communications - GSM), que é uma tecnologia móvel, utilizada em diversos países, para criar chamadas de emergência em resposta a alarmes do sistema.

Este projeto tem como objetivo criar um Sistema Inteligente de Emergência Humano (SIEH) baseado numa rede de sensores vestíveis. Este sistema permite fazer leituras dos dados vitais do utilizador que podem ser consultados na plataforma online. O sistema permite uma prestação de cuidados médicos de 24 horas. Os dados obtidos pelos sensores são armazenados na base de dados para que possam ser consultados posteriormente pelos serviços de emergência ou pelo próprio utilizador.

Se um alerta é emitido, uma chamada é feita para os serviços de emergência. As coordenadas do utilizador também são enviadas para os mesmos serviços de emergência, portanto, se necessário, um Veículo Aéreo Não Tripulado (Unmanned Aerial Vehicles - UAV) pode ser enviado ao utilizador do SIEH, onde os materiais de emergência serão contidos.

2 Hardware

2.1 Sensores Vestíveis

Os Sensores Vestíveis são um tipo de sensores que fazem parte da tecnologia vestível, são eletrónica que pode ser usada no corpo. Esta tecnologia pode ser usada como acessório ou como parte do material usado para fazer a própria roupa. Existem vários tipos, mas alguns dos dispositivos mais populares são rastreadores de atividade e relógios inteligentes. A capacidade de estabelecer uma conexão com a Internet é uma das principais características da tecnologia vestível, permitindo que os dados sejam trocados entre uma rede e o dispositivo. Essa capacidade de enviar e receber dados empurrou a tecnologia vestível para a frente da Internet das Coisas (Internet of Things - IoT).

Na Tabela 1 e 2 é possível observar algumas características dos sensores, tais como, dimensões, voltagem, consumo e preço aproximado. Estes sensores foram escolhidos principalmente devido à sua reduzida dimensão e preço competitivo:

- **Circuit Playground Express (CPX):** Este sensor é uma evolução de um modelo clássico [4], tem um microcontrolador ATSAMD21 [5] para o Cortex M0 que é melhor que o ATmega32U4 [6] usado no modelo clássico. No CPX, apresentado na Figura 2, há também um novo chip de armazenamento chamado SPI Flash e também foi adicionado infravermelhos para receber e transmitir. Esta inovação tanto permite comunicar com televisores e outros dispositivos, como com outros Circuit Playground Express. Este microcontrolador tem incluídos muitos sensores, tais como, sensor de luz, temperatura, acelerómetro, microfone, altifalante, entre outros [7].

Figura 2. Circuit Playground Express.

- **Adafruit Flora (FLORA):** É uma plataforma eletrónica vestível da Adafruit, ilustrada na Figura 3, que usa um microcontrolador Atmega32U4 [6], que possui suporte USB integrado. Neste projeto esta plataforma tem como objetivo fazer a comunicação I2C entre dispositivos [8].

Figura 3. Adafruit Flora.

– **Pulse Sensor:** Este sensor que se observa na Figura 4, pode detectar o pulso cardíaco, que é a velocidade do batimento cardíaco medida pelo número de contrações do coração por minuto. Essa medida é não-invasiva com a técnica Fotopletismografia (Photoplethysmogram - PPG), na qual um par de emissor e detector de luz infravermelha captura as variações da luz refletida pela superfície do corpo [9].

Figura 4. Pulse Sensor.

– **LilyPad Temperature:** Este sensor de temperatura que se encontra na Figura 5 é composto por um chip MCP9700. A saída deste sensor é de 0,5V a 0°C e de 0,75V a 25°C. Uma conversão deste sinal de analógico para digital permite estabelecer a temperatura ambiente. Com este sensor é possível detectar a temperatura corporal [10].

Figura 5. LilyPad Temperature.

– **Flora LSM9DS0 Accelerometer:** O acelerómetro que se ilustra na Figura 6 tem sensores 9-DOF de alta precisão. É composto por três sensores, um acelerómetro clássico de 3 eixos, que pode dizer qual a direção que está em direção à Terra ou a aceleração da placa no espaço 3D. Outro é um magnetómetro de 3 eixos que pode detectar de onde vem a força magnética mais forte, geralmente usada para detectar o norte magnético. O terceiro é um giroscópio de 3 eixos que tem a função de medir a velocidade [11].

Figura 6. Flora LSM9DS0 Accelerometer.

Tabela 1. Características Principais dos Sensores

Modelo	Dimensão [mm]	Voltagem [V]	Consumo [mA]	Preço [€]
CPX	50.6	3.3	200	21
FLORA	44.5	3.3	250	13
Pulse Sensor	15.88	3-5	4	21
LilyPad Temperature	20	3-5	10	3
Flora LSM9DS0	16	3	10	17

2.2 Módulos de Comunicação

A comunicação é um componente do IoT, uma vez que a necessidade de trocar dados é crucial para a eficiência de um projeto.

Para o desenvolvimento da parte de comunicação do projeto estão a ser utilizados os seguintes módulos:

– **Fona 808:** Este (Figura 7) é um módulo pequeno, que contém uma quantidade surpreendente de tecnologia. No centro tem um módulo celular GSM (SIM800) que permite conectar-se a qualquer rede GSM global com qualquer cartão 2G, permite fazer e receber chamadas utilizando uns fones de ouvido ou um altifalante. É também possivel enviar e receber mensagens de texto, tal como enviar e receber dados por Serviços Gerais de Pacote por Rádio (General Packet Radio Service - GPRS) [12].

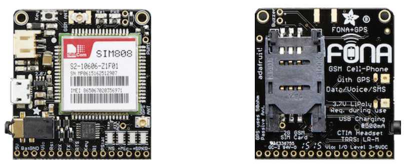

Figura 7. Fona 808.

– **Flora GPS:** Este módulo (Figura 8) é construído em torno do chip MTK3339, um módulo de Sistema de Posicionamento Global (Global Positioning System - GPS) de alta qualidade que pode rastrear até 22 satélites em 66 canais, possui um recetor de alta sensibilidade e uma antena interna [13].

Figura 8. Flora GPS.

Tabela 2. Características Principais dos Módulos de Comunicação

Modelo	Dimensões [mm]	Voltagem [V]	Consumo [mA]	Preço [€]
Fona 808	44 x 43 x 8	3-5	500	43
Flora GPS	30.5	3.3	20	34

3 Descrição do Sistema

O sistema, composto por vários elementos tem como objetivo final um protótipo de um casaco com aplicabilidade no mercado civil e militar, podendo ter vários estilos e especificidades, e.g., casual, etc.

Inicialmente já foi desenvolvido um esquema de protótipo que se apresenta na Figura 9. Este protótipo pode sofrer algumas alterações, visto que, ainda haverá uma fase de testes do sistema.

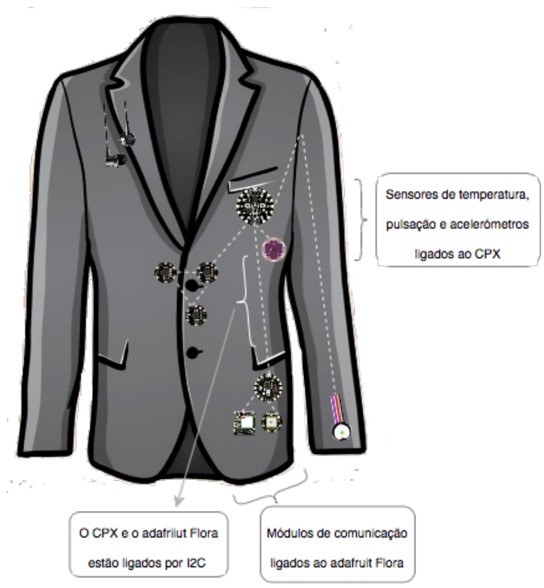

Figura 9. Esquema de Protótipo do Casaco.

Como se pode observar na legenda feita na Figura 9, a plataforma FLORA e o CPX estão ligados por I2C, i.e., basicamente um protocolo de comunicação em que os dispositivos "falam", ou seja, trocam dados entre si. O primeiro é o mestre (master) e o segundo o escravo (slave). A função do mestre é coordenar a comunicação, sendo que é ele quem envia informações a determinado escravo ou consulta informações. O CPX é o microcontrolador responsável pela obtenção de dados dos sensores. A ligação com a plataforma FLORA permite que os dados sejam enviados para o servidor tal como seja feito o alerta aos sistemas de emergência caso necessário, ou seja, a plataforma FLORA é o microcontrolador principal responsável pela parte de comunicação, ligação e envio de dados para o servidor. A localização do utilizador é obtida através dos dados do Flora GPS que também são enviados para o servidor. Os outros dados obtidos são de temperatura, de pulsação e respiração. Com o uso de três acelerómetros Flora LSM9DS0 obtém-se valores de respiração e resultados para deteção de quedas do utilizador.

O sistema apresenta duas fases como se pode observar na Figura 10, a fase de informação que é desenvolvida pelos sensores aplicados ao casaco e a fase de intervenção que é desenvolvida pelos serviços de emergência.

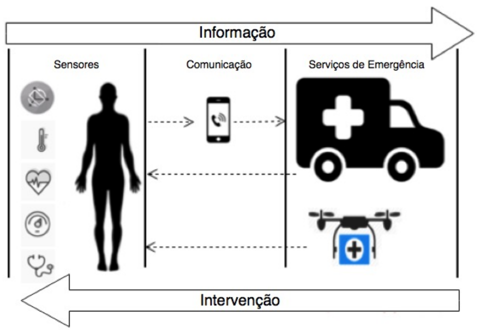

Figura 10. Diagrama de informação/intervenção.

A primeira é concebida através de um conjunto de sensores que fazem as várias medições necessárias para o funcionamento do sistema, de acordo com o objetivo proposto. Assim, estes sensores são implementados no casaco, de forma não invasiva, tendo também em atenção o conforto do utilizador. Para isso é utilizada uma linha condutora que interliga todos estes componentes. A fase de intervenção tem como propósito fazer uma ligação direta entre o utilizador e os serviços de emergência, sendo que esta apenas é ativada caso seja estritamente necessário, i.e., caso existam resultados dos sensores que ultrapassem os limites.

Na Figura 11 encontra-se um esquema da arquitetura do sistema. Este esquema está dividido em seis blocos, o bloco do utilizador em que os sensores estão integrados no casaco e fazem a aquisição e o processamento dos dados, estes são enviados para o servidor. O bloco dos Serviços de Emergência que em caso de alarme recebe as chamadas. O bloco do Servidor que recebe os dados e os disponibiliza para serem acedidos posteriormente. O bloco da Plataforma Online onde podem ser visualizadas as informações. O bloco do Administrador, que pode visualizar e editar as informações e o do Profissional de Saúde que pode consultar as informações do utente.

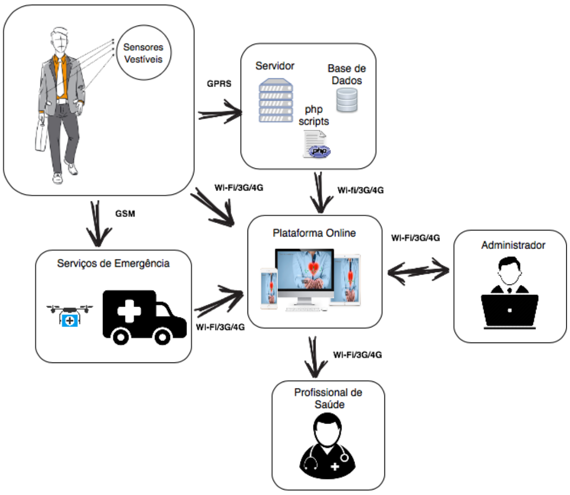

Figura 11. Arquitetura do Sistema.

4 Resultados

O projeto encontra-se em desenvolvimento. Desta forma, não é possível demonstrar o resultado final do projeto. No entanto, já são conhecidos valores para temperatura, pulsação e é também possível saber a localização atual do utilizador, assim como obter um histórico diário das mesmas. Na data da conferência já haverá mais resultados para poderem ser apresentados.

4.1 Plataforma Online

A plataforma online foi desenvolvida para o utilizador poder consultar os seus dados em tempo real. Em caso de alarme, os serviços de emergência também podem consultar os dados.

Cada casaco tem um código que permite criar uma conta de utilizador com os seus dados pessoais. Na Figura 12 encontra-se a página inicial da plataforma.

Quando o utilizador faz login é redirecionado para a sua página de dados que se ilustra na Figura 13. Estes dados são mostrados fazendo recurso a um gráfico que é atualizado à medida que são recolhidos novos dados dos sensores.

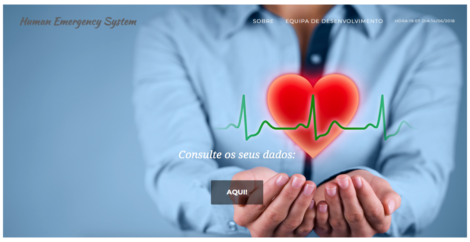

Figura 12. Página Inicial.

Ao clicar no ícone do coração é possível consultar o histórico de dados relativo a outro dia.

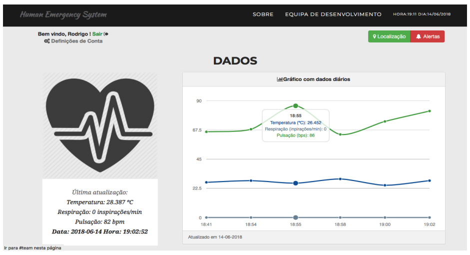

Figura 13. Dados do Dia.

A localização do utilizador também pode ser consultada através da plataforma (Figura 14). Neste caso, é possível consultar a última localização do utilizador, ou, clicando nos horários disponíveis na lista, é possível consultar a localização nesse determinado instante.

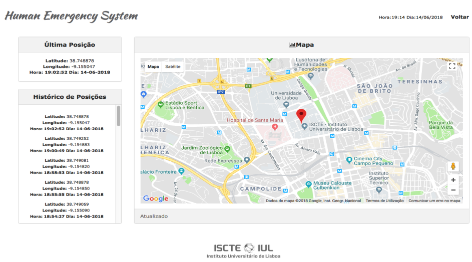

Figura 14. Localização.

4.2 Testes

O sistema passará por uma fase de testes para comprovar a fiabilidade dos resultados, tal como, ajustar ou corrigir alguns erros existentes. Desta forma serão feitas medições com aparelhos médicos especializados e aferidos que servirão de base para a análise dos dados obtidos pelo sistema.

Os dados são obtidos e enviados para a base de dados a cada 5 minutos. Serão feitos gráficos dos dados dos sensores individualmente. Estes gráficos serão validados posteriormente por um profissional na área de saúde.

Numa fase final serão feitos os testes com o drone e avaliado se este consegue chegar com sucesso às coordenadas desejadas.

5 Principais Conclusões e Trabalho Futuro

O sistema desenvolvido até ao momento permite obter algumas conclusões. Relativamente aos sensores utilizados, o sensor de temperatura é fiável sendo que os valores de output são coerentes com a temperatura expectável. Pelo contrário o Pulse Sensor oscila os valores muito facilmente, tornando-se incerto.

O módulo Flora GPS funciona corretamente, as coordenadas obtidas correspondem à posição do utilizador. O mesmo acontece com o módulo Fona 808 que permite fazer chamadas, enviar mensagens de texto, obter e enviar dados para o servidor através de pedidos de Protocolo de Transferência de Hipertexto (Hypertext Transfer Protocol - HTTP).

A fase do projeto que se segue é a aplicação dos acelerómetros no casaco. Estes vão permitir obter valores da respiração e deteção de quedas. Para isso, vai ser usada uma técnica que aproveita um estudo já existente baseado no seismocardiograma, que é uma medida não invasiva das vibrações do tórax causadas pelo batimento cardíaco [14]. Será também feita uma alteração do Fona 808 para o Fona 3G, o que permite melhor cobertura.

Terminada esta fase, segue-se a implementação dos alarmes relativos a cada um dos sensores. Estes alarmes serão definidos consoante a idade, sexo e possíveis problemas do utilizador.

Para a interligação do drone ao sistema será desenvolvido numa fase final um algoritmo que tem como objetivo receber as coordenadas GPS do utilizador e fazê-lo deslocar-se até este como auxílio.

Por último serão feitos os testes ao sistema e possíveis correções.

6 Agradecimentos

Os autores gostariam de agradecer ao ISCTE - Instituto Universitário de Lisboa e ao Instituto de Telecomunicações por fornecerem os componentes e condições de apoio ao trabalho desenvolvido e apresentado neste artigo.

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WearIoT - Wearable IoT Human Emergency System

Miriam Batista, Pedro Sebastião

Background and challenges

- The health area was one of the many beneficiaries of technological evolution, giving rise to new concepts. Wearable monitoring systems, along with wireless communications, aim to improve or even prolong people's lives with the early detection of abnormal situations.
- The main goal is to develop a 24-hour emergency system doing several readings, e.g., body temperature, pulse, and also to detect user falls. To complement the system there is an online platform.

Description and main innovation

- The system presents two phases: the information phase that is designed through a set of sensors applied in the jacket that make the various measurements necessary; and the intervention phase that is intended to make a direct connection between the user and the emergency services. In special cases, it is possible to use an innovative feature that involves the aid of an UAV in specific situations.

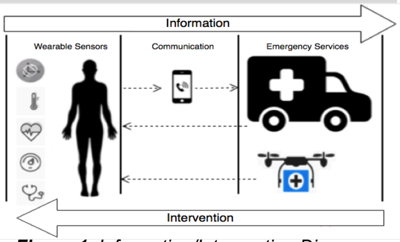

Figure 1. *Information/Intervention Diagram*

Achievements

LA CRAVATE
SWITZERLAND

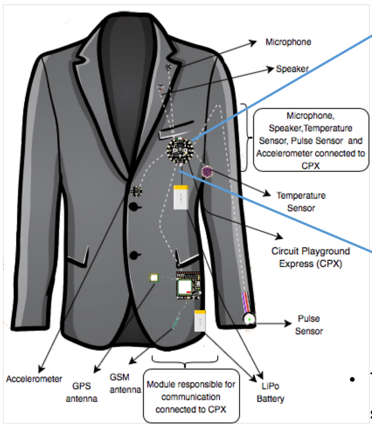

Figure 2. *Prototype Scheme*

Figure 3. *Sewable Snaps and Conductive Thread*

Figure 4. *Sustainable Jacket*

- This jacket has as its main component, pineapple fibers, which is a sustainable and environmentally friendly material that is a good replacement to leather.

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MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA
UID/EEA/50008/2013
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Appendix B

User & Technical Manual

This manual was developed with the purpose of clarifying and shows more details about the system obtained.

Department of Information Science and Technology

WearIoT - User & Technical Manual

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November 2018

Contents

List of Figures

List of Tables

Chapter 1

Developed Platform

The application developed for the system is a website. This one was developed as a working tool to allow the user to monitor his temperature, heartbeat and breathing data throughout the day. The choice of a website platform is because it is possible to access on any device, for example iOS, Android or Windows, being easier to access by anyone. In order to use the site, the device must have access to the Internet.

1.1 Website

About the application developed for the system it will be discussed below what are its main functions for the user and how it was implemented. The website developed is available on the following link:

https://sandbox.skyverse.pt/miriam/WebPage/

To access the main functionalities available on the website without user registration, the access data below can be used:

Código do Casaco: **64825**

Password: **WearIoT18**

Developed Platform

1.1.1 HomePage

The homepage of the website as can be seen in Figure 1.1, just like the whole platform, was designed to be user friendly and attractive.

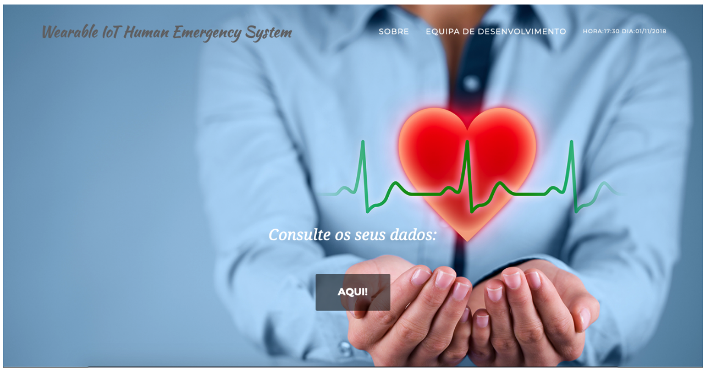

FIGURE 1.1: Homepage

Through the homepage it is possible to access the About Page. This page (Figure 1.2) addresses the development of the project, like framing and motivation and also about the objectives. It is also possible to access a page with the development team, Figure 1.3.

FIGURE 1.2: About Page

FIGURE 1.3: Development Team

2

1.1.2 Login

Clicking the button "AQUI!" which is on the Homepage, Figure 1.1, it is possible access the login page (Figure 1.4).

FIGURE 1.4: Login Page

To login, it is required to create an user account (Figure 1.6). To create the account it is needed personal data of the user such as name, age, gender, email and others. The code of the jacket that is requested is inside the jacket (Figure 1.5). Each jacket has its unique code.

FIGURE 1.5: Label Inside the Jacket

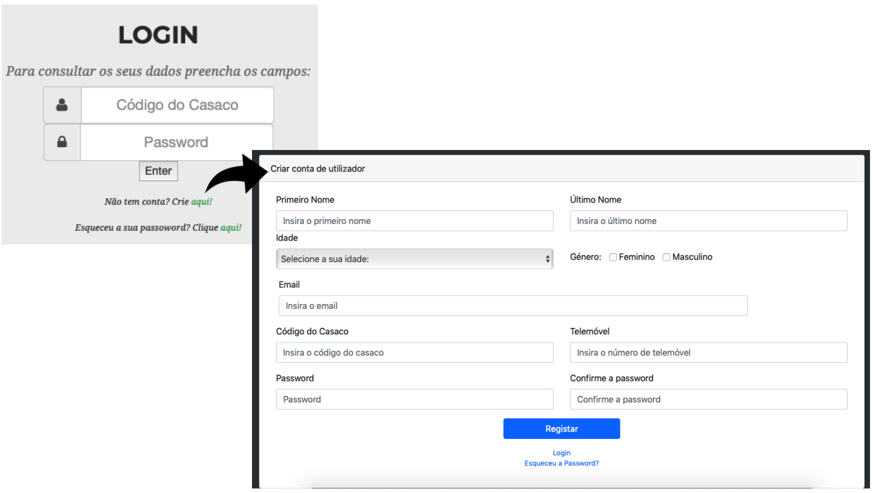

FIGURE 1.6: Create a New User

There are three possible errors when logging in:

- When the code placed does not exist, i.e., the user is not registered (Figure 1.7);
- The password must have at least 8 characters (Figure 1.8);
- The password is invalid (Figure 1.9).

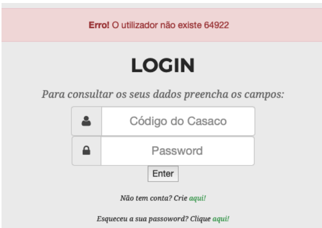

FIGURE 1.7: Error Login (A)

FIGURE 1.8: Error Login (B)

FIGURE 1.9: Error Login (C)

It is also possible, if the user does not remember his password, retrieve it (Figure 1.10) through his email. The system automatically sends an email to the user, which contains the necessary data to recover the password.

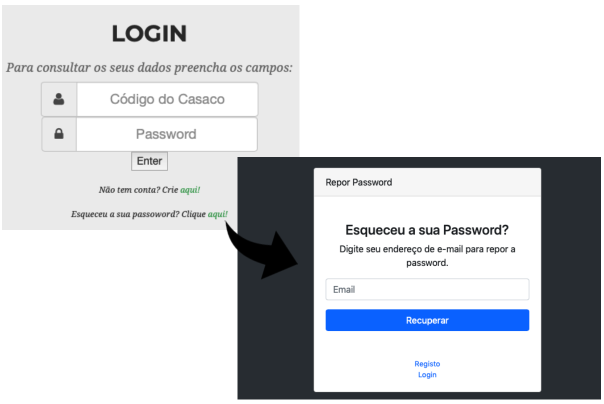

FIGURE 1.10: Reset Password

1.1.3 Data Pages

When the user logs in he is redirected to his data page which is shown in Figure 1.11. On this page it is possible to access the user's location and the user's alerts page.

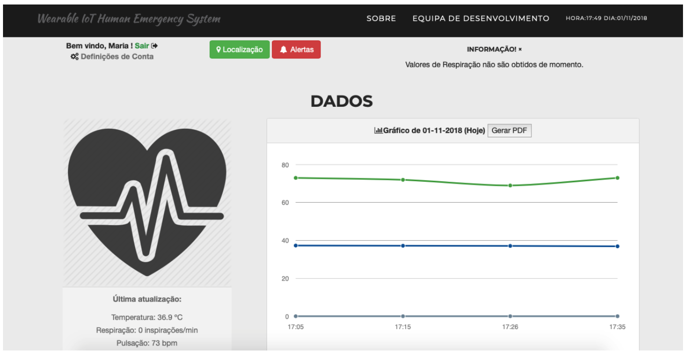

FIGURE 1.11: Data Pages

It also possible to change the user settings account, as user's personal data, e-mail, password, among others. The jacket code can not be changed.

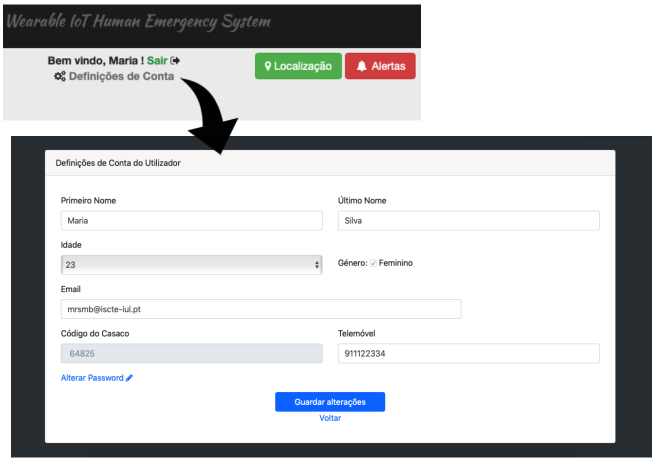

FIGURE 1.12: User Settings

1.1.3.1 Data Page

The data is shown using a graph that is updated as new data is collected from the sensors. In Figure 1.13 it is possible to verify that the last message sent is saved and in Figure 1.14 is the graph.

Developed Platform

FIGURE 1.13: Last Registered Message

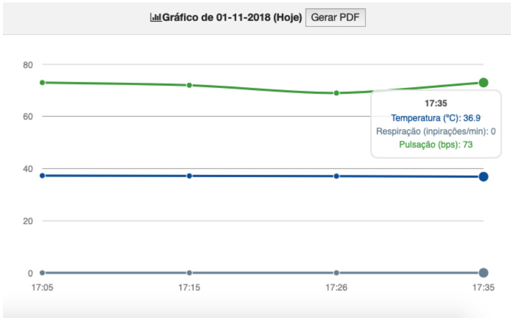

FIGURE 1.14: Data Graph

By moving the mouse through the heart, its possible to see that there is a data history (Figure 1.15).

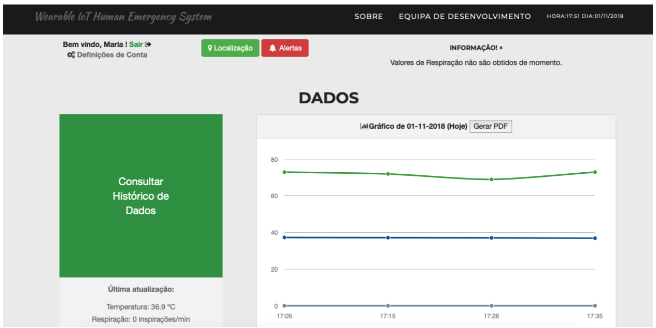

FIGURE 1.15: Data Pages

By clicking on the heart, the user is directed to a page where it is possible to choose the date of the data that is intended to be consulted (Figures 1.16).

FIGURE 1.16: See History

When selected one of the days, in Figure 1.17 it is possible to see that there is a list of messages for that day and also a graphic with all the data.

6

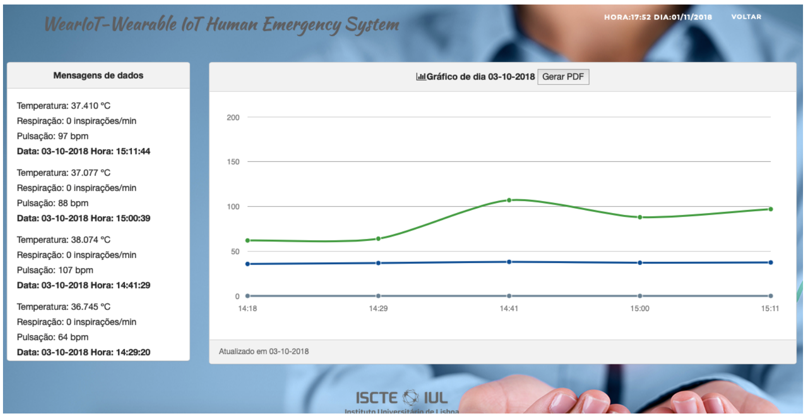

FIGURE 1.17: History

It is possible at any time to obtain a PDF of the graphic of the user data, such as historical graphs, Figure 1.18.

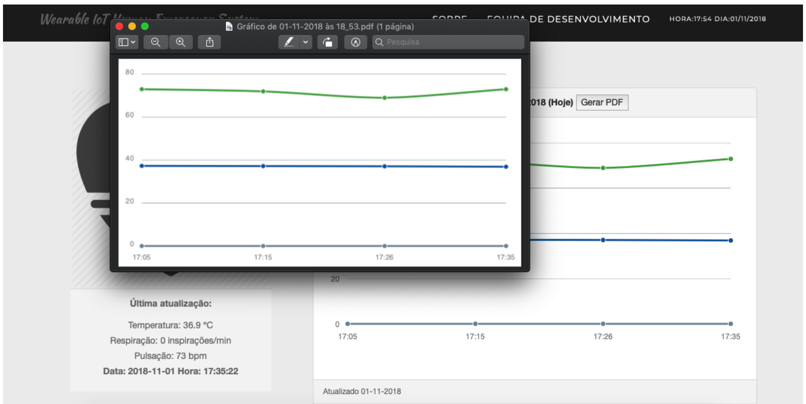

FIGURE 1.18: Graphic PDF Generator

1.1.3.2 Localization

In the upper left corner of the data page it is possible to access the user's location (Figure 1.19). As can be seen in Figure 1.19, there is a list with the coordinates of the user throughout the day. By clicking the times available in the list, it is also possible to check the location where the user was at that specific time. The map on the side shows the user's last location.

Developed Platform

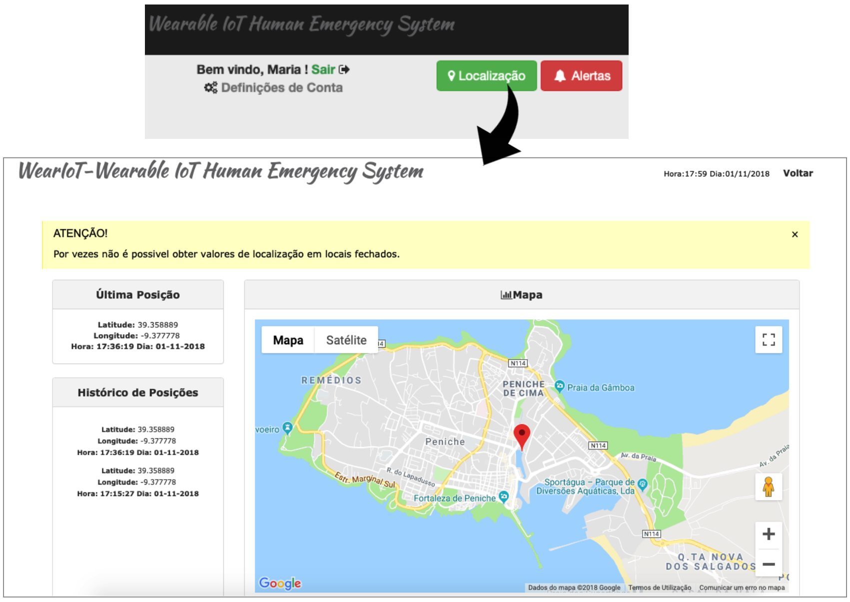

FIGURE 1.19: Localization Page

1.1.3.3 Alerts

The same situation occurs with the Alerts Page which can be accessed through the upper left corner of the data page/ In the alerts page (Figure 1.20) only the alarming data is recorded. These data is outside the stipulated limits. The user can query the data through notifications that occur or through a table. The table only shows more severe values. It is also possible to know the daily log of user falls which is recorded in a table with the respective time to which it occurs.

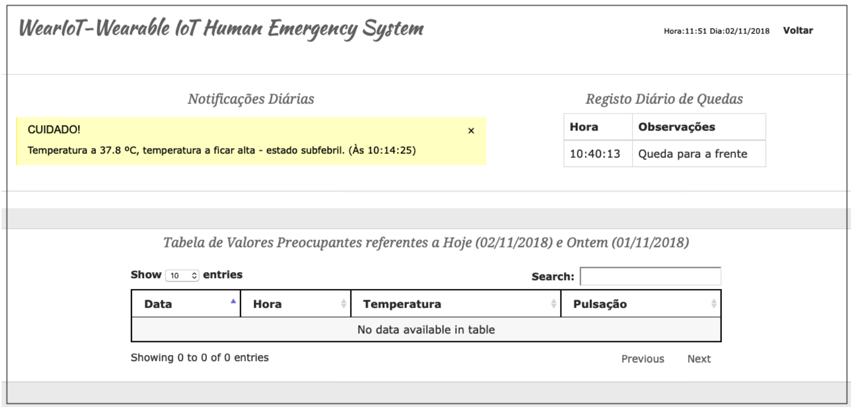

FIGURE 1.20: Alerts Page

1.2 Remote Server

For the web development was used a remote server, a database and PHP scripts.

The server available for the development of the dissertation is a remote server. The server is of type LAMP, as shown in Figure 1.21 and means:

FIGURE 1.21: LAMP

- **L**inux - Operation System;
- **A**pache - Apache HTTP Server;
- **M**ySQL - Database Server;
- **P**HP - Programming Languages;

The server is responsible for storing all patient data, the account created on the online platform as well as the vital data received through the software developed in Arduino. This way it is possible to access and analyze this information in the future through the online platform.

In this work the dynamic pages are used to process the customer's request, access the database and send the information through scripts. These are performed in PHP language which is a language developed on the server side for Web development purpose.

A File Transfer Protocol (FTP) session is required to upload PHP scripts. This is done by using a FTP client called FileZilla, which allows connection with remote server.

In Figure 1.22 it is shown the work folders on the server. This folders contain PHP files responsible for the development of the online platform.

error.log	476 889	Log File
ConnectionArduino.php	2 668	php-fichei...
log		Pasta
WebPage		Pasta

FIGURE 1.22: Folder Organization in Server

- **PHP File ConnectionArduino:** It is the PHP file that receives the data by the POST of the software developed in Arduino, treats it and sends it to the database on the server. It is the only file that connects the entire system with the server, Arduino, database and online platform.
- **Folder log:** This folder (see Figure 1.23) contains a text file containing the data obtained from the software developed in Arduino.

dados.txt

FIGURE 1.23: Content of Log Folder

- **Folder WebPage:** This folder contains PHP files dedicated to the online platform. These PHP files are separated by folders (see Figure 1.24).

Dados		Pasta
Layout		Pasta
Registo		Pasta
ReporPass		Pasta
db		Pasta
gulpfile.js	3 384	js-ficheiro
index.php	12 197	php-fichei...
login.php	1 297	php-fichei...
logout.php	77	php-fichei...

FIGURE 1.24: Content of WebPage Folder

1.2.1 Database

Initially a system analysis was performed to find out what kind of data the database should hold. The database was developed in MySQL using the phpMyAdmin tool.

In Figure 1.25 the diagram of the database is represented. The diagram consists on four tables:

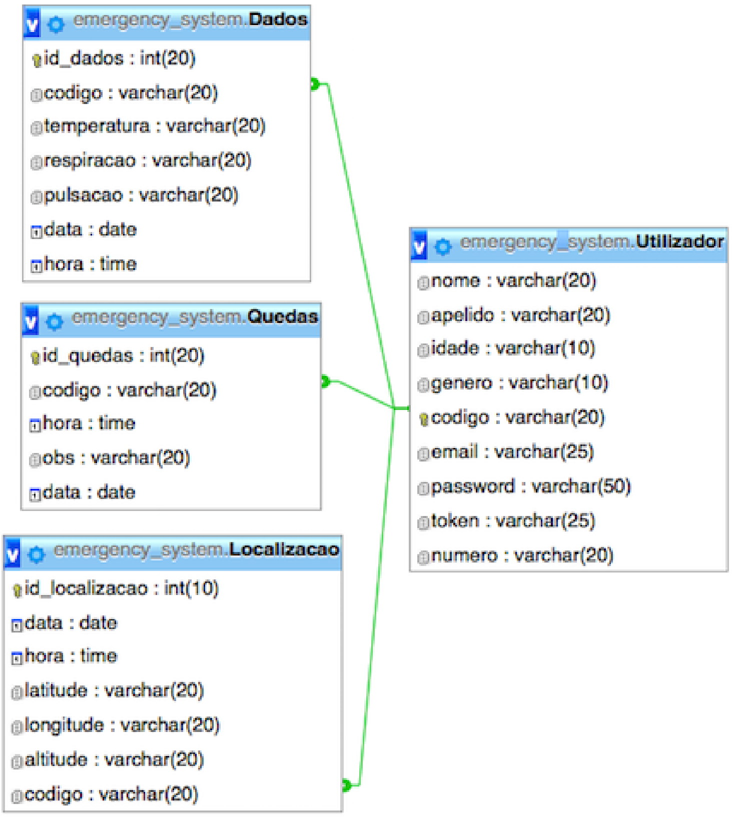

FIGURE 1.25: Diagram of Database

- **Utilizador:** This table stores user account data. The user personal information, such as nome, apelido, idade, genero, email, numero. The codigo and password fields are present in the table because they serve as the credentials for the user login. The code in the table corresponds to the code inside the jacket, which is unique. The primary key is codigo.

```
--
-- Estrutura da tabela `Utilizador`
--

CREATE TABLE IF NOT EXISTS `Utilizador` (
  `nome` varchar(20) CHARACTER SET latin1 NOT NULL,
  `apelido` varchar(20) CHARACTER SET latin1 NOT NULL,
  `idade` varchar(10) CHARACTER SET latin1 NOT NULL,
  `genero` varchar(10) CHARACTER SET latin1 NOT NULL,
  `codigo` varchar(20) CHARACTER SET latin1 NOT NULL,
  `email` varchar(25) CHARACTER SET latin1 NOT NULL,
  `password` varchar(50) CHARACTER SET latin1 NOT NULL,
  `token` varchar(25) CHARACTER SET latin1 NOT NULL,
  `numero` varchar(20) CHARACTER SET latin1 NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=utf8;

--
```

FIGURE 1.26: Script SQL of Utilizador Table

- **Dados:** It is in this table that the data corresponding to the temperature, breath and pulse of the user are stored. The id_dados, data and hora fields are also present in the table because in each data message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the data belongs. The primary key is id_dados.

```
--
-- Estrutura da tabela `Dados`
--

CREATE TABLE IF NOT EXISTS `Dados` (
  `id_dados` int(20) NOT NULL,
  `codigo` varchar(20) CHARACTER SET latin1 NOT NULL,
  `temperatura` varchar(20) CHARACTER SET latin1 NOT NULL,
  `respiracao` varchar(20) CHARACTER SET latin1 NOT NULL,
  `pulsacao` varchar(20) CHARACTER SET latin1 NOT NULL,
  `data` date NOT NULL,
  `hora` time NOT NULL
) ENGINE=InnoDB AUTO_INCREMENT=167 DEFAULT CHARSET=utf8;
```

FIGURE 1.27: Script SQL of Dados Table

- **Quedas:** It is in this table that the data corresponding to the user falls is stored. The id_quedas, time, and date fields are also present in the table because in each fall message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the data corresponds. The primary key is id_quedas.

```
--
-- Estrutura da tabela `Quedas`
--

CREATE TABLE IF NOT EXISTS `Quedas` (
  `id_quedas` int(20) NOT NULL,
  `codigo` varchar(20) CHARACTER SET latin1 NOT NULL,
  `hora` time NOT NULL,
  `obs` varchar(20) CHARACTER SET latin1 NOT NULL,
  `data` date NOT NULL
) ENGINE=InnoDB AUTO_INCREMENT=10 DEFAULT CHARSET=utf8;
```

FIGURE 1.28: Script SQL of Quedas Table

- **Localizacao:** It is in this table that the latitude, longitude and altitude data corresponding to the user's location are stored. The id_localizacao, date, and time fields are also present in the table because in each location message it is important to know the day and time. The table contains a foreign key (codigo) that corresponds to the Utilizador table, indicating to which user the location belongs. The primary key is id_localizacao.

```sql
--
-- Estrutura da tabela `Localizacao`
--

CREATE TABLE IF NOT EXISTS `Localizacao` (
  `id_localizacao` int(10) NOT NULL,
  `data` date NOT NULL,
  `hora` time NOT NULL,
  `latitude` varchar(20) CHARACTER SET latin1 NOT NULL,
  `longitude` varchar(20) CHARACTER SET latin1 NOT NULL,
  `altitude` varchar(20) CHARACTER SET latin1 NOT NULL,
  `codigo` varchar(20) CHARACTER SET latin1 NOT NULL
) ENGINE=InnoDB AUTO_INCREMENT=69 DEFAULT CHARSET=utf8;
```

FIGURE 1.29: Script SQL of Localizacao Table

```sql
--
-- Indexes for table `Dados`
--
ALTER TABLE `Dados`
  ADD PRIMARY KEY (`id_dados`),
  ADD KEY `codigo` (`codigo`);

--
-- Indexes for table `Localizacao`
--
ALTER TABLE `Localizacao`
  ADD PRIMARY KEY (`id_localizacao`),
  ADD KEY `codigo` (`codigo`);

--
-- Indexes for table `Quedas`
--
ALTER TABLE `Quedas`
  ADD PRIMARY KEY (`id_quedas`),
  ADD KEY `codigo` (`codigo`);

--
-- Indexes for table `Utilizador`
--
ALTER TABLE `Utilizador`
  ADD PRIMARY KEY (`codigo`);
```

FIGURE 1.30: Primaries Keys of All Tables

1.2.2 PHP Scripts

Hypertext Preprocessor is an open source scripting language, especially suitable for web development and can be placed inside HyperText Markup Language (HTML).

PHP scripts are required to perform communication between the software developed on Arduino, the server and the online platform.

These scripts are hosted on the server. For the development of this project several PHP scripts were used.

In Table 1.1 there are a short explain about each file.

TABLE 1.1: PHP Scripts in Server

File	**Description**
ConnectionArduino.php	File that connects all system
index.php	File that results in the online platform
login.php	File responsible for login
logout.php	File responsible for logout
db.php	Connection with database
dados.php	File responsible to create data page
alertas.php	File responsible to create alerts page
localizacao.php	File responsible for localization page
historico.php	File responsible for history page
db_alertas.php	File that analyzes the data and shows the alarming ones
db_alteraConta.php	Connects to database and change user settings
db_alteraPass.php	Connects to database and change user password
db_conta.php	Shows user information form
db_dados.php	File responsible for getting data to data page
db_datas.php	File that gets dates for history
db_grafico.php	File responsible for creating graphics
db_login.php	File that gets users to login
db_quedas.php	File responsible for creating the user's fall table
db_registo.php	File responsible for creating a new user
db_tabela.php	File responsible for creating the table of alerts page
db_ultima_atualizacao.php	Gets the last data message from the database
alteraPass.php	File responsible to change the password
defConta.php	File responsible for user settings
register.php	File that creates form to create a new user
email_conf.php	File responsible for password recovery
email_user.php	File responsible for password recovery
forgot-password.php	File responsible for password recovery
newpass.php	File responsible for resetting the password
pass.php	File responsible for resetting the password

In the case of the online platform, the following scripts are the most important for the application goal:

- **db.php:** This is the script responsible for connecting to the database. All PHP files that need access to the database require this script.
- **db_login.php:** This script checks the login, that is, it checks if any filled fields are incorrect or if the user is in the database.
- **dados.php:** Upon successful login, the user is redirected to his data page, created through the data collected from the sensors. This script is responsible for displaying a daily chart of data such as showing the last data message stored in the database.
- **localizacao.php:** This script returns a list of user positions throughout the day. In each location message listed it is possible to observe through a Google Maps API the exact location of the user on the map.

- **alertas.php:** The data obtained from the sensors is processed through this script. In case of irregular values, the data is listed in a table for the user to consult.

- **historico.php:** Through this script it is possible to list and obtain the graphic of the daily data of a certain day that exists in the database.

- **index.php:** This file, which is inside the WebPage folder, is the central script of the entire website. This is responsible for the interconnection of all the scripts that are inside the WebPage folder, that is, all the previously spoken files and others.

For the communication between the software developed in Arduino and the server the following script is used:

- **ConnectionArduino.php:** This script is responsible for sending sensor data to the server. Through this script, the data is stored directly in the database so that it can be consulted on the online platform.

Chapter 2

Developed Jacket

This chapter describes the necessary procedures to use the developed jacket.

2.1 Jacket

The user needs to have some knowledge about the jacket he uses. The jacket was produced so that it could be removed from the electronics, that is, for this procedure snaps were used.

For example, as shown in Figure 2.1, the CPX has labels on the jacket to facilitate placement of the microcontroller.

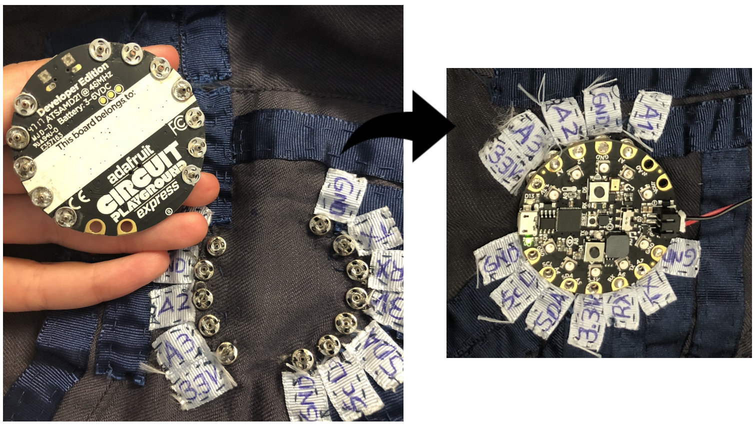

FIGURE 2.1: Snaps Connection

If this is not correctly set the possibility of damaging the component is raised. The same situation happens for all the remaining electronics in the jacket.

For the correct operation of the system, in addition to all electronic devices correctly placed in their snaps, the CPX requires the use of a Lipo battery (Figure 2.2).

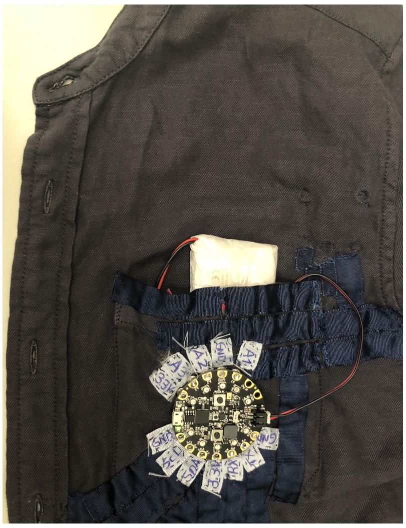

FIGURE 2.2: CPX

The FONA module also requires the use of a Lipo battery(Figure 2.5) and two antennas, GSM and GPS (Figure 2.3).

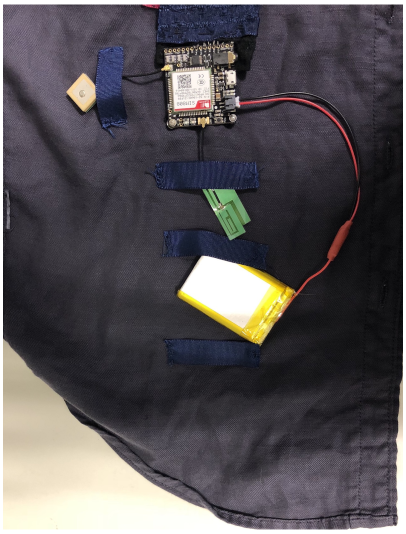

FIGURE 2.3: FONA

To charge the batteries it is necessary to remove the battery from the JST Battery Input (Figure 2.4) and use a proprietary motor to charge Lipo batteries as can be seen in Figure 2.6.

Developed Jacket

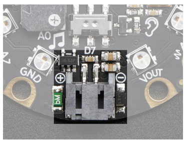

FIGURE 2.4: JST Battery Input

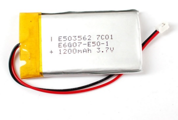

FIGURE 2.5: Lipo Battery

FIGURE 2.6: Lipo Battery Charger

When the user wants to connect the jacket it is required to put the slide switch up, only then will the system work. When the user wants to remove the jacket, the slide switch must be down. The sensor readings are no longer correct and false falls may occur. This slide switch is shown in Figure 2.7.

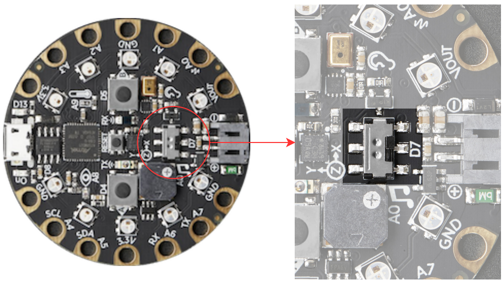

FIGURE 2.7: Slide Switch

For the system to be completely off it is necessary to disconnect the battery cable connected to the CPX as shown in figure 2.8.

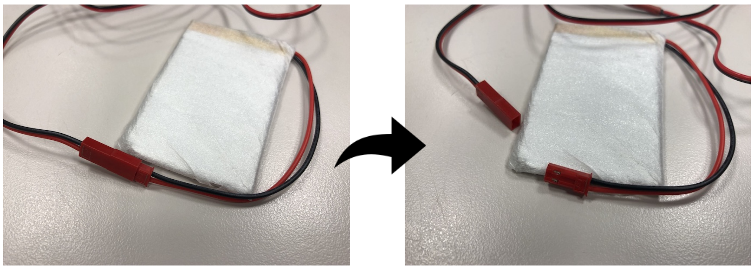

FIGURE 2.8: Battery Cable Connected/Disconnected

2.2 Arduino IDE

The chosen hardware is compatible with the Arduino IDE software (Figure 2.9), so this was the software chosen for the development of the system. This software is available on the brand website, **www.arduino.cc**.

FIGURE 2.9: Logo Arduino

The developed code is in C/C++ and the libraries used of each component are shown in Figure 2.10.

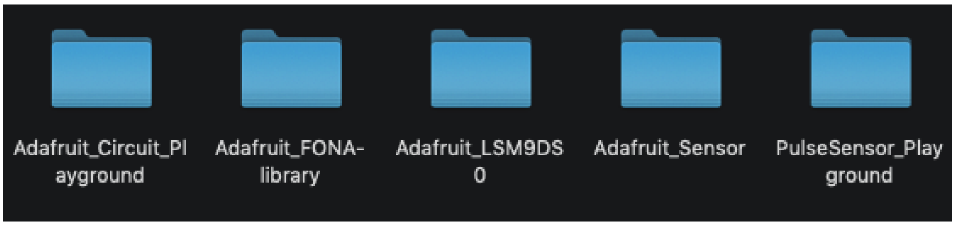

FIGURE 2.10: Libraries Used for Development in Arduino

These libraries are available on the following links:

- **https://github.com/adafruit/Adafruit_CircuitPlayground**
- **https://github.com/adafruit/Adafruit_FONA**
- **https://github.com/adafruit/Adafruit_LSM9DS0_Library**
- **https://github.com/adafruit/Adafruit_Sensor**
- **https://github.com/WorldFamousElectronics/PulseSensorPlayground**

Developed Jacket

The temperature sensor, LilyPad Temperature, does not require a library.

In the Table 2.1 are the files used in Arduino software development and a small explanation of them.

TABLE 2.1: Files Used in Arduino Software Development

File	**Description**
Master.ino	Responsible for initializing all components and initiating data loop
DATA.ino	Obtaining and processing of sensor data
Alarms.ino	Responsible for checking sensor values and creating alarms
GPS.ino	Obtaining GPS data, processing and sending data by SMS and server
POST.ino	Sending data to the server

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