EEE 2nd Year Group Project

Imperial College London

Group 7

Title of the Project: Breathcom

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Table of Contents

1 Abstract

This project explores the development of a low-cost device to allow disabled patients to more easily communicate. This device comes under the category of Augmentative and Alternative Communications (AAC) technologies for people suffering from Motor Neuron Diseases such as ALS, Parkinson's. Middle staged symptoms of the diseases include paralysis and speech limiting disabilities. Currently, 1 in 50,000 in the US and 1 in 2,000 in the UK are diagnosed with MND every year, making this topic an issue of contemporary global significance (Stats about Paralysis).

Traditionally AAC have included devices such as letter or word boards, eye tracking, and more recently brain-computer interface devices but these devices cost around $5,000. Therefore, the aim of this device was to build a cost-effective solution for patients suffering from MND. However, these technologies all suffer from issues, such as letter and word boards being difficult to use. We sought to make a device that is accessible, simple, and useful to aid these patients communicate and improve their quality of life.

The device created measures the patient's breathing patterns, via an accelerometer placed upon their person and the processing is done with the help of an Arduino. The breathing patterns are then matched against a code set and then translated into a phrase. This information is then transmitted to a smartphone, which synthesizes the phrase into speech.

In conclusion, the prototype works successfully, fulfilling all the design criteria that was defined. The breath detection worked very reliably and the translation into a phrase worked perfectly, as did too the smartphone app and speech synthetization. Despite this, there are many improvements that could be made, laid out later in this report. However, we have shown that the idea is technically feasible and has the potential to help thousands of disabled patients around the world.

Abstract Word Count: 296 words

2 Introduction

According to a study conducted in the United States, about 1 in 50 people suffer from some form of paralysis resulting from spinal cord injuries. China and India have over 11 million and 9 million people suffering from paralysis respectively. Statistics indicated that around 1 in 2000 people are diagnosed with Motor Neuron Diseases every year in the UK. In the US, that figure is around 1 in 50,000 people. These figures are rising rapidly not only in the UK or the US but many other countries, making this topic an issue of global significance. There is no cure available for such diseases but there exist devices that aim to alleviate pressure of these patients (Vital Signs).

The aim of our project is to create an Augmentative and Alternative Communication Device (AAC) which enables people with Neurological Developmental Disabilities (for example: LIS, ALS, Parkinson's Disease) and other speech limiting disabilities like aphonia, dysarthria, to converse naturally (Elridge).

The device that we developed was called "Breathcom" and it is based on an accelerometer detecting, differentiating and encoding four long and short breaths into combinations of binary sequences which would then be compared with a library of set phrases. Secondly, the phrase corresponding to the binary sequence detected is displayed on the LCD and the mobile application interface which would also output an audio file with the same contents.

This report will first consider the design criteria of the device. This will be followed by a recap of the preliminary report wherein different concept designs were considered and why the accelerometer design was chosen. Then, the report will look at technical analysis and implementation of the device in the context of three sub-groups which are: Encoding and Decoding, The Mobile Application and Design Engineering. Finally, this report will give a detailed insight into the project management of the group and recommendations for future work.

3 Design Criteria

Since embarking on this group project, several changes were made to the Design Criteria (Product Design Specification elements). In the preliminary report, the elements that were identified still continued to be relevant. However, there were other elements which also had to be considered throughout the processes of prototyping and testing. The following PDS elements were finally considered and given the utmost priority during the spring term:

- **Performance:**

This PDS element has been considered throughout the project in the spring term. As mentioned in the preliminary report, the device would measure the properties of user's breathing such as patterns, speed, intensity and then translating this into real-time audio containing the intended speech.

Through the stages of product designing and prototyping in this term, a more accurate definition of the performance element was obtained. It was concluded that the device would firstly, detect, differentiate and encode four long and short breaths into combinations of binary sequences which would then be compared with a library of set phrases. Secondly, the phrase corresponding to the binary sequence detected is displayed on the LCD and the mobile application interface which would also output an audio file with the same contents.

- **Target Product Cost:**

For this project, the maximum defined budget is £200. For the purposes of this group project, the team was able to successfully keep the cost of the product to £50. Although, a few items like NR52 microprocessor were ordered, they weren't used since, better devices like Arduino were available. This AAC device is cost-effective to a significant extent given the fact that devices such as eye tracking, on an average, cost around $1000. This makes our product eligible to easily compete in the market along with solid market research.

- **Customer:**

The product has to be user-friendly to a large extent due to the fact that users are mainly going to be paralyzed patients with speech limiting disabilities. This product will mainly target adults from the age of 40 but could potentially be used for younger patients. If that were the case, more customer data needs to be considered. This criterion can be fulfilled by not only conducting focus groups with paralyzed people but also getting in touch with doctors to understand more about the requirements of the patients.

- **Ergonomics:**

After a user-friendly AAC device has been developed, it needs to be organized such that the patients can interact with it efficiently and safely. After all, a user-friendly device is one of the most important criteria for this project. For instance, the long breath threshold for this project has been set low so that there is less strain on patients when encoding long breaths.

Moreover, this device also aims to implement a user-friendly component for the caretakers and this is done by including an application in a mobile phone within a design system. Therefore, the caretakers don't have to look at the LCD screen every single time to find out what the patient is trying to communicate. They can decipher the same since the application will be outputting MP3 audio files once the patient's breath is encoded.

- **Political and Social Implications:**

This product has extremely significant social implications since it aims to alleviate the pressure of communication for paralyzed patients with speech disabilities due to MND diseases. Currently, there is no cure available for Motor Neuron Diseases and middle stage symptoms worsen the patient's condition which includes paralysis, fatigue, losing the ability to speak and so on. This device aims to tackle the latter for such patients and make their life easier.

3.1 Current PDS Elements in Comparison with the elements discussed in the preliminary report

It can be seen from the above PDS analysis that elements such as Manufacturing Facility, Installation and Testing were not considered in this term compared to the Autumn term and as detailed in the preliminary report. Although the aforementioned elements are important, they were not quite relevant to the processes of developing the project in the spring term.

For instance, in the preliminary report it was noted that like Facilities such as Enterprise Labs and Hackspace would prove to be useful. But in this term, it was realized that only the Electronics and Robotics Labs in the EEE department would be required for product designing and prototyping which included 3-D printing for Design Engineering. These workspaces were easily accessible within the department though the group had to keep a track of the time given that working hour conditions applied for accessing these labs.

On the other hand, elements such as Customer and Ergonomics were considered. This is mainly due to the fact that this product had to be customer-focused. Through meeting with the supervisor, it was concluded that it was essential to not only understand the requirements of the patient but also the needs to the caretaker or the person, the patient wishes to communicate with. It was detailed through intensive group discussions that the product had to be user-friendly and consequently, the customer PDS element was strongly considered and given the utmost priority.

4 Concept Designs Considered

The concept designs considered before implementing the final solution was considered in the preliminary report. The section briefly discusses each of the concepts:

1. Sensor placed near the nose to detect breath exhalation

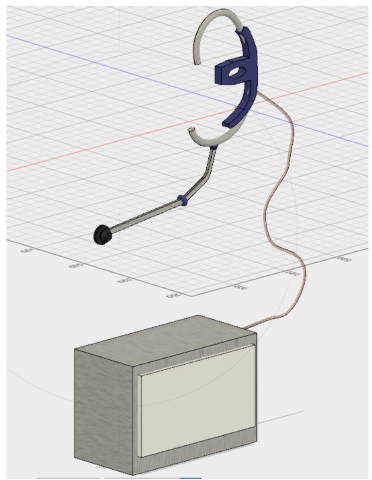


Fig: *CAD design for breath detecting sensor to be placed near the nose*

The device will operate by detecting and encoding user breath patterns and transferring the signal to the mainframe where it will be encoded into Morse code. This device requires the user provide two distinct exhalation patterns, by varying breath intensity or exhalation period. A sensor (similar to a very sensitive microphone) shall be placed under the nose to convert the analogue breath input into a signal.

2. Infrared sensors placed near the eyes to detect blinking patterns (Refer to Appendix – V for CAD design)

The device will operate by detecting and encoding user blinking patterns into a signal and transferring that signal to the mainframe where it will be encoded into Morse code. The cost of the infrared sensor is minimal and makes insignificant difference to the initial 200-pound budget. The use of the system will be relatively easy which should reduce the difficulties of installation and documentation. However, due to the ease of finding the components and design this system, the competition is relatively high compared to other solutions.

3. Thermal imaging to detect air flow patterns from breath exhalation (Refer to Appendix – V for CAD design)

The third proposed design idea uses thermal imaging to detect characteristics of the exhaled air, such as intensity, speed and so on. This design is based on infrared imaging science, which can detect radiation in the long-infrared range, usually 9 -14 µm and produce thermograms to indicate thermal distribution.

The most significant task is to convert the thermal imaging into breathing air flow pattern and declare a coding system for various breathing modes (different breathing intensities and lengths). As for knowledge it is possible to implement this technology, communication, signal, circuit analysis and math modules have taught some corresponding algorithm. The toughest aspect is to make this infeasible within the 200pound budget, as the upper range of a thermal camera varies from 300 to 5,000 pounds.

4. Accelerometer placed on the chest or back or abdomen to detect thorax or abdomen motion while breathing (Refer to Appendix – V for CAD design)

An accelerometer measures the instantaneous acceleration of a body in motion. Based on the requirements of the project, having a digital accelerometer with an inbuilt pulse width modulator is preferred. The accelerometer is connected to the mainframe, where the detected signals are converted into Morse code.

The biggest advantage of using an accelerometer is that its detection is more accurate than other viable methods within this budget range. The working environment corresponds to normal atmospheric conditions.

5. Sensor placed near the mouth to detect breath exhalation (Refer to Appendix – V for CAD design)

The most significant task in this high-level implementation would be to convert breath sequences into expressions, words and common-day phrases for the purposes of communication.

The sensor must be sensitive to minimize strain on the user’s breathing pattern, due to safety and ergonomic purposes. A MEMS microphone, as suggested in our first design idea, may also be used in this context, costing about 50 pounds for the sensor itself. The advantages and limitations to this implementation corresponds to those of our first proposed design. The most significant limitation being discomfort to the user due to the positioning of the sensor being so close to their face.

5 Concept Selection

The proposed design that was finally selected was the **Accelerometer placed on the abdomen to detect the abdomen motion while breathing**. This can be evaluated using the matrix method as follows:

Criteria and its Weight			1st Concept		2nd Concept		3rd Concept		4th Concept		5th Concept	
			Score	**W x S**	**Score**	**W x S**	**Score**	**W x S**	**Score**	**W x S**	**Score**	**W x S**
1	Performance	10	6	60	7	70	6	60	8	80	9	90
2	Cost of the product	10	9	90	9	90	1	10	9	90	7	70
3	User Friendly	10	5	50	4	40	8	80	9	90	4	40
4	Physically realizable	10	7	70	6	60	7	70	8	80	7	70
5	Size and Weight	10	9	90	9	90	9	90	8	80	5	50
				360		350		310		420		320

Fig: *Concept Selection using the Matrix method*

Using the Matrix method while considering important criteria, it was realized that the 4th concept, which concerns the accelerometer being placed on the abdomen, clearly had the highest rating overall with a total weighted score of 420. This concept consistently scored higher across the four criteria compared to the other concepts. For instance, it can be argued that although the fifth concept has a better performance than the fourth concept, the size and weight factor being rated low on the former make it less desirable.

6 Concept Development

6.1 Encoding and Decoding

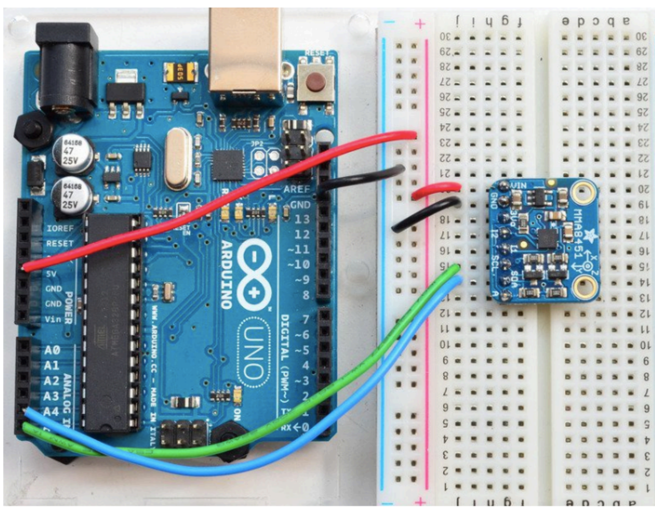
6.1.2 Components Used and Connecting the Accelerometer to the Arduino and Displaying the Data

The following are the components that were used in this sub-group as part of this group project:

- **Microprocessor:** Arduino Uno used to capture the accelerometer data, processes it into Morse binary code, and decodes the code into phrases.

- **Accelerometer:** MMA8451 is used to measure acceleration in the z direction. It's low cost but, has a high precision with 14-bit ADC. This sensor communicates over I2C. Since it's a 3V sensor, it is perfectly safe to use with 3V or 5V power and logic.

- **LCD:** Hitachi HD44780 LCD is used to display the phrases



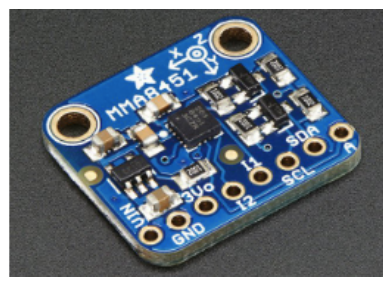


***Fig:** Connecting the Accelerometer to the Arduino and displaying the data*

The following were the hardware connections made between the accelerometer and the Arduino:

- **Vin** to the power supply, 3.3V as the accelerometer is a 3V sensor
- **GND** to common power/data ground
- **SCL** pin to the I2C clock **SCL** pin on the Arduino. On an UNO, this is also known as **A5**
- **SDA** pin to the I2C data **SDA** pin on the Arduino. On an UNO, this is also known as **A4**

6.1.2 Analysis of the Accelerometer Data

An MMA8451 accelerometer was used to measure thoracic or abdominal acceleration, measured in the z-direction. Initially, the acceleration was measured in the thorax, by placing the accelerometer on the chest. Upon plotting the accelerometer data, slight variations in acceleration along the y-axis was detected, while variations along the other two axes were noted to be negligible. Though variations on y-axis were evident, they were too insignificant for reliable data analysis.

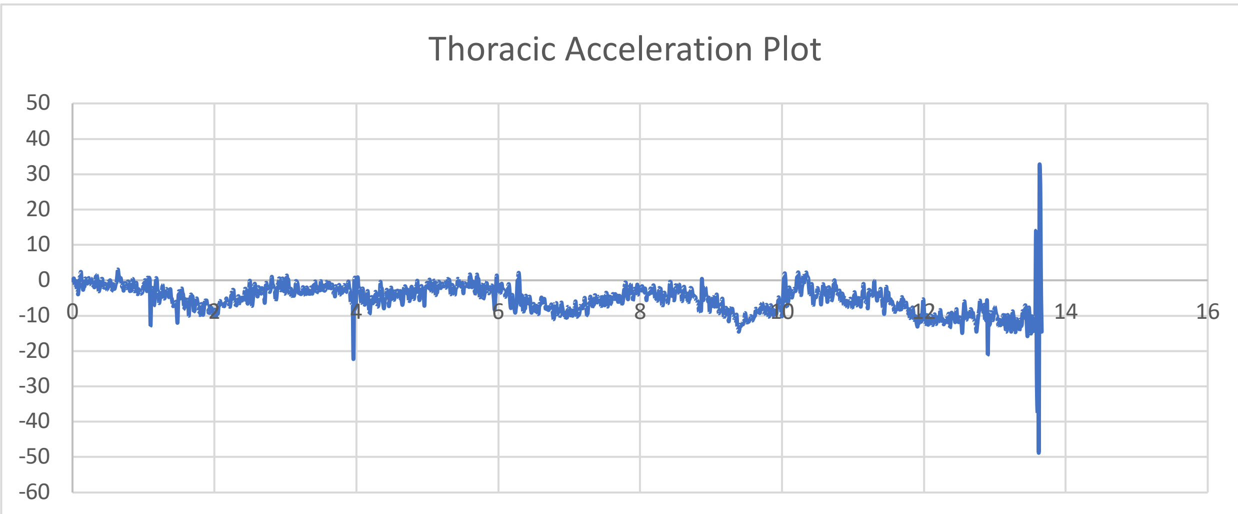


Fig1: *A plot of the thoracic acceleration on Microsoft Excel based on data collected from accelerometer being placed on the Thorax and transmitting the data to the Arduino Uno*

As an alternative, the accelerometer was placed on the abdomen, where we observed greater movement of the abdomen during inhalation and exhalation process. The lateral movement of the abdominal region provided more significant acceleration values, however this data was extracted from the z-axis instead of the y-axis due the change in plane of motion.

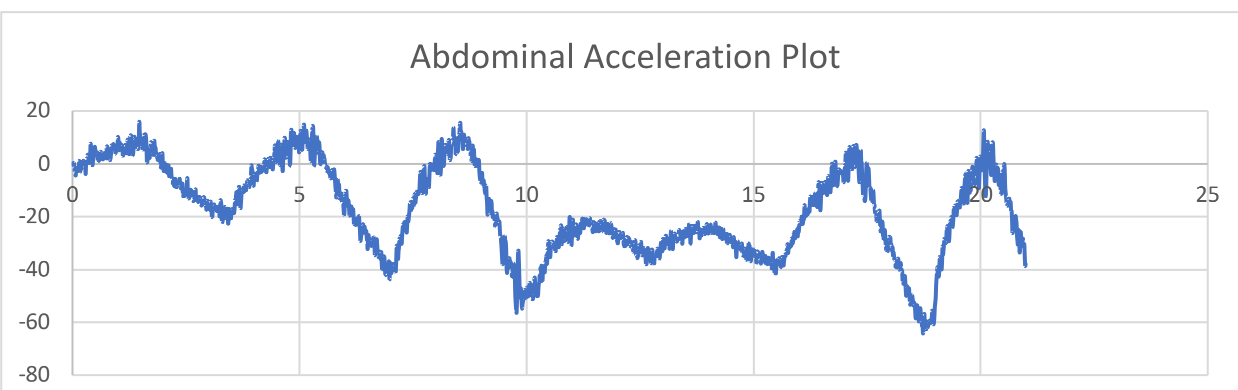
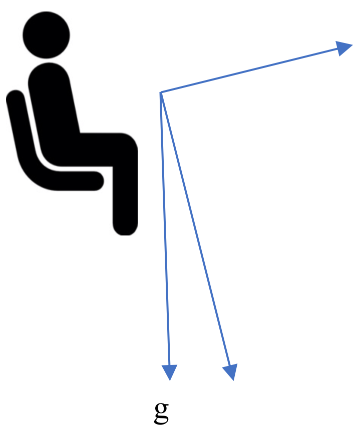


Fig2: *A plot of the abdominal acceleration on Microsoft Excel based on data collected from accelerometer being placed on the Abdomen and transmitting the data to the Arduino Uno*

6.1.3 Setting a Threshold on Acceleration

The code (please refer to Appendix - I) considers values of acceleration in the z-axis. A threshold is set on the acceleration to discriminate between a long breath and a short breath. If the sample acceleration in a breath cycle is above that threshold value it is encoded it as a "–", signifying a long breath. If it is below the threshold, it is encoded as a ".", denoting a short breath.

Setting the threshold was a challenging process as the acceleration value also depends on the component of gravity acting in the z-direction, meaning the acceleration value is a function of orientation with respect to gravity as well as bodily movement. It is important to remove the offset caused by the gravitational component to remove the dependency on orientation. This calibrates the accelerometer such that it will output useable data regardless of the user's plane of orientation.



$$A_z = -g \sin\theta + A_A$$

Parameters

A_z : Acceleration in the z-axis
g : Value of gravity, which is $9.8 m/s^2$
θ : Angle between y-axis of accelerometer and g
A_A : Abdominal Acceleration

6.1.4 Removing the Offset

The initial value of acceleration is equal to the component of gravity acting on the z-axis, which is equal to the offset. The first sample, taken at time t = 0, is subtracted from every subsequent sample to effectively remove the offset due to gravity. Hence, after offset removal, the values of the plots in Figures 1 and 2, begin from (0,0).

6.1.5 Encoding into Binary Morse Code

The code was run with a sampling rate of 100 samples per second, and a breath cycle time period of 2.5 seconds. An additional gap of 1 second between consecutive breath cycles was also implemented to allow the user some allowance time to reset their breaths. This also reduced the chances of random errors affecting the acceleration values.

The preliminary approach towards setting a threshold value entailed double integration of the acceleration and setting a threshold on the calculated displacement value. However, this process was too time consuming and despite extensive research and time commitment, this logic couldn't be implemented effectively. To utilize the remaining time left optimally, the group decided to look into implementing a different logic that would still allow our device and code to function as desired. If the group were to extend this process, one of the main plans would be revisit the double integration method as it would allow a variable threshold to be set, by calibrating it as per the user specific breathing patterns. This would lay the foundations for a self-calibrating feature in the device.

For the purposes of this project, the code was tested on a generic sample group to find a threshold which can work on an arbitrary user. After testing and recalibrating the threshold for 12 different people, the value of $12m/s^2$ was found to be applicable in a general case. The code compared the offset vale at each sample with threshold set. If any sample in a breath cycle has an acceleration higher than $12m/s^2$, a "-" is encoded, symbolizing a long breath. If the sample acceleration is below $12m/s^2$, a "." is encoded to denote a short breath. This procedure continues for four breath cycles, and a sequence of dots and dashes is generated, which serves as a binary Morse code with four symbols.

6.1.6 Decoding into Phrases

Instead of using international Morse Code where each sequence represents a letter, a conventional form where each sequence corresponds to a phrase of words is implemented. As the code includes four symbols, the maximum number of combinations possible is $2^4 = 16$. Therefore, there are 16 phrases currently included in the phrase list (Appendix - II). The library of phrases can be extended, if a greater number of symbols (thus breath cycles) is considered.

After the accelerometer data in encoded into Morse code, the decoder function is called. The decoder function contains a string of 16 sequences of dots and dashes, where each sequence corresponds to a phrase (Please refer to Appendix – II for the phrase list). The encoded sequence is then compared to this string of sequences, such that when the input sequence matches one of the stored sequences, the corresponding phrase is displayed.

6.1.7 Displaying the Text and Conversion into Speech

The Hitachi HD44780 LCD is used to display the decoded phrase. The following circuitry connects the Arduino Uno to the LCD screen.

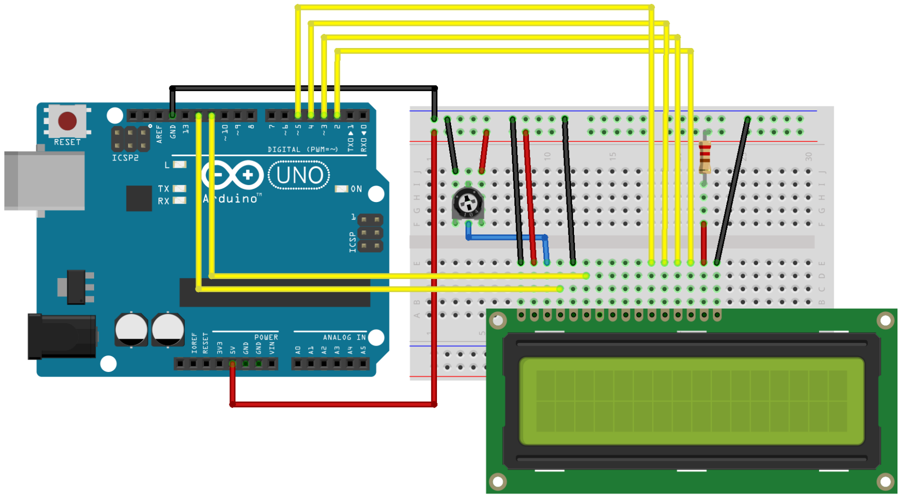


***Fig:** Circuit connections between Arduino UNO and the LCD screen*

A 10kΩ potentiometer and 220Ω resistor is used. The phrase is displayed on the LCD screen is also shown on the mobile app interface, which also has the additional functionality of allowing the displayed phrase to be spoken out loud. This will be explored in section 6.2.

6.2 The Mobile Application

6.2.1 What is the Application?

So far, the group had a working model that worked perfectly as a stand-alone model. The LCD screen displayed all the information required for the user as well as the caretaker to use the device. But it was noticed that in order for the user to communicate with others, it was rather unintuitive for the caretaker and other users to have to read the communicated data from the LCD screen.

As smart phones are so commonly available nowadays, it was a natural progression of the project to build a smartphone app. Since more than 80% of smartphones run on Android, we decided to build on app on that platform. Since this is a proof of concept project, we built the app using the online app building platform 'MIT App Inventor', which allows Android apps to be built using nodes.

6.2.2 The Benefits of the Application

There are many benefits of using an app as an extension to the product. Firstly, instead of using expensive hardware and integrating it into the device itself, a much more cost-effective solution would be, to use the speakers on the connected smartphone. The speakers can be used to play certain voice MP3 files which make the conversion flow far more intuitive and traditional. Furthermore, it alerts the caretaker and surrounding people that a communication has been made with the loud signal.

Secondly, the Bluetooth connection between the phone and the device allows for free movement of the caretaker for up to eight meters away from the device and the patient. This increases usability of the device since they no longer have to maintain a watch on the LCD screen attached to the wheelchair.

The mobile application allows for certain additional functionality for commands. For instance, the SOS command triggers an SMS being sent out to a pre-input phone number which also gives the device a safety aspect. Lastly, the app allows information to be stored in memory and hence the previous command is retained until a new command overwrites it. Consequently, this allows communication to go unmissed.

6.2.3 Technical Analysis and Implementation

In order to connect the device to the smartphone, a Bluetooth module was required. The HC-06 Bluetooth Module was used which had four pins, connecting to the TX, RX, V+ and ground terminals of the Arduino. The pseudocode for the application is included in Appendix C.

The application first connects to the module and this is visually indicated. As mentioned in the decoding portion of the report, after every decoding cycle of four breaths, the result would be one of the sixteen available phrases. A number from 0 to 15 was then serial printed by the Arduino corresponding to every phrase. The application was then able to pull data from the serial monitor of the Arduino via Bluetooth,

Analyzing the data every clock cycle by comparing it to the same numbers, certain outputs can be triggered, such as text output, sound output and additional functions such as text messaging. All these outputs are indicated clearly and visually which allows for a more intuitive user experience. Moreover, an additional feature was implemented that allows voice notes to be played even when the screen is turned off so that people are alerted.

The group envisions an application where a lot of functions of the phone can be controlled by the device. For instance, to improve mental well-being of the user, one can allow entertainment functions, such as improving capability to select a certain song to be played or a movie to be watched. Secondly, if one switches from connection via Bluetooth to over WiFi and build a web app for Breathcom, one can allow users to remotely access communications made by the user. Next, a transcript of all past communications can be included along with timestamps for medical purposes as well as to allow caretakers to view a history.

6.3 Design Engineering and Hardware

6.3.1 The Material

It was decided that the group would use cast acrylic (0.3 mm sheets) to make our prototype. One reason for this that it is a lightweight material. This makes it easy for the caretakers of the user to carry and attach. It also makes the prototype easy to secure to the wheelchair, as there is not much weight to support. Lastly it makes manufacturing and shipping inexpensive and simple.

Another advantage of cast acrylic is its shatter-resistance. This is important, as the device would be used by disabled patients. Therefore, if the device were to be, for any reason, impacted it would be very unlikely to cause injury to the user. The prototype was tested by dropping it from the height that one would expect it to be attached to a wheelchair and the acrylic sustained no damage.

Additionally, acrylic is a durable material. It degrades only over a very long span of time, and it quite chemically inert as well as heat resistant (up to 460℃). This is important as it reduces the financial burden on customers, both personal and commercial, as the device should last a long time. It also means that the device is less likely to fail when the user needs to use it, making it more dependable.

Lastly, cast acrylic is a 100% recyclable material. When the device would be eventually decommissioned, it is easy to dispose of in a responsible manner. Also, by using acrylic one can utilize partially recycled material in the construction, further reducing the environmental impact.

6.3.2 Technical Implementation and Concept Design Selection

Failed concept	**Shortage**	**Improved concept**
The device had a flat top, with the LCD screen installed on the left side, so that the user could still comfortably rest their arm on it.	The user was unable to see the screen, so they could not check if the phrase was correct	The LCD screen is installed on the top face of the device. The top face was then tilted at a 21.8° angle, which was tested by group members as being a comfortable angle to view the screen without free movement of the neck. This angle also helps reduce light reflections.
Only the bottom face was removeable, to provide access inside for servicing.	The internals of the device are in close proximity to one another, which made them very difficult to access through only one face.	The enclosure is hinged into two halves, with them secured with screws when closed. This allows for ample access to all the components when fully opened.
Two U shaped hooks were 3D printed for hanging onto and armrest for a wheelchair, which is suitable for armrests with approximately 5-6cm width.	The hooks only work for a very narrow range of chair arms.	A hole was drilled into the one side of the hook, with a screw and nut placed through this. This allows the screw to be used to clamp the device down onto chair arms ranging from 1.5-6 cm, a much broader range
The accelerometer was attached to the fabric of the users' clothes via a hook-and-loop fastener.	Not all fabrics work well with hook-and-loop and could over the long-term cause damage. The accelerometer needs to be tight against the belly, so loose clothing is an issue.	A small "buckle" was made of acrylic. To this the accelerometer was screwed down. Then a strip of elasticated fabric belt was threaded through the buckle which could then be wrapped around the users' abdomen and secured using hook-and-loop at the back. The length of belt was chosen on the prototype to accommodate as wide a range of people without being uncomfortable.

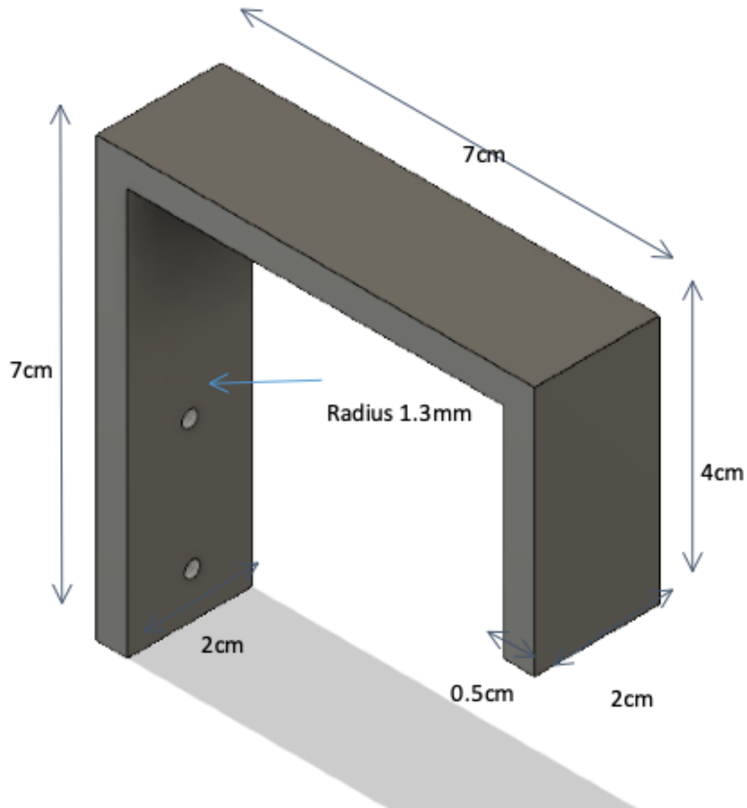


Fig: *Adjustable device for attaching to the wheelchair*

7 Project Management

Beginning the project, it was realized that we had to be well organized to work effectively and efficiently. Therefore, one of the first things done was to choose a group leader so that it's one person's responsibility to delegate tasks, enforce deadlines and generally organize the group. This meant that the rest of the group could focus all our attention on doing the work relevant to the project, and not waste time due to organizational issues.

Additionally, a Gantt chart was created at the beginning of the project (Refer to Spring Term Gantt Chart in Appendix - III). Because of this, the group had a timeline of progress to work to, deadlines to meet and know whether the project was on track. The Gantt chart was helpful at the beginning for the purposes of breaking down the entire problem into many, but much more solvable, tasks. This meant that the group was able to easily delegate work and organize itself such that each group member could operate as efficiently as possible.

The greatest difficulty in making the Gantt chart was estimating how much time each task would take. Although, the group had a rough idea, it was realized that this wouldn't be entirely accurate. Additionally, it was better to not have too many tasks overlapping as this can cause confusion on what needs to be done.

On a few occasions, for example on the task *Assembly: Assemble Individual Parts* (see Gantt Chart), the group was ahead of the schedule that was set. At these points, additional time that was left was leveraged to get a head start on the remaining tasks. Conversely some tasks, such as *Design: Test/Write Code*, took longer than expected. Here it was very important that we were able to work together as a group effectively. Team members who were struggling with their work would ask other members for aid, and other members would also take up some of the work of team members who were too busy with their current tasks.

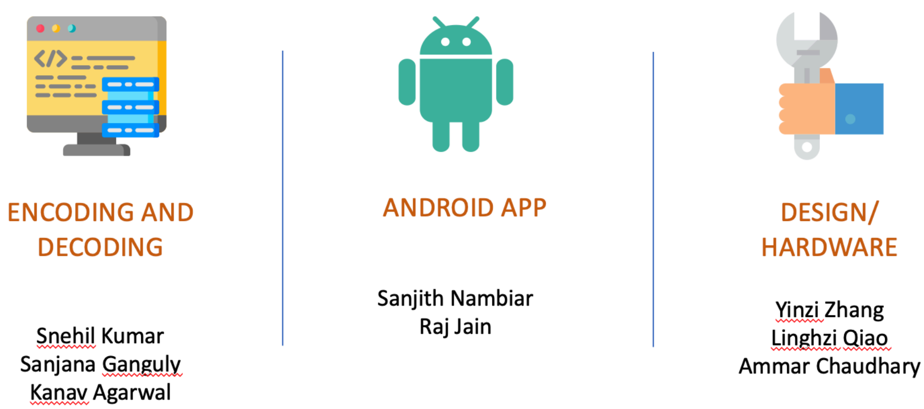


***Fig:** Organization of the group into three different sub-group along with the names of the people responsible for the same*

The team was organized into three sub-groups:

Encoding and Decoding: This team worked on the breath pattern detection from the accelerometer data and translated it to the corresponding phrase.

Mobile Application: This sub-group worked on getting the device to communicate with a phone via Bluetooth and developing an android app that could display the phrase once translated and speak it aloud.

Design: This worked on creating the design for the device and manufacturing the mechanical components.

Although there were different sub-groups, it was ensured that the whole team was involved and kept up-to-date. This was achieved mostly with a combination of regular meetings, and instant messaging. The main purpose of the regular meetings was so each subgroup could show what progress had been made in their work, and so that the work needing to be done could be delegated.

Another important part of organizational strategy involved the use of Google Drive. This made it very easy for the team members to collaborate on work, such as when assembling reports or presentations as we could all contribute in one centralized location. Additionally, it was a very useful platform for collecting ideas, information and research into as it could be accessed by all group members.

8 Recommendations for Future Work

The prototype developed was fully functional and reliable but despite this, further improvements could've been made. One limitation with the device is that it requires a second person, for example a caretaker, to initialize the device every time the user wishes to use it. As one of our aims with this project was to create greater autonomy and freedom of expression for the user, in a future development a system can be implemented such that the user could trigger the starting of the device themselves. This could be developed such that the device is constantly "listening" for an obvious and deliberate pattern by the user which triggers it into its main sequence.

Another area of improvement would be in the physical design of the device. A small device was developed however, the availability of the hardware was quite limited due to a fixed budget. In a future revision, one of the main aims could be designing a smaller and more aesthetically pleasing device. This could be easily accomplished by using custom surface-mount PCBs as opposed the development boards and breadboards, which are currently used by the prototype.

Additionally, the device could be made far more ergonomic. Button placement in the prototype is restricted due to the hardware and form factor of the device, and in future developments these could be made more accessible.

Furthermore, another aspect that will need to be considered in future would be the phrase list. Currently, the phrase list is a fixed set and consequently, this imposes a restriction on the users' freedom to express themselves. An improvement would include creating a larger list of phrases/codes. This could be based on market research on paralyzed patients suffering from MNDs or further research can be conducted based on focus groups. Another aim would include the ability for the user to define their own phrases, as we can only provide a generic phrase set.

Moreover, the sensor could also be made wireless. Currently, the sensor is connected to the control box via a multi-core cable. This has been identified as a possible point of failure, and potentially unsightly. As such, by removing the cable the device can be made more durable and more easily put on.

During the testing, it was realized that having a more obvious cue signaling when to breath could prove to be more useful. It was noted that some testers had the difficulty of reading instructions on the LCD screen. One of the potential solutions could be implementing a buzzer that would signal the user with a discrete beep sound when they need to start their breathing for the purposes of communicating. Similarly, it would also be a good idea to add an LED as well to provide a visual cue that simpler than the LCD since some potential users of the device could be deaf.

Finally, the speech aspect of the device could be implemented in the control box. In the device's current state, speech is only generated when a phone is used in conjunction. Although, the device can be used without a smartphone, since the LCD screen provides all the required information, but doing so limits its functionality. By giving the device the ability to produce its own speech, it becomes self-contained in that all the functions of the device can be performed without any external accessories. This would become particularly useful when the user wishes to talk to someone without a smartphone, for example a child or another disabled patient.

9 Conclusion

The product developed by the group has the capability to significantly improve the quality of life for patients unable to communicate via traditional means. The prototype has demonstrated that the detection of breathing patterns is a practical and feasible solution to ease communication with a paralyzed patient. Additionally, the low cost and simplicity of the device makes it accessible to a much greater market in comparison to available alternatives. We believe that because of these reasons, further work and development into these ideas is justified, and has the potential to improve individual lives on a global scale.

Works Cited

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Appendix – I

<u>Encoding and Decoding code programmed in Arduino IDE for implementation in Arduino UNO</u>

```
#include <LiquidCrystal.h>
#include <Wire.h>
#include <Adafruit_MMA8451.h>
#include <Adafruit_Sensor.h>

Adafruit_MMA8451 mma = Adafruit_MMA8451();
double dx=0.0, dy=0.0, dz=0.0;
int long t = 0;
double offset;
double newacc, sub_acc, acc_diff;
double arr[10];
double rollingaverage=0;
int i=0, j=0, k=0;
double sum=0;
bool check = false;
bool start = true;
String code = "";
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

void setup(void) {
Serial.begin(9600);

if (! mma.begin()) {
Serial.println("Couldnt start");
while (1);
}

mma.setRange(MMA8451_RANGE_2_G);
lcd.begin(20, 4);
lcd.setCursor(0, 1);
delay(2000);
lcd.clear();
lcd.print("START BREATHING");
Serial.println("22");
}

void loop() {

if(start == true){
```

35. mma.read();

36. ++t;
37. if(t==1){offset = (float)mma.z/(float)16384;}

38. newacc = ((float)((float)mma.z/(float)16384)-offset)*1000;
39. //Serial.println(newacc);
40. if(j==0){sub_acc = newacc;}
41. acc_diff = abs(newacc - sub_acc);
42. //Serial.println(acc_diff);
43. //Serial.println(j);
44. if(j <250)
45. {
    a. if(acc_diff >12)
    b. check = true;
46. }
47. else if(j == 250){
    a. if(check == true){
    b. code+= "-";
    c. }
    d. else{
    e. code += ".";
    f. }
    g. k++;
    h. check = false;
    i. Serial.println("STOP BREATHING");
    j. lcd.setCursor(0, 1);
    k. lcd.clear();
    l. lcd.print("STOP BREATHING");
    m. lcd.setCursor(1, 1);
    n. lcd.print(code);
    o. Serial.println(code);
    p. delay(1000);
    q. if(k<4){Serial.println("22");}
    r. lcd.setCursor(0, 1);
    s. lcd.clear();
    t. if(k<4){lcd.print("BREATHE NOW!");}
    u. j = -1;
48. }

49. if(k==4){
    a. //Serial.println("Printing word!");
    b. //lcd.setCursor(0, 1);
    c. //lcd.print("Printing word!");
    d. //Serial.println(code);
    e. convertor();

```
start = false;
}
j++;
delay(10);
}

}


void convertor()
{
static String letters[] = {"----", "---.", "--.-", "--..", "-.--", "-.-.", "-..-", "-...", ".---", ".--.", ".-.-", ".-..", "..--", "..-.", "...-", "...."};

if (letters[0] == code){
//----
delay(1000);
Serial.println("0");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I WANT TO SLEEP");}

else if(letters[1] == code){
//---.
delay(1000);
Serial.println("1");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I WANT TO USE THE WASHROOM");
delay(5000);
lcd.clear();}

else if(letters[2] == code){
//--.-
delay(1000);
Serial.println("2");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I NEED SOME WATER");
delay(5000);
lcd.clear();}

else if(letters[3] == code){
//--..
delay(1000);
Serial.println("3");
```

```
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I AM HUNGRY");
delay(5000);
lcd.clear();}

else if(letters[4] == code){
//-.--
delay(1000);
Serial.println("4");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I DON'T FEEL WELL");
delay(5000);
lcd.clear();}

else if(letters[5] == code){
//-.-.
delay(1000);
Serial.println("5");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("PLEASE LEAVE");
delay(5000);
lcd.clear();}

else if(letters[6] == code){
//-..-
delay(1000);
Serial.println("6");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("CHANGE MY CLOTHES");
delay(5000);
lcd.clear();}

else if(letters[7] == code){
//-...
delay(1000);
Serial.println("7");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("YES");
delay(5000);
lcd.clear();}
```

```
else if(letters[8] == code){
//.---
delay(1000);
Serial.println("8");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("NO");
delay(5000);
lcd.clear();}

else if(letters[9] == code){
//.--.
delay(1000);
Serial.println("9");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("I LOVE YOU!");
delay(5000);
lcd.clear();}

else if(letters[10] == code){
//.-.-
delay(1000);
Serial.println("10");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("TAKE ME FOR A STROLL");
delay(5000);
lcd.clear();}

else if(letters[11] == code){
//.-..
delay(1000);
Serial.println("11");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("READ ME THE NEWS");
delay(5000);
lcd.clear();}

else if(letters[12]== code){
//..--
delay(1000);
Serial.println("12");
lcd.setCursor(0, 1);
lcd.clear();
```

```
lcd.print("SOS!");
delay(5000);
lcd.clear();}

else if(letters[13] == code){
//..-.
delay(1000);
Serial.println("13");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("FEED ME MY MEDICINES");
delay(5000);
lcd.clear();}

else if(letters[14] == code){
//...-
delay(1000);
Serial.println("14");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("PLAY MUSIC/TV");
delay(5000);
lcd.clear();}

else if(letters[15] == code){
//....
delay(1000);
Serial.println("15");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("HI! HOW ARE YOU?");
delay(5000);
lcd.clear();}

else{
delay(1000);
Serial.println("INCORRECT INPUT");
lcd.setCursor(0, 1);
lcd.clear();
lcd.print("INCORRECT INPUT");
delay(5000);
lcd.clear();}

code = "";                    //reset code to blank string
}
```

Appendix – II

The Phrase List

PHRASE LIST

1.	I want to sleep	▬ ▬ ▬ ▬
2.	I want to use the washroom	▬ ▬ ▬ •
3.	I need some water	▬ ▬ • ▬
4.	I am hungry	▬ ▬ • •
5.	I don't feel well	▬ • ▬ ▬
6.	Please leave	▬ • ▬ •
7.	Change my clothes	▬ • • ▬
8.	Yes	▬ • • •
9.	No	• ▬ ▬ ▬
10.	I love you!	• ▬ ▬ •
11.	Take me for a stroll	• ▬ • ▬
12.	Read me the news	• ▬ • •
13.	SOS (sends text)	• • ▬ ▬
14.	Feed me my medicines	• • ▬ •
15.	Play music/TV	• • • ▬
16.	Hi! How are you?	• • • •

GROUP 7

Fig: *Phrase List for the Decoding aspect of the project*

Appendix – III

Gantt Chart

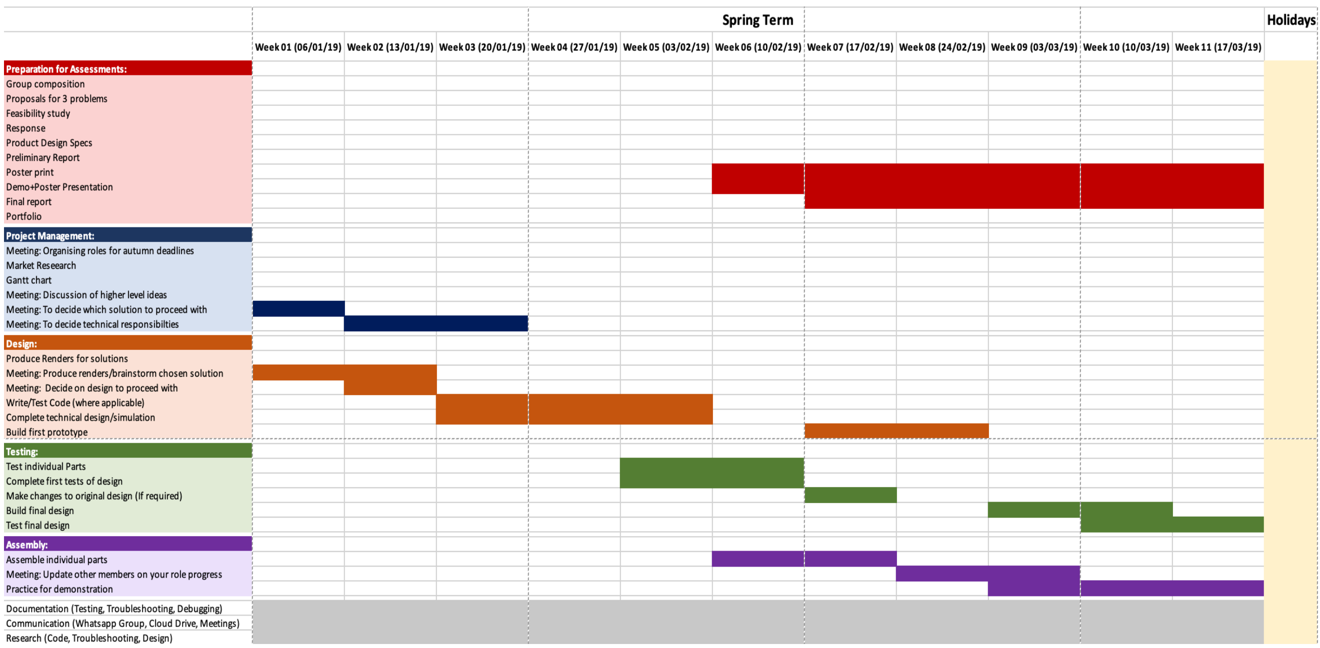

Fig: *Gantt Chart for Spring Term as part of the EE2 Group Project for Group 7*

Appendix – IV

Schematic of the Design Engineering and Hardware

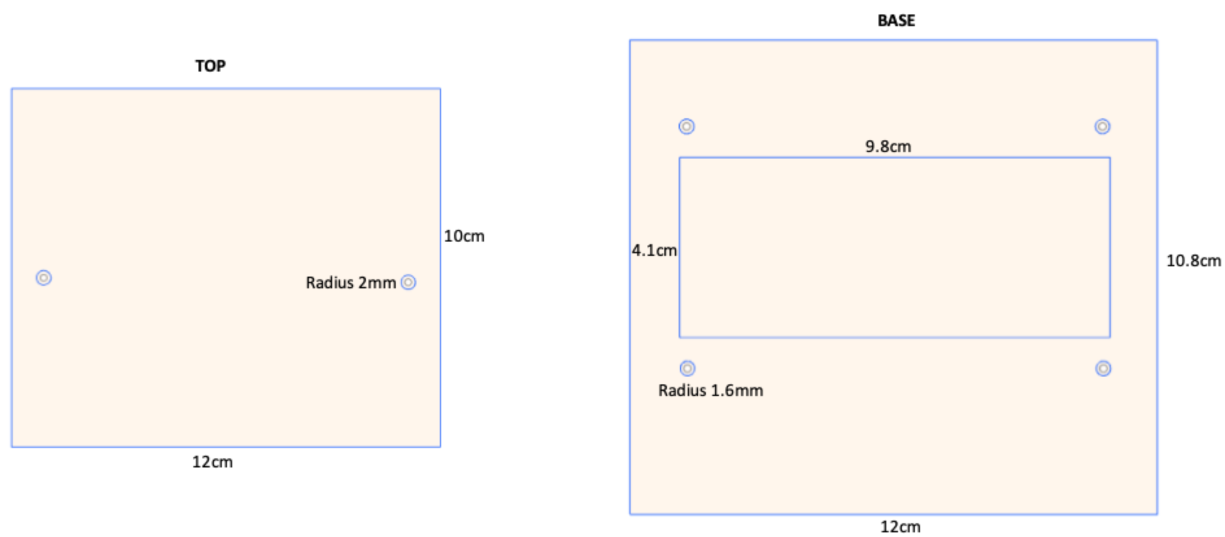

Fig: *Schematic of the top and base before laser cutting*

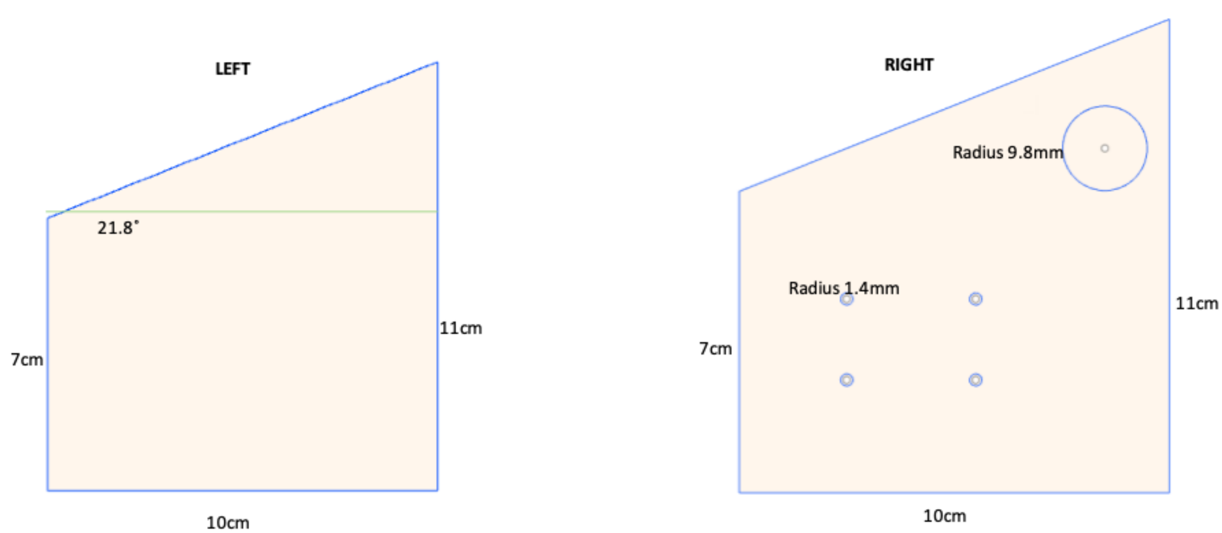

Fig: *Schematic of the lateral view (left and right) before laser cutting*

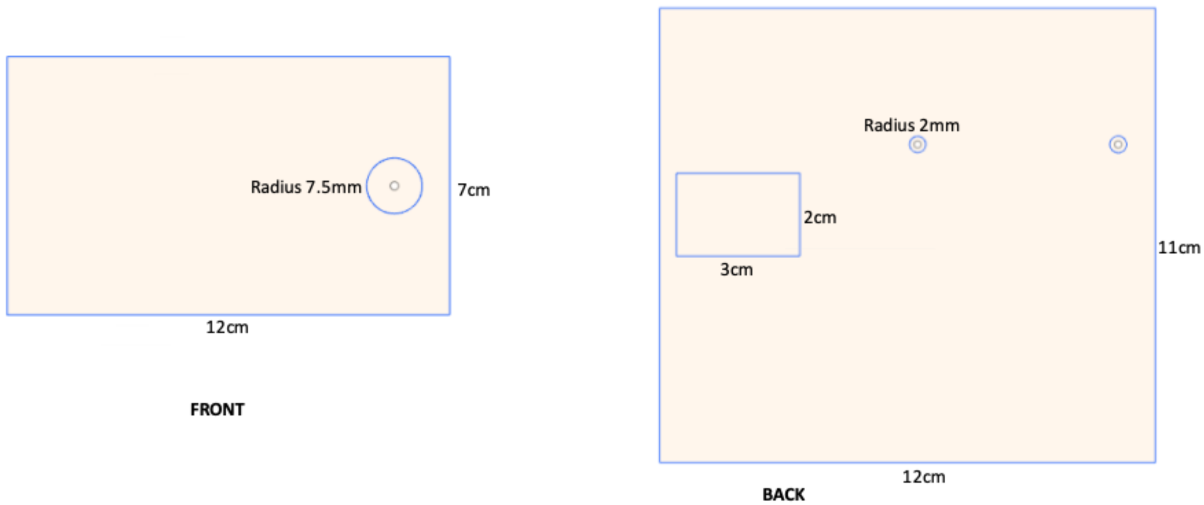

Fig: *Schematic of the front and the back before laser cutting*

Appendix – V

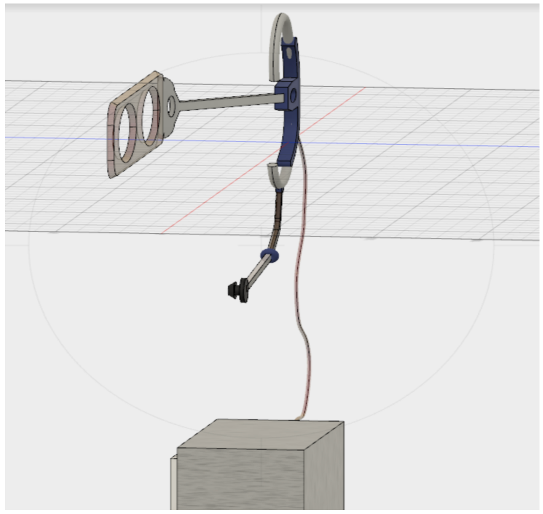

Fig: *CAD designs for eyeblink sensor*

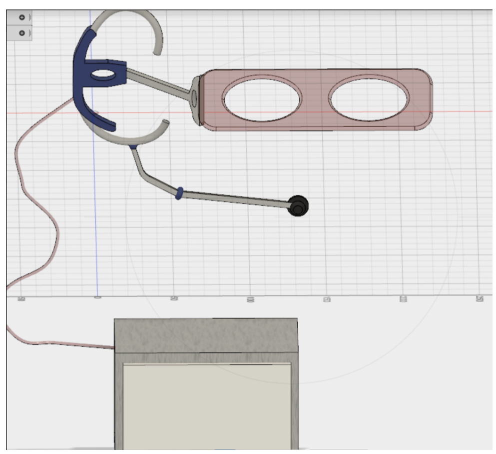

Fig: *CAD designs for eyeblink sensor*

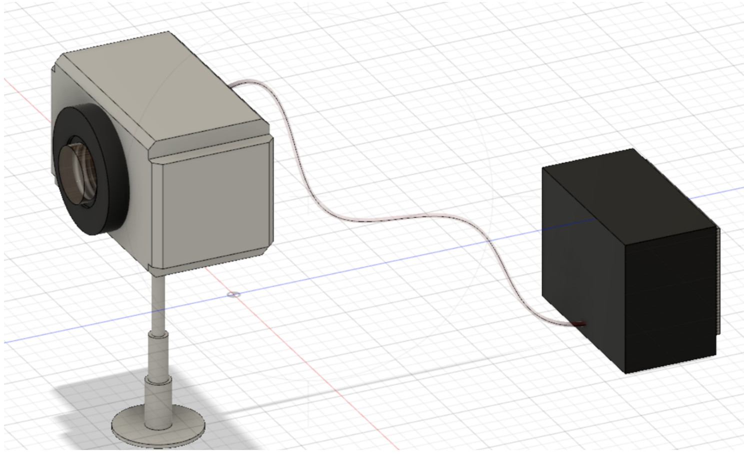

Fig: *CAD designs for the Thermal Imaging Concept*

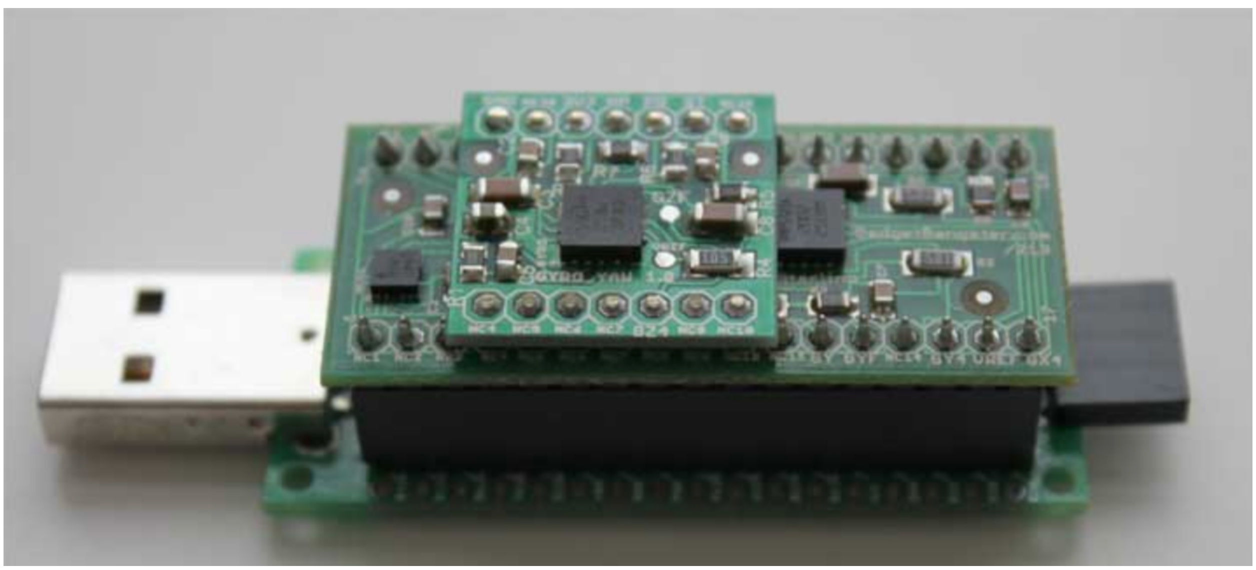

Fig: *Accelerometer Embedded System Design*

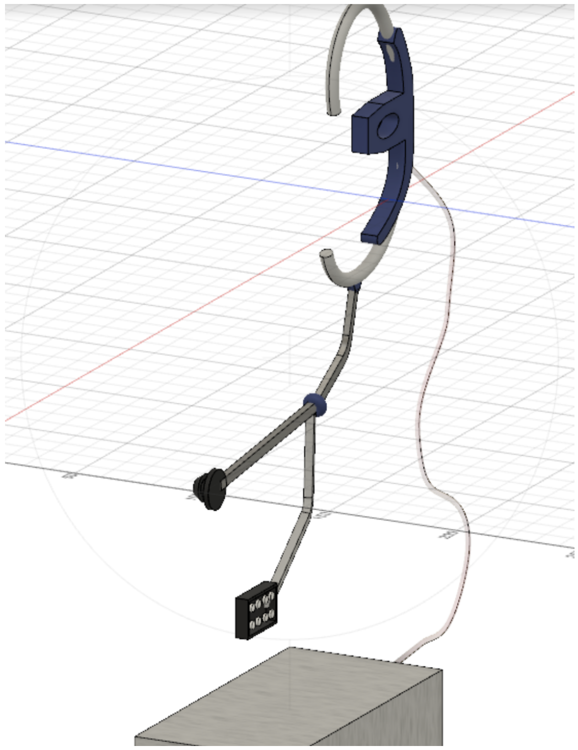

Fig: *CAD designs for the eye blink sensor solution*

Appendix – VI

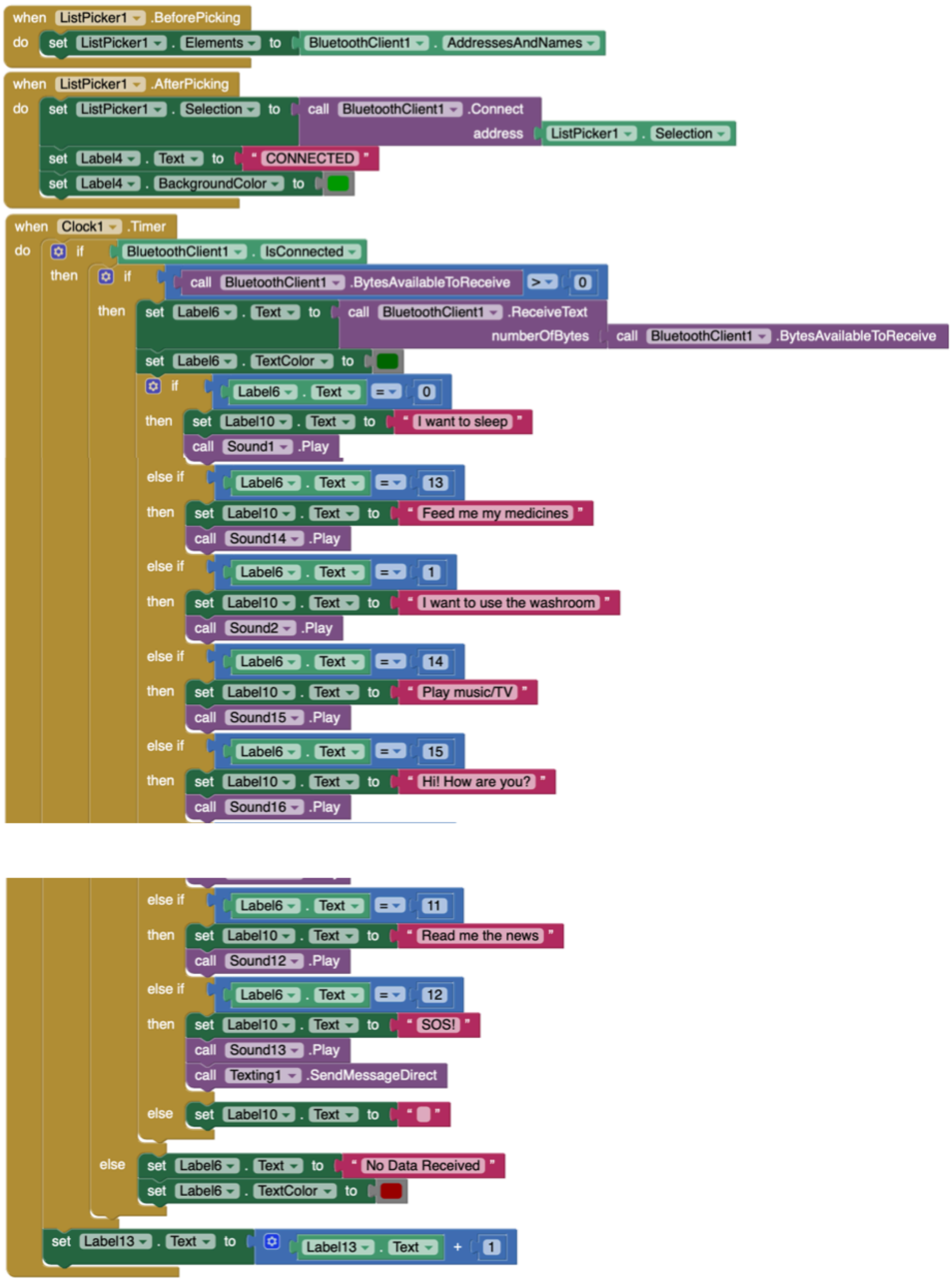

***Fig:** Pseudocode for the Mobile Application*