Elderly Monitoring – An EPS@ISEP 2020 Project

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Abstract. In the spring of 2020, six undergraduate students from diverse countries and engineering fields decided to design together a solution to monitor the elderly. This project was conducted as part of the European Project Semester (EPS) programme at Instituto Superior de Engenharia do Porto (ISEP). The EM-BRACE solution encompasses two interconnected devices, a base station and a bracelet, and mobile/Web twin applications. The bracelet measures and transmits vital user data (pulse, temperature and falls) to the base station, whereas the base station measures home environment parameters (temperature, humidity and pressure) and sends base station and bracelet data to an Internet of Things (IoT) platform. The data stored in the IoT platform is accessible via the mobile/Web application. Thereby, EM-BRACE monitors the health and environment of the elderly and timely notifies caregivers about problems, contributing to the well-being of the elderly and their families.

Keywords: Collaborative learning, Elderly Monitoring, European Project Semester, Health, Innovative solutions, Internet of Things, Project-based learning, Sustainability

1 Introduction

The European Project Semester (EPS) is a one semester programme that offers students from different countries the opportunity to study at another university to develop the bachelor capstone/internship project within a team. The EPS concept was created by Arvid Andersen in 1995 with the aim to prepare undergraduate engineering students for their future professional challenges [3]. Specifically, it adopts a project based learning framework with a strong emphasis on multicultural and multidisciplinary teamwork and on the development of hard and soft skills. The syllabus is composed of a central project module supported by a set of complementary seminars, all taught in English. The programme has since been implemented by 19 European universities, called EPS providers, including, in the academic year of 2010-2011, the Instituto Superior de Engenharia do Porto (ISEP) of the Polytechnic of Porto. EPS@ISEP has, in addition to EPS concept features, a strong focus on ethically aligned and sustainability driven design and development [8]. The programme in Porto runs in the spring semester and has, so far, welcomed 213 students from 24 nationalities and 64 engineering, product design and business degrees.

In the spring of 2020, a gender-balanced team of six students from Mechanical Engineering (Germany), Production Engineering and Management (Poland), Biomedical Engineering (Portugal), Industrial Design (Romania), Transportation and Logistics (Estonia), and Telecommunications Technologies and Systems (Romania), chose to address the problem of elderly monitoring. Each member contributed with his/her own and different skills, culture and vision to create an innovative solution.

Humankind is facing global population ageing. There are many old people living alone, suffering from health problems and in need of frequent assistance [30]. Several accidents are not reported timely because elderly are simply unable to ask for help, leading to delayed treatments or even fatalities. Through non-stop monitoring, problems and accidents can be quickly detected and the repercussions substantially diminished. This made the team consider the design of a privacy preserving product, focused on improving the well-being of the elderly user and on helping care-givers.

One of the biggest challenges that arise from care-giving is being able to monitor patients with few staff. Thankfully, due to technological evolution and constant cost reduction of electronic components, affordable remote monitoring has become a reality. This allowed the team to idealise a system capable of measuring vital signs and recognising falls of patients. The final solution targets elders who still have a degree of mobility (albeit reduced), and spend most of the time indoors at home.

Health is a delicate subject that we must take into account when it comes to the development of any type of project. Also, there are numerous constraints involved in the process of designing a product such as respecting ethical requirements, sustainability, and environmental protection. Furthermore, the International System of Units will be used and the team will comply with the EU Directives. Another restriction is related to the maximum budget of € 100 which involves the use of low-cost materials and components.

This document is structured in five sections. It presents the objectives of the project and the functionalities of the device. Moreover, it describes the EMBRACE solution, detailing how it was designed, developed and tested, and, finally, summarises the project and personal achievements of this European Project Semester.

2 Background

The learning journey started with the research on related products, marketing, sustainability, ethics and deontology. The aim was to identify the mandatory values, principles, and criteria to be respected and, then, derive the requirements of the solution.

2.1 Related Solutions

Five different categories of monitoring devices were considered: (*i*) wearable elderly monitors; (*ii*) unwearable elderly monitors; (*iii*) domestic hand-held vital signs monitors; (*iv*) fitness trackers; and (*v*) smartwatches.

Each category has different specifications and characteristics. Wearable elderly monitors have integrated fall detectors and emergency buttons but they do not monitor vital signs [14,22]. Unwearable elderly monitors are based on artificial intelligence, record behaviour patterns, and detect irregularities. Being unwearable, they do not have the ability to monitor vital signs [32,5,13]. Domestic vital signs monitors, such as electrocardiograms, blood pressure or heart beat readers, target people in general and monitor only a small number of vital signs. They are particularly suitable for sports enthusiasts or for people with known diseases [21,6,23]. Fitness trackers are wearable devices that monitors daily physical activities and fitness-related metrics such as steps, running distance, heart rate, sleep patterns, swimming laps or calories burned [11,12,17]. Smartwatches are wearable computers, integrating wristwatch, smartphone and fitness tracker functions. However, they suffer from reduced battery autonomy due to the many functions performed [4,10,25]. Smartwatches and fitness trackers were not designed with old people in mind and, therefore, provide only partial vital monitoring and are difficult to use and understand. Products created for the elderly must include, as a prerequisite, safety features, such as emergency buttons or drop sensors [24].

Since none of the devices analysed incorporate simultaneously vital signs monitoring and safety features, the team decided to design a solution integrating both requirements as well as information about the living space, and automatic notifications. The potential of innovation of this idea lies mainly in connecting individual products because this combination represents the gap on the market. Thus, the team decided to develop a device that measures environmental and vital parameters, recognises falls, and allows remote monitoring. Furthermore, since the modularity of unwearable monitors opens a large market and wearable devices facilitate customisation, the adopted concept includes both a wearable and an unwearable device.

2.2 Ethics

The project has a profound ethical component because the product will contribute to the well-being of consumers. The team developed a device in accordance with the engineering profession ethical values [20] and in compliance with the applicable European Union (EU) directives. The goal of this study was to find an ethically aligned solution that contributes to monitor the elderly and to better quality of human life.

The goal is to monitor the health of aged users, while adopting safe components and processes, *i.e.*, which have been previously tested, validated, and certified. The gathered data must be encrypted and stored, ensuring restricted access and compliance with EU General Data Protection Regulation. This way, the team fulfils the health, security, safety and privacy requirements of the consumer, boosting the confidence and independence that many elders dream of.

In this study, the team also contemplated the transformation of the concept into a product through the creation of a dedicated company. The company should use quality components and certified providers. Each collaborator should be respected, and their work recognised and appreciated. Each one should be assigned the merits for the effort done and the results obtained. Considering environmental ethics, the device should present an eco-friendly design and ensure easy part replacement and, at the end of the product life cycle, minimal waste by reusing or recycling materials and components. In terms of marketing ethics, the promotion of the product should focus on the real benefits and its true purpose, namely, the well-being of the user.

The product name EM-BRACE was checked against existing trademarks to avoid infringing the intellectual property of another company. The adopted logo does not contain elements that can be found in other brands on the market. Also, in case open source designs or patents are used, they will be mentioned or the licenses purchased after negotiating a contract with the patent holder. All sources used in this work were referenced.

The identified ethical requirements were: (*i*) promote the real benefits of the product; (*ii*) respect the stakeholder rights; (*iii*) establish transparency; (*iv*) communicate information with clarity and accuracy; (*v*) design appropriate labels; (*vi*) provide truthful information about manufacturing, materials and components; (*vii*) foster responsibility, fairness, and honesty; (*viii*) comply with the law and follow standards; (*ix*) sell efficient and beneficial products.

2.3 Marketing

The marketing strategy provides an opportunity to face competitors and develop goods and services with high-profit potential. The number of older people living alone is growing worldwide and steadily over the years. In northern countries, over 30 % of the elderly live alone [9], suggesting a major market potential for the product. Unaccompanied elderly are prone to accidents and the main objective of the product is to ensure the safety and independence of this segment of people.

In terms of the geographical product distribution, the team decided to focus on the markets of Denmark, Norway, Switzerland, Sweden, Germany, and The Netherlands. The target is the set of "men and women over 60 years old with an average income, individuals and families interested in a healthy lifestyle".

The analysis of the Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) factors [29] highlighted several opportunities: (*i*) the single EU market is a free trading area, including the targeted countries; (*ii*) the adoption of sustainable practices, *e.g.*, the optimisation of product lines to reduce energy consumption and carbon dioxide levels decreases costs; (*iii*) customers are willing to share personal and health data; (*iv*) demand for wireless monitoring devices is expected to increase globally; (*v*) increasing life expectancy rates; (*vi*) the pension expenditure indicator increases over the years; (*vii*) the attitude towards the government in the northern countries is reliable; (*viii*) remote monitoring is less expensive compared to hospital care; (*ix*) the market for health monitoring devices is expected to increase; and (*x*) higher pensions.

The strengths, weaknesses, opportunities, and threats analysis [28] of the project allowed the team to conclude that the:

Strengths are mainly innovation, sustainability and that the product is addressing a market gap and offering numerous benefits to consumers.

Weaknesses are related to storing large amounts of data and cyber security. Also, the initial costs of launching the device on the market will be high.

Opportunities are represented by the technological evolution and the possibility to put the product on the Business to Business (B2B) market as well as the Business to Consumer (B2C) market. Moreover, customer needs are changing, and families want to be able to monitor the loved ones remotely.

Threats are related to competitors and the fact that a new brand on the market requires a relatively long time to gain the trust of consumers and to increase sales. Another threat is the rapid change in the technology industry, so the product must remain up to date.

Different marketing channels were considered to promote the product such as social media, newspapers and distribution of leaflets to senior houses, hospitals, and social security services. Specifically, the team considered allocating a monthly marketing budget of 1978 €, distributed by Facebook (558 €), LinkedIn (500 €), newspapers (800 €) and leaflets (120 €).

2.4 Sustainability

In terms of sustainability, the project focused on meeting the needs of the present without compromising the ability of future generations to meet their needs. Elderly monitoring presents enormous opportunities for the economy, society, and human well-being at a global scale. The team has a passionate commitment not only to discover, develop, and deliver innovative products that improve the life of the consumer, but also to pursue a sustainability driven practice [2].

Recently, the United Nations identified 17 Sustainable Development Goals (SDG) to be met by 2030 as a means to achieve a better and more sustainable future for all [31]. They address global challenges, namely, poverty, inequality, climate change, environmental degradation, peace and justice. This project contributes, mostly, to the promotion of good health and well-being (SDG 3) and, to a lesser extent, to responsible consumption and production (SDG 12).

To this end, the project must comply with regulations on waste management, pollution, and energy efficiency, as well as human rights and labour responsibility. The footprint of resources will be small by focusing on waste reduction, resource efficiency, sustainability innovation, and green supply. The main goals are to minimise greenhouse gas emissions and explore new low-carbon market opportunities. Also, the team strives to eliminate manufacturing inefficiencies and waste which will reduce the environmental impact and operating costs. Thus, these measures will improve resource efficiency and present new models and approaches to stimulate innovation. Regarding the product, the following measures will be implemented concerning the: (*i*) extraction of the raw materials – buy from local suppliers and to use recycled materials. (*ii*) manufacturing of the product – manufacture locally and use renewable energy sources. (*iii*) packaging of the product – use fewer and/or recycled materials and repurpose packaging. (*iv*) distribution of the product – outsource distribution to zero-emission logistics companies. (*v*) usage of the product – make a durable, easily repairable (changeable parts) product. (*vi*) disposal of the product – be easy to dismantle and with most parts recyclable or reusable.

3 Proposed Solution

This section presents the concept, design and development of the proposed solution. Based on the previous analyses, the team conceived EM-BRACE, a solution for semi-autonomous elderly who live alone comprising a home station, a long-lasting monitoring bracelet, mobile/Web twin applications for remote monitoring and a sustainable repurposable packaging.

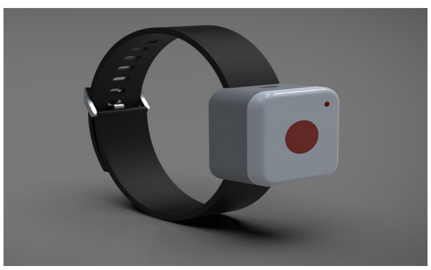
3.1 Concept

The final solution is composed of two paired devices: a wearable bracelet to measure user vital signs; and an unwearable base station to measure room pressure, temperature, and humidity. The data collected by the bracelet will be transmitted via Bluetooth to the home station, where it will be stored on a memory card, and, then, encrypted and transmitted to an IoT platform. A dedicated mobile/Web application will allow authorised persons to monitor non-stop the status of the user and home environment. The packaging will be recyclable and completely reusable as a pill organiser and medication storage box.

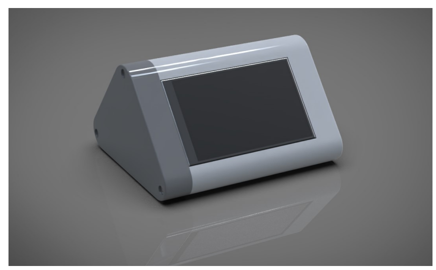
3.2 Design

As the product is addressed to the elderly, the chosen design is simple and easy to use. The bracelet has an emergency button, which is completely recessed in the lid to avoid false alarms caused by accidental activation, and a light emitting diode (LED) to indicate when recharging is required. The upper part of the casing is light grey, and the lower one is dark grey as can be seen in Figure 1a. These neutral colours are suitable for any age and clothing and direct the user attention to the button. The control station has a triangular shape that allows the display to be mounted at an angle that facilitates the reading of data (Figure 1b). This solution has better ergonomics compared to a rectangular shape with a vertical or horizontal screen. The housing consists of a main part whose cover is attached with three screws.

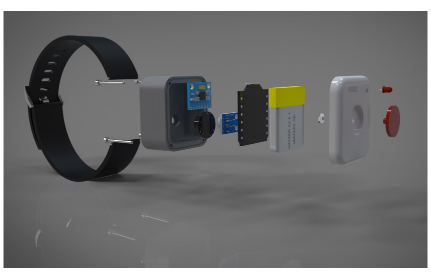
The bracelet monitors the vital signs of the user through the pulse and temperature sensors. To improve reading accuracy, these sensors are placed on the bottom of the housing, where recesses have been created to shorten the distance between the device and the wrist of the user. A gyroscope is included to detect falls. Due to their small size, the three sensor units can be placed next to each other inside the case. The Beetle Bluetooth Low Energy (BLE) microcontroller is responsible, among other things, for the exchange of data between the two devices and their processing. A micro Universal Serial Bus (USB) port is lined up in a recess to recharge the lithium polymer (Li-Po) battery that powers the device. A small button is attached to the battery and facilitates the connection with the alarm (Figure 1c). The latter is protected against falling by a shaft locking ring. The housing parts were provided with sealing gaps to meet the splash protection requirement. The size of the box is $45 \times 40 \times 24.6$ mm^3 and the total weight of the bracelet is 103 g.



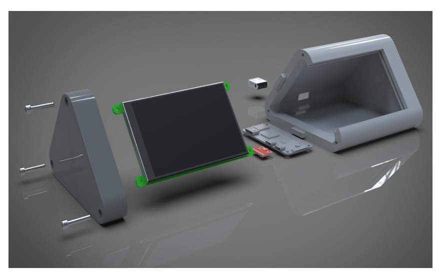
(a) Bracelet 3D Model



(b) Station 3D Model



(c) Bracelet Exploded Axonometric View



(d) Station Exploded Axonometric View

Fig. 1. EM-BRACE Design

The two components of the home station housing are centred with by two rectangular bumps located on the main part. The mounting screws are levelled with the housing. The screen is slid into the case. The circuit board shown in green in Figure 1d is guided in a groove inside the housing and held in place. The display is easy to install and can be quickly removed for maintenance. The Raspberry Pie and the room environment sensor, which measures temperature, humidity, and pressure, are attached to the bottom of the station. The device connects to a power source via a USB port. The total weight of the control station is about 383 g and its dimensions are $119 \times 104 \times 72.1$ mm^3. The design of the bracelet and the home station contemplates different colour options (Figure 2), taking into account the preferences and needs of the user.

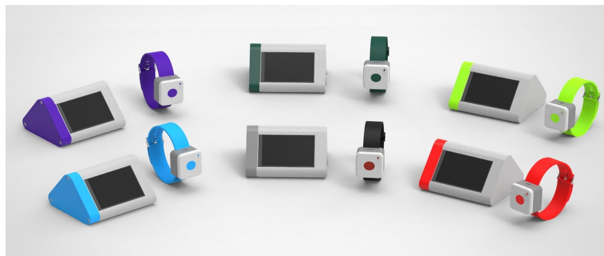


Fig. 2. Colour Options

The designed control system encompasses the bracelet and home station. On the bracelet side, the circuit has a battery, an Arduino BLE, which includes a Bluetooth communication interface, a LED to indicate when to recharge, an emergency button, a gyroscope to detect falls and vital data sensors (oxygen saturation, pulse and body temperature). The system reads and stores emergency and sensor data in the local flash memory and, once connected through Bluetooth, sends these data to the home station. On the home station side, there is Raspberry Pi 3 single-board computer, a battery and a temperature, humidity and pressure sensor. The Raspberry reads the local environment data and, if connected to the bracelet, receives the bracelet data. Then, it interprets, encrypts and sends all data to the IoT database, where they become available for the mobile and Web applications. Emergency events trigger the notification of the caregiver or family.

The packaging consists of a box with rounded edges containing the two devices, separated by an element that is removable and can be used as a coaster for cups. The lid includes a pill organiser that can be placed in the box after the user removes the two devices as shown in Figure 3a. The inside of the box under the medicine organiser can be used to store pill blister packs, jewellery, or other items. For better protection during handling, storage, and transport, a wrap made of old or damaged cardboard that replaces the usual bubble wrap will be used. The packaging elements are made of cork, a sustainable, reusable, and biodegradable material with a minimal impact on the environment [27].

3.3 Development

The data measured by the two devices are available on the home station display and transmitted to the IoT platform. The Firebase IoT platform allows the simple provision, management, and automation of connected devices [19]. Furthermore, it supports direct connection from hardware, provides several connection

(a) Packaging (b) Cardboard Wrap [1]

Fig. 3. EM-BRACE Packaging

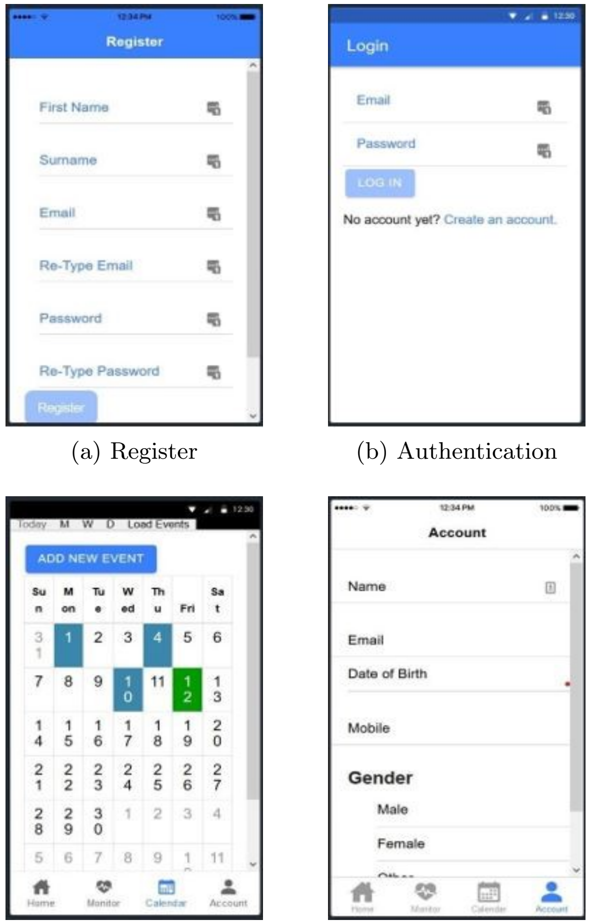
options, enterprise-quality security mechanisms, and broad data processing. The stored data is accessible through the mobile/Web applications. Since they are intended for the family, doctor, caregiver, or the elderly, these twin applications must be easy to use and understand.

Mobile App The mobile application has a registration function for maintaining a database of users and their roles (patient, doctor, caregiver, family), an authentication function for accessing the app, and a set of four tabs:

- Home tab provides the welcome screen and user notifications;
- Monitor tab displays real-time measurements;
- Calendar tab allows scheduling and checking appointments;
- Account tab shows the account information (such as e-mail and name) and grants monitor as well as calendar synchronisation permission.

Figure 4 shows the implemented functions.

Web App The Web application provides cross-platform access from Android, iOS, Linux, MacOS or Windows. The Web application encompasses: (*i*) the front-end, that defines the User Interface (UI), developed with Ionic Framework and AngularJS; and (*ii*) the back-end that offers an Application Programming Interface (API) to store and retrieve data, supported by Google's Firebase. Ionic is built on top of Angular, meaning it uses the Terminal/Command Line Interface to initialise a server for development/testing, with the advantage to see how the code modifications impact the application as soon as the file is saved. Firebase provides analytics, databases, messaging, and crash reporting, making it perfect for testing and simulation [16]. Although it has pricing plans, the free version is more than enough to create a proof-of-concept. The code tree structure is similar to that of any AngularJS website, having HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and other Angular components such as page module for loading components, the page itself for using the components, and routing.



(a) Register (b) Authentication

(c) Calendar (d) Account

Fig. 4. Mobile Application

Control System Due to the pandemic situation, most of the necessary components were either out of stock, available at a higher price or shipping taking over 30 days. Therefore, the components were not ordered. Consequently, the solution was to develop what was possible and simulate the rest. Nevertheless, the team assembled a reduced version of the designed control system using a Raspberry Pi 3, a DHT22 humidity and temperature sensor, an Arduino Uno with two buttons, an HC-05 Bluetooth Low-Energy module and a LED.

The Raspberry was used together with the DHT22 sensor to partially implement the home-station control, while the Arduino Uno together with the HC-05 Bluetooth Module to partially implement the wearable-side control. The "Simulation Button" triggers a emergency event on the bracelet-side, indicating a potential fall. Once pressed, the user has 5 s to report a false alarm by pressing and holding the red button for 3 s, and reset the 5 s timer. If no action is taken, the emergency event is confirmed and sent to the database, where the notification and email push system are triggered. Figure 5 display the assembled circuit.

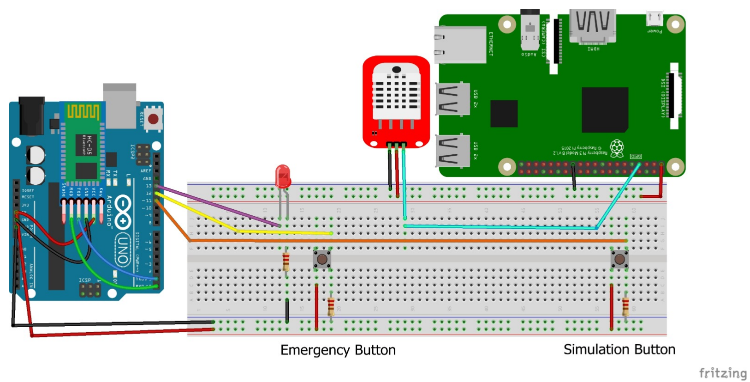


Fig. 5. Assembled Circuit

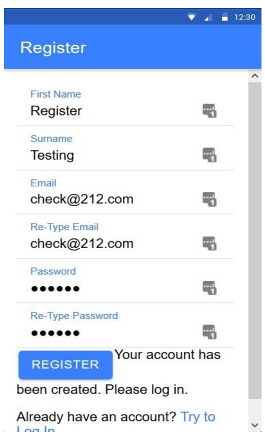
The Arduino executes a pseudo-random number generator to produce values within the expected range of the bracelet sensors. Once the connection is established between the Arduino (bracelet) and the Raspberry (home station), all bracelet values are sent to the Raspberry (emergency state, pulse, blood oxygenation level and body temperature). Next, the Raspberry processes the bracelet data as well as the local humidity and temperature data. To calculate the pulse rate, first, it discretises the signal and, then, applies a digital gradient peak detector to several heart beats. Since the heart rate may vary between 50 beat/min to 200 beat/min, an analysis interval of 4 s will always include at least 3 heart beats. Considering that the pulse sensor has a theoretical sampling frequency of 400 Hz, the peak detector processes then 1600 samples (400 Hz×4 s= 1600) to determine the heart beat. Finally, the heart rate, level of oxygenation, emergency and average temperatures (using a 10-sample filter) are uploaded to Firebase.

The Raspberry Pi code was developed in python 3.5. To manage all the necessary dependencies, a source environment was created using Conda. Conda is an open-source package and environment management system that quickly installs, runs, and updates packages and their dependencies [7]. This was especially useful to use the SciPy package, which is a Python-based ecosystem of open-source software for mathematics, science, and engineering [26].

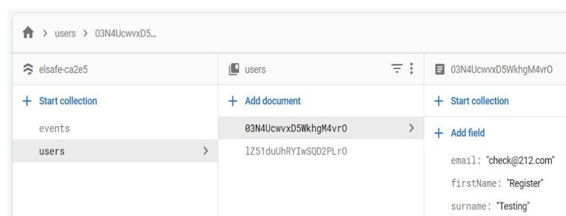
3.4 Tests

The performed tests validated code rather than the control system operation. The latter was not fully implemented due to the undergoing pandemic. Nevertheless, it was possible to verify the proper functioning of the Mobile app, Web App and parts of the control code both on the bracelet and home station sides.

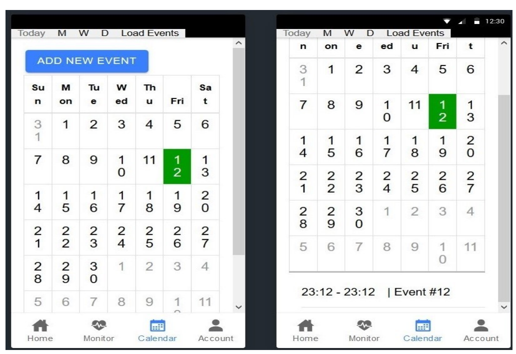
Mobile App The mobile application was developed and tested. First, the user must register to create a new account. The registration is a validation form which checks the email format, the password size (at least six characters) and a re-type field (Figure 6a). As shown in Figure 6b, when a user registers, the



(a) Registration



(b) IoT Database

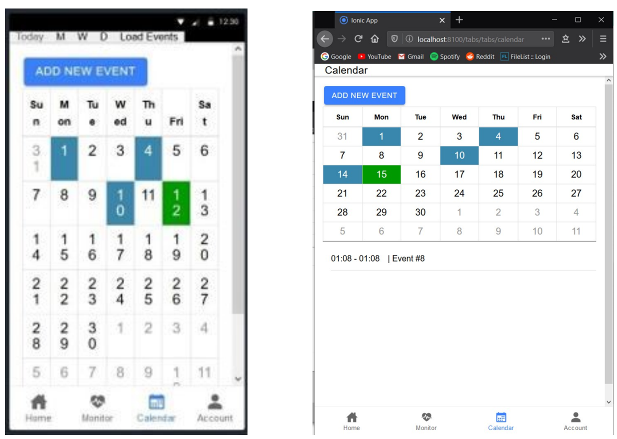


(c) New Event

Fig. 6. Mobile Application Tests

process is managed by linking the Web App and sending the data to Firebase using AngularJS [15]. After registration, the account is created. Once the user is authenticated, the home tab opens to greet the user and show upcoming appointments. The calendar tab provides an interface to view, add, or remove personal events. For testing, a random event generator was used to verify if the information was correctly displayed. The "Add new event" button simply adds an event for the next hour and synchronises with the database, as seen in Figure 6c. The account tab shows the information already provided by the user and allows record updating, *e.g.*, age, weight or gender. Switching to the monitor tab accesses the sensors to which the user has permissions.

Web App The tests with the Mobile App validate also the Web App since Ionic is a cross-platform framework. Albeit mostly oriented on the mobile side, the same Ionic source-code adapts automatically to various platforms. This includes the ability to build and push the code into the official Google Play Store and iOS App Store. Moreover, individual changes can be made according to each platform in order to implement OS specific features. Figure 7 shows the "Calendar" on the mobile (Figure 7a) and Web (Figure 7b) applications.

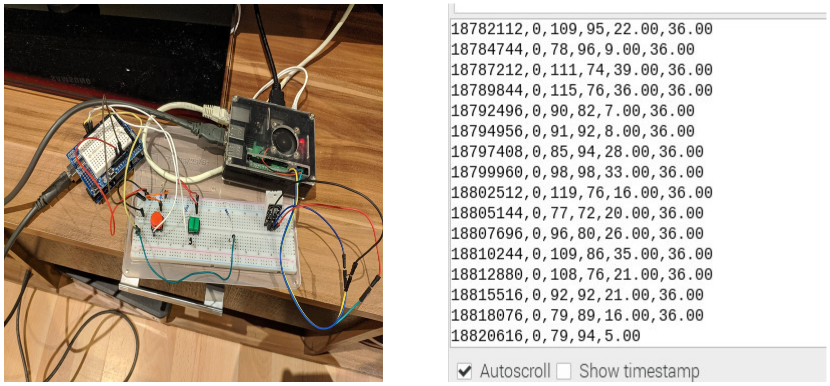


(a) Mobile App (b) Web App

Fig. 7. Mobile and Web Calendar Views

Control System The tests were performed with the physical set-up presented in Figure 8a, which corresponds to the circuit displayed in Figure 5. The bracelet is controlled by the Arduino and the home station by the Raspberry. This set-up allowed testing the: (*i*) creation and communication of environment and vital data to the database; (*ii*) processing of pulse data; and (*iii*) generation and communication of emergency events to the database.

Unfortunately, the Bluetooth communication between Arduino and Raspberry was not established due to a technical difficulty. Although the Arduino



(a) Set-Up (b) Measurements

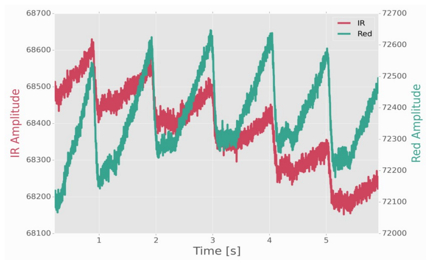
Fig. 8. Control System Tests

paired with the Raspberry Pi, the connection systematically failed regardless of the connection method (Bluetooth serial communication and socket communication). Therefore, communication was established via a USB connection. The Secure Shell (SSH) protocol was used to establish the communication between a master computer and the Raspberry Pi, allowing remote management of the system. This code, running on the master computer, was also able to successfully interact with the IoT platform.

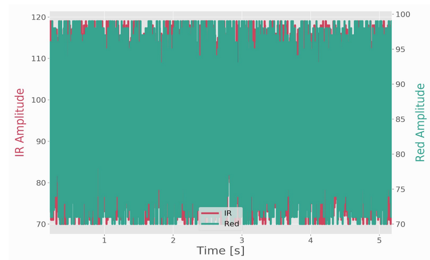
The Arduino code was tested in the Terminal/Command Line Interface mode as shown in Figure 8b. It successfully generated the random sensor values and printed to the serial connection, from left to right, the running time (ms), emergency state (true or false), pulse rate (beat/min), blood oxygenation level (SpO_2) and body and environment temperature (°C).

Figure 9 displays real pulse readings obtained from [18] (left) and the random pulse values generated by the Arduino and processed by the Raspberry Pi (right). Figure 9a presents the infrared (IR) and red light measurements obtained by the a pulse sensor. The first plot represents the values read by the internal IR receiver and the second shows the red light emitted. While the red/infrared modulation ratio indicates the SpO_2 level, the processing of the IR signal provides the pulse rate (beat/min).

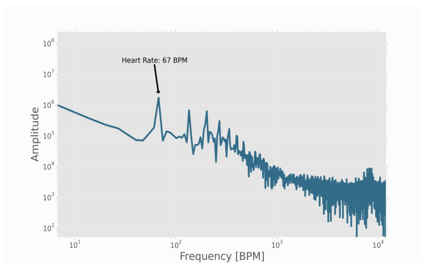
To try to obtain a meaningful pulse rate, several signal processing algorithms were explored on the Raspberry side. The first Python sketch reads the serial line, saves the data, removes noise, saves the data to a Comma Separated Value file, plots the samples, and saves the graph as Portable Network Graphics file (Figure 9b). The second sketch performs a Fast Fourier Transform (FFT) analysis on the previously saved samples. The fundamental frequency will correspond to the pulse rate (beat/min). However, the FFT requires reading several heart cycles to determine the correct rate (Figure 9d). Finally, a second-order gradient function was used to approximate the pulse rate. Since the steepest point in the



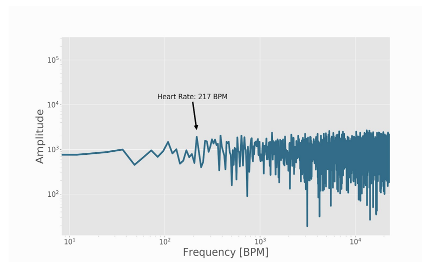
(a) Real Data Plot



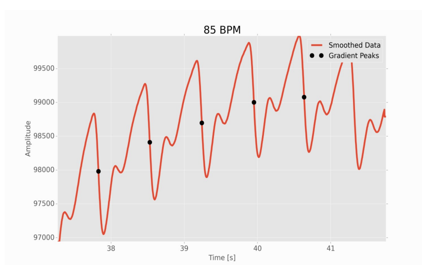
(b) Random Data Plot



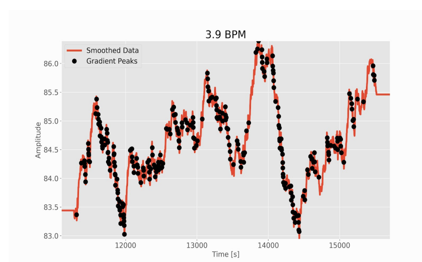
(c) Real Fast Fourier Transform



(d) Random Fast Fourier Transform



(e) Real Gradient Peak Detection



(f) Random Gradient Peak Detection

Fig. 9. Signal Processing Experiments

circulatory cycle is the systolic point (heart contraction), the method applies a gradient peak detection algorithm to identify the systolic gradient peak. Figure 9f displays promising results.

4 Discussion

EM-BRACE allows the remote monitoring of the health and environment of the elderly. The performed tests have indicate that the device potential, leading to a successful future implementation. Thus, the main goal of designing a solution to improve the live of elderly, caregivers and family has been achieved. EM-BRACE is in line with the remote health monitoring trend supported by the continuous technological evolution.

The development of a proof-of-concept prototype would allow real testing, debugging and refinement. Also, a larger budget would allow choosing higher quality components, *e.g.*, providing longer bracelet battery autonomy, better accuracy and more frequent readings or reducing dimensions. Smaller and lighter components will improve the product design and daily comfort. Moreover, the team would need to continue to pursue high-performance solutions for the privacy and encryption of data.

Despite the difficulties encountered due to the COVID-19 outbreak, the team managed to fulfil the initial objectives of the project. The members adapted to the new requirements, but, unfortunately, it was impossible to make the prototype. However, the cases of the two devices were 3D-printed, obtaining a realistic image of the products and their dimensions, the control system was simulated, the mobile application developed and tested, and mock data stored in the IoT platform.

The functional tests and simulations were carried out exclusively online due to the impossibility of making the prototype. Because of this, the relevance of the results is affected because certain initial objectives cannot be achieved and not all components and their mode of operation can be tested. Also, the Bluetooth communication was not simulated. These tests are intended to ensure the proper functioning of the products and to prove that the product is reliable.

A future implementation of the project will take into account the assembly and test of the prototype, leading to the refinement and addition of new features to EM-BRACE.

5 Conclusion

All the initial objectives were accomplished except for the prototype and the physical tests due to the undergoing pandemic. Teamwork and communication went very well and the team worked as a whole to meet all deadlines. In terms of personal goals, the members developed new knowledge and skills as part of a multicultural experience, while, at the same time, made new friends. ISEP offered the opportunity to participate in a well organised and established programme, allowing the development of an ambitious capstone team project.

5.1 Project Outcomes

The team designed the EM-BRACE solution (device, control system, mobile/Web applications and packaging) due to its inner organisation and the support of the teaching staff. The design meets all the initial requirements and is able to monitor the elderly. In addition, regarding the main deliverables, the team developed a mobile application, produced a video, poster, leaflet, flyer and a user manual with instructions and safety information for proper use; wrote a detailed report of all activities and this paper; and made several presentations.

5.2 Personal Outcomes

In this section, the team wants to give credit and to thank the teachers and supervisors who guided us throughout this semester and, thanks to whom, we managed to make a unique project. Below are the testimonials of the team members about this learning experience.

– "The EPS was an exciting experience for me, especially in relation to the different nationalities and the interdisciplinary structure of the project. The project framework was very well organised due to the deadlines of the deliverables and the wiki structure. With questions and ambiguities, one could count on help and feedback from the professors. I only take positive memories from my time in EPS and believe that the project semester will help me, particularly in terms of team communication and organisation. Despite the COVID-19 outbreak, the very best was made of this difficult situation." – Julian.
– "Through the European Project Semester at Instituto Superior de Engenharia do Porto, I will be able to expand the knowledge gained during the Mobility Programme and use it in my future life. Our project, called Elderly Monitoring, gave me an opportunity to take part in a project which prepared me for my future career as an engineer. The project also gave me the opportunity to put in practice the knowledge I had and integrate with the new gained from all sources. EPS prepared me to work in an international group and deal with the problems that occur. Mainly, it taught me how to think outside the box." – Klaudia.
– "I believe that a remarkable academic path must include not only theoretical knowledge but also new life experiences. EPS provides the opportunity to dive into the real process of the development of a product/service and learn topics, like sustainability and ethics, regarding engineering practices that every engineer should know. It gives creative freedom and covers multiple topics, that, otherwise, would probably be left out of a traditional syllabus. The semester fosters communication and responsibility and, for once, on team rather than individual success, i.e., how individuals can contribute to the accomplishments of the team. I cannot think of a better way to end my Bachelor degree." – Margarida.
– "International experiences have always contributed to my personal development. In this semester, as in the case of previous mobilities, I visited a different country, discovered a new culture, and met people of different nationalities, who became my friends. During the courses, I learned many things and enriched my knowledge. Thanks to EPS, I managed to develop, together with five colleagues, an innovative project that contributes to the well-being of the elderly. Despite the difficulties caused by distance learning, we overcame the challenges thanks to the support of the teachers and the motivation of the team, achieving an excellent report. I believe this unique opportunity must be experienced by any student who wants to test their limits, qualities and skills." – Roxana.

- "Choosing EPS at ISEP was natural for me. Many of my good friends have done it in the past and I had heard only good things about it. The five weeks I got to spend in Porto were filled with new knowledge and exciting moments. In the academic sense, EPS was something completely different from what I have ever experienced and I am sad that the pandemic forced to cancel contact classes. I have never been good at studying at home and it showed. The beginning of the semester was strong but, week after week, my contribution decreased. Luckily, Roxana, Tiberius, Margarida, Julian, and Klaudia are a dream team to work with. I would personally like to thank them and all the teachers." – Mihkel.
- "Having spent both semesters of the academic year abroad at ISEP, I had high expectations for the second-semester project (except for COVID-19, nobody expected that). From the first day, the teachers were kind and open to questions and provided feedback whenever needed. Our team clicked from the beginning and was focused on creating something new and helpful from scratch. The project took a swerve when everything moved online because of the pandemic, but we adapted quickly and maintained the initial commitment to work together as an international team and go through the process of creating something useful and with the concerns of production in mind. Truly an enriching experience from start to finish." – Tiberius.

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