Imperial College EEE 2nd Year Group Design Project - Group 3

Arjun Bhushan (01511448)
Priya Chhaya (01497507)
Luke Gonsalves (01518417)
Rhys Johnson (01526052)
Nima Karshenas (01500753)
Lindsay Murray (01522527)
Alexander Scott (01503330)
Sebastiano Zane (01507731)

Supervisor: Ayush Bhandari

20th March 2020

Contents

1 Abstract

Technology and dementia are words that don't usually go hand in hand, there are very few technologies on the market that are focused on improving sufferer's lives. Many people with dementia are forced to spend extended periods of time alone, leaving them prone to various potential accidents and hazards. In many cases accidents leave sufferer's unresponsive and thus unable to notify their carer of such an accident. The objective of this project is to provide an automated interface that enables notification in the event of an accident as well as serve as another medium of communication between carer and patient.

Initially, a Gantt Chart was created. This outlined the detailed plan to be carried out, boiling down the multiple tasks and timelines into a single document. It also served as a tool, facilitating great time management by enabling easy progress tracking as well as co-ordination with other team members. Our prototype contained two main components, a wristband and a home hub. They each have two main attributes to address, Hardware and Software, but they both follow the same general design plan. That is Research, Initial Design, Initial Design Development, 1st Prototype, Refinement, Testing, Final Prototype.

The wristband produced was able to detect falls with 95% accuracy and efficiently send a signal to the home hub via a cloud service, ThingSpeak. The home hub in turn, processed this information and sent an alert to the carer via Telegram utilising a chat bot. The home hub, also included a variety of Dementia friendly features, such as an integrated day clock, medicinal reminders, the ability the display and read aloud custom messages and a website containing patient medical records that could be accessed via an NFC tag.

Of both components, the wristband proved to be the most difficult to produce due to the size of constituent parts and power consumption of the micro-controller. Thus, a compromise on its dimensions had to be made. In terms of the home hub, the primary problem encountered was its integration with the wristband, due to differing bluetooth protocols, which was easily overcome by utilising WiFi. In spite of these difficulties the final prototype produced worked very well and was efficient in performing the desired tasks.

The following report documents and presents the design process and production of Group 3's 2nd year project.

2 Introduction/Background

In the previous report it was identified that Alzheimer's and Dementia are serious conditions that can cause several problems to the day to day activities of people who are suffering from it. With an ageing population and an increasing dependency on the working population, the number of sufferers from these diseases will increase exponentially over the next decade, with 10 million new cases every year worldwide. The following report outlines the group's final design for a potential solution to aid sufferers.

Dementia and Alzheimer's are incurable with modern medicine at the time of writing. In light of this, the designed prototype is going to be aimed at improving the living quality of the sufferers and aims to reduce some of the struggles that they face because of these diseases.

Due to a significant number of Dementia and Alzheimer's sufferers being of a significant age, many of them are prone to accidents such as falling, which can be extremely detrimental. According to the CDC (Centers for Disease Control and Prevention) [2]. an estimated 3 million elderly people are treated in an emergency due to a fall therefore the group determined that the best method to address this issue would be to alert carers or medical help in an emergency and to provide the patient's medical information easily. The group believes that this would best improve the livelihood of the user as well as being the most feasible prototype within the given time limit.

One of the key focuses of the project was to produce a prototype that provided some innovative factor to the market. Despite fall detection wearable devices being in an abundance at the moment, most if not all of them are costly and are targeted at consumers who are already familiar with technology. Our prototype aims to create a fall detection system that is ideal for users with Alzheimer's and Dementia as it will require little user input and the most of the User interaction will be with a carer. As well as this the project adds in components from other products that exist in the market and aims to produce a prototype that caters to several issues that are faced by the Alzheimer's and Dementia community.

3 Design Criteria

The design criteria for the product is printed below. Any changes to this from the initial report are noted. A brief evaluation of how each element has been met is included.

3.0.1 Maintenance

The product should not require an excessive amount of maintenance as the user may struggle, or be incapable of doing high amounts of maintenance for continued independent use of the product. Therefore, the product should be designed to be durable and long-lasting after initial installation. The only maintenance that the product may require would be minimal, for example the replacement of batteries or a charging feature - both of which should be designed to be easy for a user to carry out.
This element of the PDS has been unchanged from the initial report. It was constructed with key thought to the target demographic and this is still the case. The final design does meet the outlined criteria with battery changes being the only required user maintenance to the product.

3.0.2 Customer

As described in the problem definition, the target consumer of the eventual product is going to be focused on people suffering with Dementia and Alzheimer's. The vast majority of this demographic are elderly and so the design of the product should take into account both the cognitive implications of suffering with these diseases, as well as physical limitations of being at such an age. The main objective in the design of the product is to ensure that there are few requirements in terms of attention to and general use of the product.
The customer for the product remains the same but with a broader focus on elderly people in general. This is as the features included in the product will be beneficial to elderly people without Alzheimer's's, but with still considering people with Dementia as the main target customers. It is believed that the product does improve the quality of life of the customer and with the limitations of the user demographic, such as physical ability and sensory decline, in mind.

3.0.3 Ergonomics

The difficulties of handling and interacting with technology is one of the resulting problems of suffering with dementia and Alzheimer's. This means that if any sort of interface is to be used, the complexity of it must be kept to a minimum to prevent its misuse. In the event of a wearable solution being implemented it must not cause the user any discomfort.
This element has been unchanged with development of the product leading to easy & simple usability. The user interface of the Home Hub is simple. However, implementation of accessibility features such as audio description has very limited functionality due to time constraints on the project.

3.0.4 Quality & Reliability

The product that is selected to be developed should be as robust as possible, this possibly means using automated methods of construction, for example, laser cutting or 3D printing. The main source of unreliability of the developed product would come from electronic components. To increase reliability, waterproof containment of electronic components may be required to prevent water damage depending on the selected solution design. The lifespan and probabilities of individual electronic components should be in line with values found in the IEEE database.
The criteria for Quality & Reliability has not been met. It was found to be difficult to design and acquire perfectly waterproof casing in given time. Also, the electronic components are likely to experience damage after excessive amounts of falling or direct striking. These events are unlikely but possible given the environment and usage of our product. The product is acceptable with regards to this element but does not meet the standards set in the initial report.

3.0.5 Testing

An adequate amount of time should be allocated for testing to be done. This is especially important in order to determine product proficiency in its various qualities/aspects. In addition, due to the product being intended for those suffering with Alzheimer's/Dementia, it would be ideal to test the prototype on a first-hand basis after having received relevant clearance and permission. It would also be important to ensure that any sort of testing would not lead to the product straining the allotted budget.
Adequate time was allocated to allow for comprehensive testing. However, we were unable to test the final prototype

on the target demographic, this was one of our main hopes but delayed progress on the prototype meant such was not able to be organised before the project deadline.

3.0.6 Safety

This product has a significant proportion of its user base being of old age as well as suffering from Dementia or Alzheimer's. Thus, safety needs to be considered greatly. Whatever is made must reduce the risk of injury anywhere possible. Some ways of doing this are smoothing edges of anything that could house the potential product, and make sure there is nothing that could cause the user to fall or lose balance. However, the exact safety requirements for the product are currently undecided as those are specific to our final design choice.
The safety standards set out for the product have been met. No harm is placed on the user and the desired emergency contact feature has been successfully implemented.

3.0.7 Documentation

This element has been removed from the design criteria after the decision that alternative elements were more important to adhere to. Therefore, documentation for the product has not been designed within the project deadlines. In light of this, further attention was paid to delivering an accessible video tutorial directed at the target demographic. Additionally, extensive care was taken to ensure that the audio description driven UI was intuitive.

3.0.8 Time-Scale

The manufacturing stages of the prototype should take 3 months. This is a strict deadline as the product must be complete by 2nd March. Most final testing must be done by mid to end of February. This allows 8-10 weeks for the manufacturing stage, at the end of which, the product should be complete. After the demonstration of the prototype, the production and distribution of the product should be ready for mid 2020.
The time scale was constant throughout the project. Development of the project was segmented into achievable goals within the time period. This meant that we would have a demonstrable product at the end of the project and additional features & modules could be added if time allowed. The constraints for this were met and allowed for the expansion of the product as planned.

The following elements have been added to the Design Criteria since the initial report. This was done as, after the proposed solution had been selected, the specifications of these elements could be more accurately addressed. These have been split to address the wristband system and Home Hub system separately.

3.1 Weight

For Wristband: The constraints set on the weight of the wristband were designed with the aim of minimal discomfort to the user. Therefore, the criteria is to keep the weight to a minimum. The wristband product at the time of demonstration weighed 63 grams. The product is easily wearable for long periods of time without strain or discomfort. Although this could be lowered, the weight of the wristband has been evaluated as acceptable and meets the design criteria.
For Home Hub: The design criteria for the weight of the home hub had very lenient specifications. The weight needed to allow for easy installation into a home, by not having to great a weight that installation difficult. This has been met.

3.2 Size

For Wristband: The constraints set on the size of the wristband were designed with the aim of minimal discomfort to the user. Therefore, the criteria is to keep the size to a minimum. The wristband product at the time of demonstration was 48mm x 30mm x 18mm. Although this size allowed for the wristband to be easily worn, the size was not ideal for a final product. The casing was bulky and not suitable for wearing on the user's wrist for extended periods of time. The size would need to be reduced to meet the design criteria.
For Home Hub: There were no specific dimensional constraints on the size of the Home Hub. The screen size of the product is 6.1 inches by 3.5 inches. The total rectangular size is 6.5 inches x 4 inches x 3.8 inches. This would allow for easy placement into a home on a suitable surface. However, the screen size is smaller than ideal due to eyesight difficulties which many of the target demographic would suffer from. This element has been evaluated as met but with ideal improvements.

4 Concept Development

The group envisioned the project as several sub-systems that would combine to form cohesive unit. The project would operate as follows:

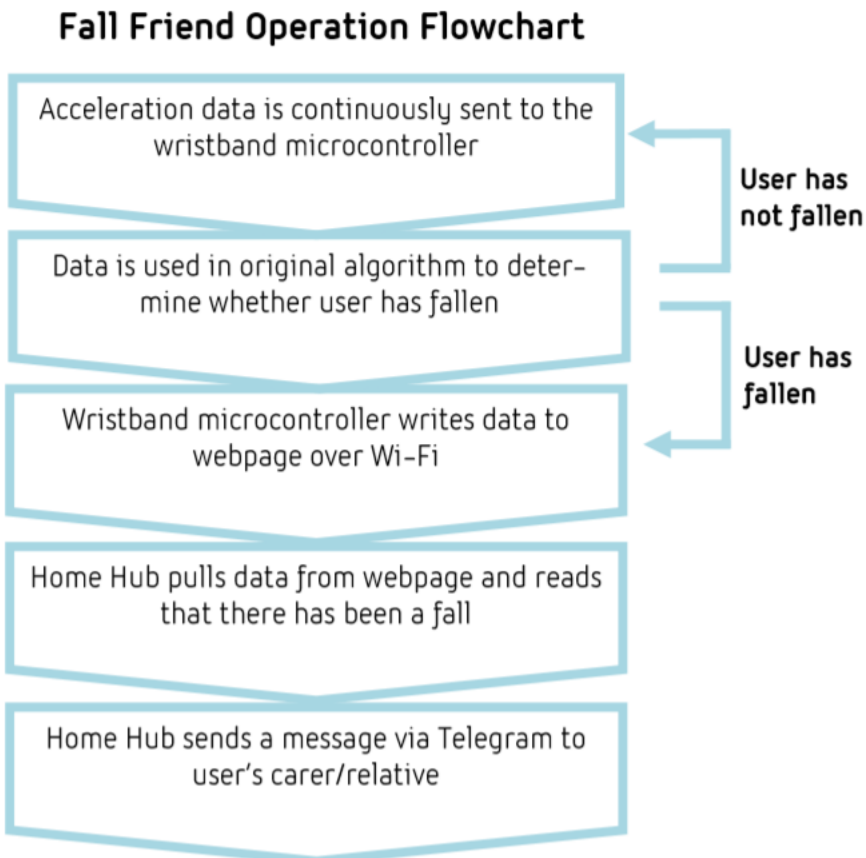

Figure 1: Flowchart detailing the operation of the project

Following the breakdown of the project into subsystems, work was divided between team members according to these subsystems to ensure efficient completion of the project as a whole.

4.1 The Medical Wristband

The purpose of the wristband is to alert the user's carer or relative via a message, when the user falls. If the system misinterprets a fall, the user can then scan their wristband at the home hub to send another alert that informs the carer that the user is okay. As well as this, the wristband can be scanned by emergency and medical services to find the patients medical history, as well as emergency contact information. The benefit of this is that the carer would no longer have to keep a hard-copy of their patient's information on-hand at all times, they would be able to scan the wristband. For example, if the user needed to be rushed to hospital, all the information a paramedic or doctor would need is available with the scan of the device.

4.1.1 Functionality

The wrist band is composed of several different systems that are combined to form a coherent product.

Firstly, the wristband contains an NFC (Near Field Communication) tag that is linked to an online database - this stores the patient's medical history and current health securely. When scanned by a mobile device, the medical information can easily be presented if needed by a carer of a medical professional at short notice.

The wristband contains Arduino Nano IoT 33 that uses a built-in accelerometer with a self-designed algorithm to detect falls. The Arduino Nano is a BLE (Bluetooth Low Energy) and WiFi device that is able to easily transmit data to the home hub. When a fall is detected, this information is sent to the home hub that relays this to the patient's guardian or carer.

If a fall is interpreted, the device automatically transmits a signal over Wifi to the home hub. The home hub then relays this information to the carer in the form of a text message over an app called Telegram.

4.1.2 Development

This device went through several phases of development and each phase posed a different problem the group had to over come.

Initially , the group decided to purchase a DFRobot BLE Bluno Beetle as the wearable micro-controller as it had the smallest dimensions of any BLE micro-controller on the market and it used Arduino, a software which every member of the team had prior experience in using.

A problem that was encountered when attempting to connect the Bluno Beetle to the Home Hub was that it required a specific DFRobot BLE dongle in order to maintain communication between the two devices. Unfortunately, the DFRobot dongle was not available in EEStores. We then allocated some of the budget to develop the fall detection on a slightly larger Arduino micro-controller, the Arduino Nano 33 IoT. This provided greater library support and could easily communicate with the Raspberry Pi via WiFi.

A power supply was then chosen for the fall detector. This selection was based on the amount of power it was able to supply, size, and cost. Lithium Button Cell batteries were first chosen as they were realtively small and reliable. Initially, 4 of these cells were used to try to power the Arduino. The cells were contained in a 2 button cell battery holder. The holder's dimensions as well as its cost were ideal for the wristband design. However, upon more rigorous testing it was discovered that the power supplied by the button cells was insufficient for a reliable connection to be established between the Arduino and the Raspberry Pi. A steady current of approximately 100mA (higher when actively transmitting and receiving) as well as a booting current (this is needed to establish WiFi connection) of 190mA were determined to be ideal operating conditions. Thus, Lithium Polymer batteries were then selected as they were able to efficiently supply the needed current. However, it was extremely rare and expensive to find LiPo batteries of reasonable size that provided more than 3.7V (3.7V is not sufficient to power the Arduino Nano according the recommended criteria of the on-board regulator the MPM3610).

In order to satisfy the need for a 4.5V threshold voltage, We initially considered Two 3.7V LiPo batteries connected in series. However, there are such significant safety issues associated with the unbalanced loading of such chemical cells that it was collectively deemed most sensible to include an Adafruit module, which combined both a safe charging circuit for battery recharging as well as a boost converter to provide a constant voltage of 5V. Therefore only a singular, 3.7V LiPo battery connected to the Adafruit module was needed to ensure sufficient power to the wristband and allow for easy user-charging via USB C.

4.1.3 Design Sketches

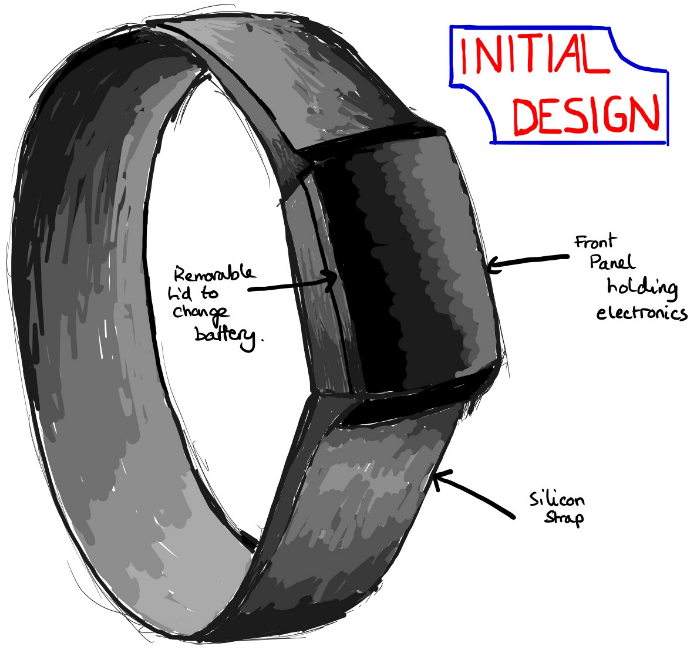

Figure 2: Initial sketch of wristband

The final design of the wristband was done using SolidWorks and it was then 3D printed. The size of wristband was an issue as it had to be large enough to enclose the battery, the Arduino Nano IoT and a boost converter. In addition, it had to be small enough to be considered comfortable and not intrusive to the user. Thus, exact measurements of the various components were taken and the case that was made used dimensions only slightly larger than these to ensure a compact fit. The final design was cuboid in nature and included a sliding cover to enable easy access to components.

4.1.4 Cost

Component	Cost	Quantity
Arduino Nano (IoT)	£14.95	1
Lithium Ion Polymer Battery - 850mAh	£15.00	1
NFC Tags(Pack of 10)	£5.00	1
Adafruit PowerBoost 1000 Charger	15.45	1
Wristband Strap	£7.00	1
Total	£57.4	1

The table above shows the cost of the wristband prototype as on the demonstration day. Additional funding was spent during the process for the purposes of testing different components and designs for the wristband. These have not been included in the final costing table.

4.1.5 Testing

For a device that is designed to help people who have fallen, it required us to do a thorough and rigorous set of testing such that we could try and minimise where possible the probability of failure; where in this scenario failure

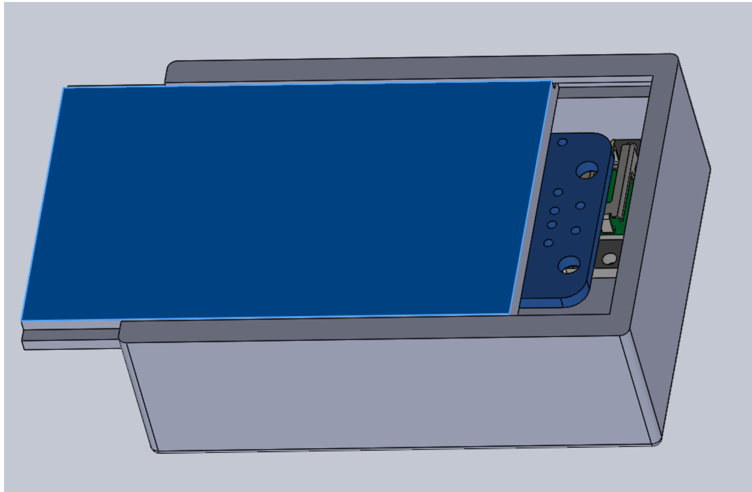

Figure 3: Final solidworks design(closed)

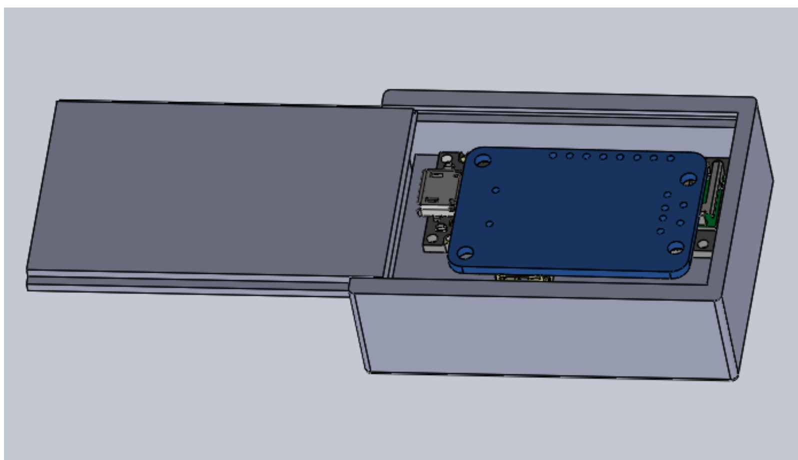

Figure 4: Final solidworks design(open)

is ONLY considered as a 'Type 2 Failure', i.e. the device's inability to recognise that a fall has occurred and hence potentially leaving the user at risk. Given the potential risks of not recognising a fall has occurred it was decided that the device should recognise that a fall has occurred a minimum of 95 % of the time.
The group tested the wristband's ability to detect falls extensively using 'trust falls' between group members. This is when one person leans forward or backward until they feel the sensation of falling , at which point a secondary group member prevents them from hitting the floor. This technique allowed us to accurately simulate a patient falling or stumbling. When conducting these falls, we achieved a success rate of 92%.

Figure 5: 3D printed case attached to strap

4.2 The Home Hub

The Home hub concept came from one of the currently existing products that were found when were initial research was conducted for this project. The product was called a 'Day Clock' and it was used to aid those people with Alzheimer's and Dementia who are more susceptible to disturbances in their circadian rhythm [1]. It was decided that this could be integrated with the wristband and other system to provide a greater and easier experience for users. This is separate module that is much less restricted in size and power consumption therefore it allows the group to add new features constantly, providing the possibility for the product to adapt and improve as time goes on.

4.2.1 Functionality

The primary role of the home hub is to communicate with the wristband and to transmit data from the wristband band to the user's carer. When a fall is interpreted, the wristband transmits a signal over WiFi to the hub, which then triggers python code that relays this information to the carer in the form of a message on the Telegram app. Telegram was chosen as the messaging service to alert the carer, as it is free to use (as opposed to SMS), which keeps the overall cost of the product lower. In addition to this, telegram can be easily synced to laptop as well as mobile, and is an extremely secure and encrypted messaging service.

Another feature that was implemented was the 'Day Clock', which allows patients to easily determine the time of day, through displaying the day and time of day (ie, Afternoon), as well as the actual time. Studies have shown that due to anxiety and loss of memory, simpler clocks like these help dementia patients distinguish between day and night. The the text on the display had to be large and easy to read, without being overwhelming.

The final feature that was chosen was a communication channel between the carer and the user in the form of a minimalist alert system integrated into the Day Clock display screen. The idea was to enable administrative access for the carer to the user's dedicated web page, whereby there is to be a box where the carer can type and send alerts. The user then should be notified via notification sound played on the home hub. As the user approaches the Home Hub, they can scan their wristband, enabling them to access the alert, this also sends a signal back to the carer that they have received this.

4.2.2 Development

The first stage of development consisted of constructing a reliable interface between the Raspberry Pi and the Arduino Nano. This reliable communication channel would be crucial in ensuring that no fall would go undetected.

Initially Bluetooth was developed to provide this connection due to its low power consumption. However, establishing this connection proved to be arduous, furthermore, the data sheet for the radio module of the Arduino showed that the typical current consumption of the Bluetooth transmitter was 130mA compared to the 190mA of the WiFi transmitter. If the transmitter were to only be used to notify the Raspberry Pi of a fall and otherwise be in sleep mode, this additional current consumption would prove to be negligible in the overall battery consumption of the wristband. We had to ensure that the power supply used in the wristband would be able facilitate this additional instantaneous current. Moreover, WiFi provides further connectivity range and so increases the reliability of the connection, especially in larger households.

After the initial purpose of the Home Hub had been established and developed, the additional functionality components were developed. This included the interface of the Home Hub, as well as the capabilities for user interaction. Software was designed which provided multiple display interfaces to appear on the screen of the Home Hub. This included a 'Day Clock', showing basic information about time of day. This was designed to provide the user with reassurance and prevent confusion, which the vast majority of Dementia patients experience. Another screen designed was the medical tracking display of the Home Hub. This provides the user with information about the time till their next medicinal treatment and any other necessary details regarding this, (e.g, dosage). The final screen was a notifications centre. This would display any messages sent to the user by a relative/carer from our website, allowing for a relative/carer to easily communicate with the user and provide essential information.

This screen updates every 60 seconds to ensure the information shown is accurate. While on this screen, the website is regularly accessed to detect if a new notification has been sent. This will then be displayed on the screen. If the website is unable to be accessed due to the Home Hub having lost a stable internet connection, then the user if notified of this. Otherwise, all features of the Home Hub are accessible at all times.

The targeted user demographic of our product is likely to have difficulties with eyesight or hearing. Considering this, A speaker is implemented into the Home Hub providing the capability for audio description. Pre-recorded audio files are outputted as the Home Hub operates. This includes informing the user of which screen the Home Hub is currently on; any actions the user has performed on the Home Hub; when the user's medicine is due and when a new notification has been received.

Development of the hardware attached to the Home Hub took place simultaneously to the software. This included implementing features which allowed the user to interact with the Home Hub. To simplify the controls three photo-transistor sensor were introduced to the Home Hub, giving the user the ability to utilise the different features of the Hub easily. The sensors wired in series with suitable valued resistors, which allowed the node between them to be pulled to either a high or low value, dependent on the light intensity allowed to be incident on the photo-transistor. Below is the circuit used for the photo-transistors:

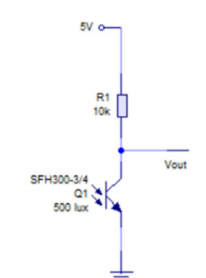

Figure 6: Photo-transistor sensor circuit

Each output node of the three circuits is connected to test pins on the raspberry pi. Moving a hand or object over the sensor will decrease the light incident on the sensor, causing the equivalent resistance of it to increase. This pulls the output node to a high value. Combining the hardware and software of the Home Hub allows the user to control the interface shown on the screen and communicate with their carers/relatives.

The leftmost sensor displays the Day Clock for the user. The centre sensor will send a help request to a carer/relative via Telegram messaging. The right sensor allow the user to return to the notifications screen, as well as being able to cancel help requests or falls incorrectly detected if necessary.

4.2.3 Design Sketches

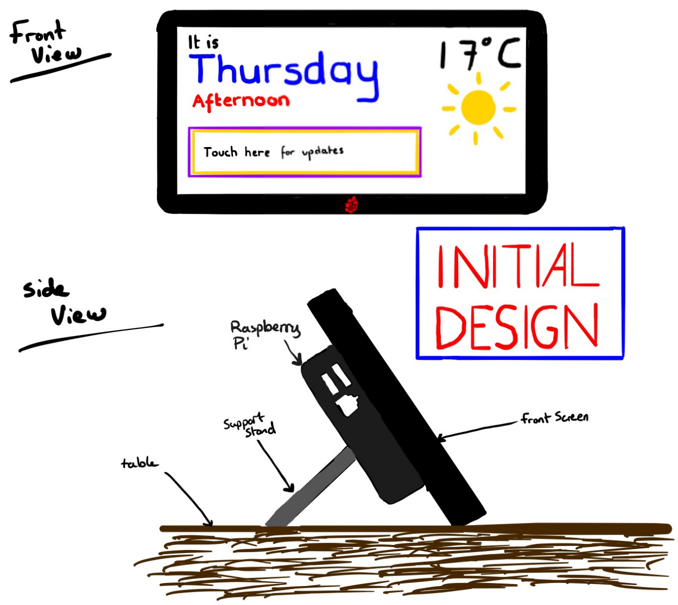

Figure 7: Initial sketch of the home hub

4.2.4 Final Prototype

The case holding the hub and its electronics was designed using SolidWorks and the final prototype can be seen below:

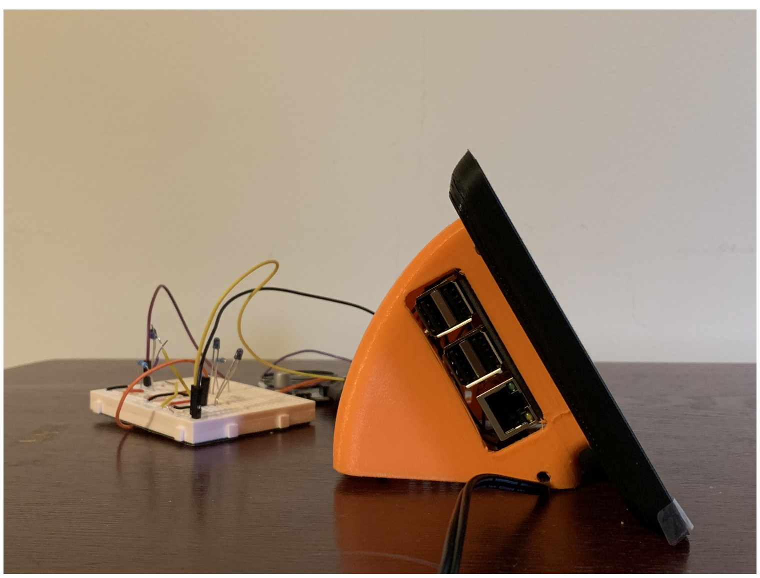

Figure 8: The home hub inside its case

Figure 9: 'Day Clock' screen

4.2.5 Cost

Component	Cost	Quantity
Raspberry Pi 4.0 (2GB)	£52.51	1
Raspberry Pi Screen	£58.50	1
Raspberry Pi Speaker	£13.18	1
Infrared Receiver	£0.103	3
Total	124.29	1

4.2.6 Testing

All of the relevant design of the Home Hub interface was done on python, therefore testing proved simple. It consisted of verifying and modifying changes by running the program scripts. Initially, sub-programs were written to test individual parts of the full script to make issues easier to identify and correct. The first stage consisted of writing a script obtaining the time from the Pi operating system and displaying it in an easier-to-understand format for the Day Clock. The next set of testing was to make sure that scraping from the website(mentioned) could correctly obtain the relevant information and display it on a separate screen to the Day Clock. The final separate section that required testing was the Infrared sensors, testing was done using a breadboard and an oscilloscope to aid choose a suitable pull-down resistor value. The sensors were then integrated into the Pi via a Python script and it was made sure that each sensor would have a unique action assigned to it once activated. All these separate elements then had to be integrated into one python script, this was again done in stages to ensure more simple debugging.

4.3 Website Application

4.3.1 Functionality and Development

The website was built using the Laravel PHP framework which uses Model-View-Controller (MVC) architecture. MVC architecture is useful as it allows the web application to be developed very quickly whilst maintaining scalability, both of which were very important to a proof of concept for our product within our time frame.

The website was made to fulfil the following objectives:

- to store patient data that would be accessed via NFC tag, allowing any person with a phone or indeed NFC reader, to access potentially lifesaving patient information; see the above section: The Medical Wristband.
- to facilitate alerts to be sent to 'The Home Hub', allowing the Carer to contact and send any necessary information to the patient.

To fulfil the first objective, a 'patient' model database schema was created, which stored the patients 'attributes' or 'properties' (language dependent): name, medical details, and automatically incremented an id which served as the primary key.

```
// Patient Database Schema Migration
    public function up()
    {
        Schema::create('patients', function (Blueprint $table) {
            $table->increments('id');
            $table->string('name');
            $table->text('detail');
            $table->timestamps();
        });
    }
```

An administrative dashboard was also created to allow for Create-Read-Update-Delete (CRUD) functionality on the patient model database, this page was protected by a middleware authentication controller to only allow users with Carer permissions to use the Create, Update and Delete actions. These are illlustrated in the PHP blade snippet below:

```
// Patient Model index.blade.php iterating patients and their unique CRUD actions
        @foreach ($patients as $patient)
        <tr>
            <td>{{ ++$i }}</td>
            <td>{{ $patient->name }}</td>
            <td>{{ $patient->detail }}</td>
            <td>
                <form action="{{ route('patients.destroy',$patient->id) }}" method="POST">
                    <a class="btn btn-info" href="{{ route('patients.show',$patient->id) }}">Show</a>
                    <a class="btn btn-info" href="{{ route('alerts.show',$patient->id) }}">View
                        Notification</a>
                    <a class="btn btn-primary" href="{{ route('patients.edit',$patient->id) }}">Edit</a>
                    @csrf
                    @method('DELETE')
                    <button type="submit" class="btn btn-danger">Delete</button>
                </form>
            </td>
        </tr>
        @endforeach
```

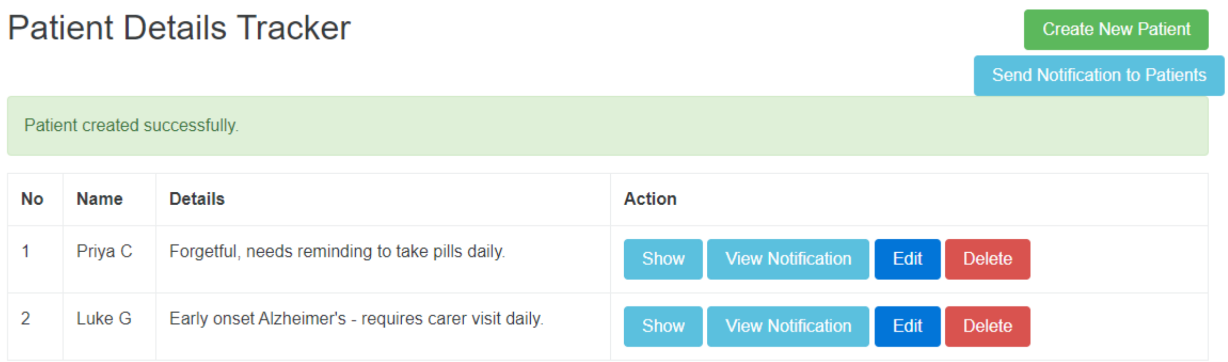

Figure 10: Administrative Dashboard

A URI to the website was stored with the patient's unique identifier on the NFC to protect physical confidential data transfer from the NFC tag. The URI pointed to the user's profile view and displayed their data from the patient model database and served as the Read action from CRUD.

To fulfil the second objective, an 'alert' model database schema was created with the following attributes: message-detail, alert-type, recipient-id, automatic created-at and an alert-id. Clearly having a primary key id for the patient model now allows for a one-to-many relationship to be established between the patient and alerts models.

```
// Alerts Controller -> Show - API reference
public function show($id){
    $alerts = Alert::where('name', '=', $id)->orderBy('created_at', 'desc')->get();
    return view('notifications',compact('alerts'));
}
```

The $alerts variable returns a list of alert objects ordered by date to the notifications page. This makes it trivial to 'dump' alerts intended for a specific user on a patient user's uniquely identifiable page in JSON format and therefore formed an API that could be accessed by 'The Home Hub'.

Figure 11: JSON Alert Data Dump

The website was deployed on a local web server using the XAMPP application to host a LAMP stack on the localhost

/ 127.0.0.1 port and then this port was mirrored to a publicly accessible IP address using the open source ngrok project. Git was used to track changes and additions to the codebase. The repository is published online and remains

Figure 12: ngrok Port Forwarding

accessible at github.com/lukegonsalves/fall-detect

4.3.2 Testing

The entire website was initially and finally tested by the standard GUI testing method. This covers all of the essential requirements of website functionality. Specifically, this covered testing functionality of all front-end elements by tracing logic to their respective back-end codebase. The relatively small codebase meant this was simple to do by hand. This ultimately proved to be a thorough and comprehensive method of testing, catching various intricacies of logic written in the code.

The Laravel framework allows for straightforward database testing using the 'Model Factories' seeder which automatically generates 'random' data to fill the database schema and test all nominal and non-nominal cases. This then effectively tests how the back-end logic deals with unsupported data. It was found that in some cases data of the wrong type could enter the system which could easily mutate into other errors down the system pipeline. Indeed the best way of dealing with unsupported data was by adding validation to all inputs to check if the data was of a supported type and therefore prevent unsupported data injection. An error handler was also implemented to return useful error messages where appropriate; in the case of unsupported data type entry the validation would return a prompt to the user via the error handler.

5 Project Management

Below are the two main methods that were used to organise the group and to ensure progress was being made.

5.1 Tasks and Roles

Necessary administrative roles were assigned as a group to manage aspects of the project. These were:

- Project Manager: Sebastiano Zane
- Secretary: Rhys Johnson
- Treasurer: Priya Chhaya
- Component Purchasing: Arjun Bhushan

Initially the project was split into several smaller tasks and modules, the most notable of which were as follows:

- Software development for the fall detection
- Software development for sending the user's carer a message through Telegram
- Design of website application
- Photo-transistor circuit for the Home Hub
- Battery and Power for the Wristband
- Home Hub display and interface
- 3-D printing the Wristband case
- etc.

Each group member initially chose or was assigned a task, this was completed by one or two people before moving onto another task - allowing the group to make consistent progress and easily see what parts of the project were left incomplete at all times.

5.2 Mid-Project Review

During the week beginning 10th February, a mid-project progress review was carried out. This included updating the Gantt chart and ensuring all team members were aware of the progress made at the time and what needed to be done to successfully complete the project. Included below is also some short explanation to the key findings at the time and the updates made.

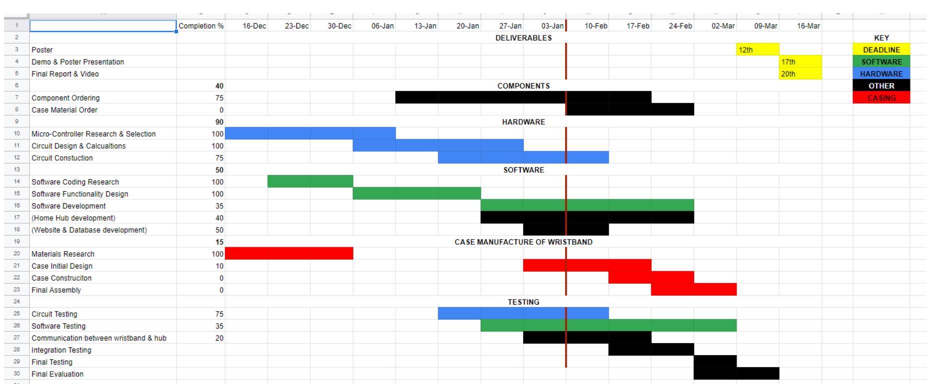

Figure 13: Updated Gantt Chart

- The ordering of components was initially delayed by a week and would be ongoing throughout the project due to needing to choose alternative components after testing was carried out.

- Case Material Order had been delayed consistently to this point. This was due to lack of final vision of prototype as well as prioritising on alternate aspects of project.
- Micro-controller research and selection extended by a week to discuss as team and come to a collective decision.
- Circuit Design and calculations extended by a week. This also delayed construction of circuits.
- Software Development extended, this was despite good progress being made the overall time needed to complete was initially underestimated.
- Home Hub Development has been added to Gantt chart. This comes from decision to make a hub key to our project and a main focus additional to the wristband. Began when ordered on 22$^{\text{nd}}$ February with consistent progress.
- Website & Database development has been added. Quick progress made on this and this was completed in good time.

The Gantt chart was primarily used to track progress and control a large number of activities and tasks that had to be completed. Clearly, it proved useful to visualise the subsequent delays in the project pipeline that would be incurred as a result of a particular activity taking longer than expected.

5.3 Meetings

Weekly group meetings and indeed where we felt more discussion was necessary, more frequent meetings were held. Keen not to minimise wasted time, a general structure and agenda was adopted that allowed the meetings to flow effectively and engage all project members. The agenda would consist of presenting individual task progress to the group (assigned from the previous week), both to track in reference to the Gantt Chart the overall project, but also then to facilitate a question and answer session to allow critical analysis of all work. This proved to be an invaluable resource, particularly when major decisions had to be made and it was critical that the 'most correct' outcome was reached - selecting the most appropriate communication system for example. After extensive discussions, any further actions and tasks were assigned to individuals or sub-teams, carefully considering all information available to strike a fine balance between remaining on schedule but also investing resources into important activities. All meetings had minutes recorded by the secretary, this was an incredibly useful supplement as they provided extensive notes of meetings allowing all team members to refer back to valuable information in future.

6 Future Work

With limited development time and resources, the group was restricted in developing an extremely effective prototype, below are several aspects of the prototype that could be further developed in the future.

Firstly, the group was restricted in how small they could make the wristband. Had the group had more time they would have reduced it's size significantly and reduce the intrusiveness on the user. With limited skills in solidworks, providing an ergonomic and aesthetic wristband design proved difficult, with extra time, these skills could be developed to provide this.

Secondly, the home hub allowed wide array of potential features; a few that the group specifically would have liked to further add on are:

- More Notifications: Although the home hub already passes several notifications to the user the group would have wanted to add a more extensive set of potential notifications to better allow for communications to the user and the carer.
- Home Control Integration: Remembering to turn off lights is a problem that faces many people, a the group would have wanted to include the ability to either control the lighting from the hub, or to remove user interaction and automate the whole lighting process for the whole house removing the need for the user to do anything. (This process could also be extended to heating and other house appliances)
- Security: The notifications page could easily contain private information. In the future, more work could be done on the website, to require a username and password from the carer in order to be able to access the notifications page.

As well as this, the group was only able to run testing simulations in labs using the group members as the testers. However with more time the group would have tested on the actual target demographic and would be able to get their opinions on the product.

7 Conclusion

It remains important that the project is critically evaluated at its conclusion, to gauge the success of the project, and to outline and discuss the process of developing such a product.

Initially the group consulted Hertfordshire Independent Living Service, they highlighted the extent to which their personal resources are stretched and how carefully they must consider the types of carer support they offer, to whom when. The group therefore recognised that the solution would need to be cost-effective and also provide a personal touch in order to ensure that where resources are limited in offering the best possible care service to as many sufferers as possible, that those living alone are not left alienated.

The Design criteria was met and the final prototype was successful as it combined several sub systems that used algorithms, circuit design and communications. . Although, significant plans and discussions were made prior to prototyping, the project still warranted a large volume of trial and error, across many disciplines, with the group regularly being introduced to new challenges coupled with unfamiliar programming languages and hardware, therefore the project broadened each group member's abilities and skills. Indeed, the ability to continually adapt to new conditions proved to be a very important skill.

Presently, the most significant drawback with the final prototype is the high cost. However, the group believes that in the commercial arena, we would be radically driven to reducing these overheads in order to seize access to the widest demographic possible for our product.

The primary objectives for the prototype were completed well-before the demonstration deadline, allowing for expansion of the design, implementation of additional features, and therefore is viewed as a success. The group believes that they satisfied the overarching motivation for the project.

References

[1] M Okawa, K Mishima, Y Hishikawa, S Hozumi, H Hori, and K Takahashi. Circadian rhythm disorders in sleep-waking and body temperature in elderly patients with dementia and their treatment. *Sleep*, 14(6):478–485, 1991.

[2] Angelina R Sutin, Yannick Stephan, Martina Luchetti, and Antonio Terracciano. Loneliness and risk of dementia. *The Journals of Gerontology: Series B*, 2018.

8 Appendix

- All information relevant to the project which has not been included in the main body of the report

8.1 Full Code Python files 1 & 2

Unfortunately, owing to the pandemic, we are not at present able to access the Home Hub in order to supply the fully-integrated Python code files. Should any further description of any afforementioned behaviour be desired, please do not hesitate to contact the team directly. We will be more than happy to assist you promptly.
Code for sending messages to telegram:

8.2 Excerpt of Wristband code

```
#include <SPI.h>
#include <WiFiNINA.h>
#include <ArduinoLSM6DS3.h>
#include "secrets.h"
char ssid[] = SECRET SSID; // your network SSID (name) char pass[] = SECRET PASS; // your network password
int status = WL IDLE STATUS;
WiFiServer server(80);

// ThingSpeak Settings char thingSpeakAddress[] = "api.thingspeak.com"; String APIKey = SECRET WRITE APIKEY

// Initialize Arduino Ethernet Client WiFiClient client;

void setup() ( // Start Serial for debugging on the Serial Monitor Serial.begin(9600);
// attempt to connect to Wifi network: while ( status != WL CONNECTED) { //Serial.print("Attempting to conn
// wait 10 seconds for connection: delay(10000);
//initialize IMU
if (!IMU.begin()) { ,1,.
void loop() { // read values from pins and store as strings
String set = "1"; String reset = "0";
if ( status != WL CONNECTED) { status = WiFi.begin(ssid, pass);
if (!IMU.begin()) { while (1);
delay(10000);
// Print Update Response to Serial Monitor if (client.available()) { char c = client.read(); Serial.print(c
// Disconnect from ThingSpeak float x, y, z, total; // Update ThingSpeak if (!client.connected() && IMU.acc

void updateThingSpeak(String tsData) { if (client.connect(thingSpeakAddress, 80)) { client.print("POST /upd
if (client.connected()) { Serial.println("Connecting to ThingSpeak..."); Serial.println(); } } }
void printWifiStatus() { // print the SSID of the network you're attached to: Serial.print("SSID: "); Seria
// print your WiFi shield's IP address: IPAddress ip = WiFi.localIP(); Serial.print("IP Address: "); Serial
// print the received signal strength: long rssi = WiFi.RSSI(); Serial.print("signal strength (RSSI):"); Se
```

8.3 Talking Clock & Scheduled alerts

```
from playsound import playsound

import schedule
import time

def demo():
    playsound("minute.mp3")

#KILL DEMO AUDIO HERE!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
schedule.every(1).minutes.do(demo)
```

```
def fall():
    playsound("fall.mp3")

schedule.every(5).to(10).minutes.do(fall)

def notif():
    playsound("new_message.mp3")
    playsound("carer_message.mp3")

schedule.every(10).to(12).minutes.do(notif)

def med():
    playsound("med.mp3")

schedule.every().day.at("09:15").do(med)

def carethree():
    playsound("carer3.mp3")

def caretwo():
    playsound("carer2.mp3")

def careone():
    playsound("carer1.mp3")

def carenow():
    playsound("carernow.mp3")

schedule.every().wednesday.at("11:58").do(carethree)
schedule.every().wednesday.at("12:58").do(caretwo)
schedule.every().wednesday.at("13:58").do(careone)
schedule.every().wednesday.at("14:58").do(carenow)



def nine():
    playsound("9am.mp3")

def ten():
    playsound("10am.mp3")

def eleven():
    playsound("11am.mp3")

def twelve():
    playsound("12pm.mp3")

def one():
    playsound("1pm.mp3")

def two():
    playsound("2pm.mp3")

def three():
    playsound("3pm.mp3")

def four():
```

```
    playsound("4pm.mp3")

def five():
    playsound("5pm.mp3")

def six():
    playsound("6pm.mp3")

def seven():
    playsound("7pm.mp3")

def eight():
    playsound("8pm.mp3")

# schedule.every().hour.do(job)
schedule.every().day.at("09:00").do(nine)
schedule.every().day.at("10:00").do(ten)
schedule.every().day.at("11:00").do(eleven)
schedule.every().day.at("12:00").do(twelve)
schedule.every().day.at("13:00").do(one)
schedule.every().day.at("14:00").do(two)
schedule.every().day.at("15:00").do(three)
schedule.every().day.at("16:00").do(four)
schedule.every().day.at("17:00").do(five)
schedule.every().day.at("18:00").do(six)
schedule.every().day.at("19:00").do(seven)
schedule.every().day.at("20:00").do(eight)

def wedmor():
    playsound("wedmor.mp3")

def wedlun():
    playsound("wedlun.mp3")

def wedaft():
    playsound("wedaft.mp3")

def wedeve():
    playsound("wedeve.mp3")

schedule.every().wednesday.at("09:01").do(wedmor)
schedule.every().wednesday.at("09:30").do(wedmor)
schedule.every().wednesday.at("10:01").do(wedmor)
schedule.every().wednesday.at("10:31").do(wedmor)
schedule.every().wednesday.at("11:01").do(wedmor)
schedule.every().wednesday.at("11:30").do(wedmor)
schedule.every().wednesday.at("12:01").do(wedlun)
schedule.every().wednesday.at("12:31").do(wedlun)
schedule.every().wednesday.at("13:01").do(wedlun)
schedule.every().wednesday.at("13:31").do(wedlun)
schedule.every().wednesday.at("14:01").do(wedaft)
schedule.every().wednesday.at("14:31").do(wedaft)
schedule.every().wednesday.at("15:01").do(wedaft)
schedule.every().wednesday.at("15:31").do(wedaft)
schedule.every().wednesday.at("16:01").do(wedaft)
schedule.every().wednesday.at("16:31").do(wedaft)
schedule.every().wednesday.at("17:01").do(wedeve)
```

```
schedule.every().wednesday.at("17:31").do(wedeve)
schedule.every().wednesday.at("18:01").do(wedeve)
schedule.every().wednesday.at("18:31").do(wedeve)
schedule.every().wednesday.at("19:01").do(wedeve)
schedule.every().wednesday.at("19:31").do(wedeve)
schedule.every().wednesday.at("20:01").do(wedeve)

# # Other scheduling examples we might want...
# schedule.every(5).to(10).minutes.do(job)
# schedule.every().monday.do(job)
# schedule.every().wednesday.at("13:15").do(job)
# schedule.every().minute.at(":17").do(job)

while True:
    schedule.run_pending()
    time.sleep(1)
```

8.4 Telegram code

```
import requests

def telegram_bot_sendtext(bot_message):

bot_token = '1037658295:AAGdTpsgqFQi2ilhW2IKJrZwMgyLWS-q-WY'
bot_chatID = '-381819308'
send_text = 'https://api.telegram.org/bot' + bot_token + '/sendMessage?chat_id=' + bot_chatID +
'&parse_mode=Markdown&text=' + bot_message

response = requests.get(send_text)

return response.json()


test = telegram_bot_sendtext("The patient has fallen!")
print(test)
```

8.5 Full Website Code

The full repository for the website remains accessible at www.github.com/lukegonsalves/fall-detect