Aspire Create
Centre for Rehabilitation Engineering and Assistive Technology

Coursework Submission Coversheet

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UCL Policy on Extenuating Circumstances

INDIVIDUAL PORTFOLIO

Week 1

The project brief was designing a device that enables a person with tetraplegia to activate a switch action. Assumptions of the user included: no speech and cognitive impairment, no physical movement below neck, and may be ventilated.

Week 2

On our first meeting as a team, we discussed existing switches that we had gathered before. They include:

a) Sip and puff switch [1]. As the name suggests, the device comprises of a tube which the user can sip and puff into. This device is low cost, easy to wear and requires low power. However, it is hard to control and presumably tire the user's respiratory system. It requires wire, so it takes more space and makes the design complicated. It also needs regular maintenance and cleaning.
b) Neuronode [2]. It uses electromyography (EMG) as input to activate the switch. It can be placed on any muscle, so it is relatively easy to control. Another advantage is wireless; it uses Bluetooth. However, the device only has 24-hour battery life and is quite expensive. It is also attached on the skin, which may cause problems if used for a long period of time.
c) Emego [3]. It is essentially similar to Neuronode, with added specification which can be used by two people.
d) Nous [4]. Unlike Neuronode and Emego, the device uses electrooculography (EOG), which detects intentional eye blinking. It may interfere with the user's appearance and visual function.
e) EarFieldSensing [5]. It includes an ear plug which enables the device to detect facial expressions. Since it is quite intrusive, it may cause inconvenience.
f) Twitch Switch [6]. The device is activated by wrinkling of forehead. It may cause false operation if the user involuntarily wrinkles.

Some of the devices are wired, require regular maintenance, and takes time to set-up and operate. A common issue that we found was affordability. To understand the requirements that the device should have, Paporn and I defined the stakeholders involved in the use of switch and predicted their requirements (Table 1).

Table 1. Stakeholders involved in the development and operation of a switch.

Stakeholder	**Requirements**
Patient	• Easy to use product • Cheap/affordable price • Safe for user • Long lasting product • Reliable • Comfortable • Good appearance • Minimal set up/ removal

Caregiver	• Easy to use product • Simple maintenance • Minimal set up/ removal • Reliable
Family	• Product cost • Simple maintenance • Set up/removal process • Payment can be reimbursed • Warranty
Doctor	• Product specification • Advantages/disadvantages of product • Patient's condition and prognosis • Patient and family's preferences • Set up/removal process
Emergency service	• Patient's condition and prognosis • Removal process • Reliable
Insurance	• Patient's condition and prognosis • Cheap/affordable price • Reliable • Warranty
Bank	• Patient's condition and prognosis • Patient's insurance information • Product specification • Product cost • Financial status of supporter
Supplier	• Product specification • Patient condition
Manufacturer	• Patient condition • Materials • Cost • Ethics and regulation; including standards • Schedule • Funding
Ethics	• Manufacturing process • Product test, clinical test • Standards
Regulator	• Risk assessment • Patient condition • Manufacturing process • Product test, clinical test • Standards
Maintenance service	• Training on how to set up, operate, fix problems • Product specification
Government	• Cost of product; to determine tax • Access to patient information

From the limitations of existing device and requirements of each stakeholder, we conclude that a switch should have the following requirements: portable, wireless, low cost, non-invasive, and easy operation and maintenance. We derived them into technical specification which includes Bluetooth and battery powered. We came up with some ideas:

a) Voice recognition device. The device employs a pre-recorded voice commands to activate actions.
b) Electronic retainer. The idea is to have a thin circuit board in a teeth retainer, so user can activate the switch by biting it. We thought this is a novel idea, but currently we are limited by knowledge and time.
c) Chewing switch. The principle is similar to electronic retainer, but the design is a simple board placed outside the mouth.
d) Touchpad display. It employs a force resistive sensor which can be activated by close proximity.

We decided to choose voice recognition device because it is non-invasive and can use multiple commands. The components will be comprised of a voice recognition module, Bluetooth module and battery. Initial design was to include all components in a box and attach the box to a strap so it can be hanged around the neck.

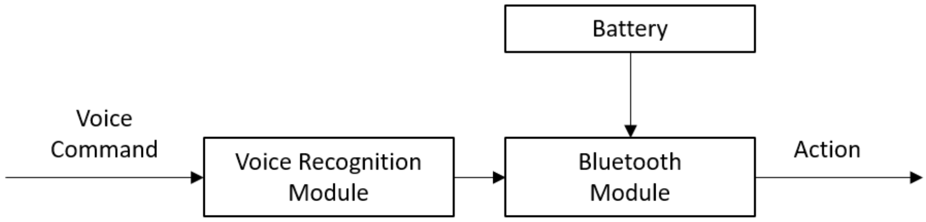


Figure 1. Diagram representing the major components of voice recognition device.

The major limitation to this device is the reliability of the voice recognition module, because voice recording is sensitive to noise. This problem can be mitigated by use of filter and good quality microphone.

We have not decided team roles yet, but for the next few weeks Federico and Alina would start working on the Bluetooth module, and Paporn and I would learn the basics of Arduino.

Week 3

We had a lecture by Mr Andrew Kell on assistive technology for ICT access. Speech recognition was mentioned in his lecture. The major advantage of speech recognition is it can dictate text. However, there are a lot of commands that user should learn to perform the functions. This idea is similar to our idea, although our device is only a prototype.

This week we bought a Bluetooth module, HC-05. Federico and Alina were working to connect the Bluetooth module to computer.

Week 4

Mr Irving Caplan gave us a lecture on basic electronics and introduction to Arduino, specifically Arduino Uno. I learned how to install the drivers and upload template sketch to the board.

Week 5

I managed to make a circuit to light an LED with Arduino Starter Kit for Beginner by following Arduino Projects Book. The circuit instruction and sketch were provided in the book. Basically, a sketch consists of three parts:

a) The definition of parameters.
   e.g. int ledPin = 13; // define the number of LED pin on the breadboard
b) Void setup ()
   This part sets what needs to be done only once.
c) Void loop ()
   This part contains the commands that will be repeated over and over.

Week 6

We were advised to include stakeholder's opinion on designing the device. We decided to collect data by questionnaire. Initially, we asked if we could have an interview in Aspire as well, but we could not due to time limit. Paporn and I created two separate questionnaires, one for user and another one for family, caregiver and clinician. The first draft of the questionnaire was intended to specifically asks what user wants from a voice recognition device (Please see Appendix I).

By this week, we still had problem in connecting the Bluetooth module.

Week 7

Since the voice recognition module had not arrived yet, we started to devise alternative options, including sip and puff switch, chin switch and capacitive sensor. A chin switch uses a force sensitive sensor embedded on a tubing with the main component worn around the neck. A capacitive sensor senses when there is an object in close proximity interfering with a self-generated electric field surrounding the sensor. It could be mounted on a flexible tubing close to mouth so it can be gritted or chewed by the user. Finally, we decided on the capacitive sensor because it requires less energy than other options, and the components are readily available on the market. We can use material like silicon rubber to cover the sensor, as it can be moulded easily. It was also decided that I would design the device in CAD.

Week 8

We had a meeting with Andrew and Tom and received feedbacks on our alternative plan. A device that requires contact with mouth has several limitations, including robustness and hygiene. It will be chewed repeatedly, so the protecting cover should have high fatigue strength, high abrasion resistance and long lifetime without limiting the function of the sensor. The device would require regular maintenance because it would be constantly covered in saliva. A suggestion was to put the sensor outside the body as something to wear. Therefore, it would be non-invasive, less conspicuous, and require less maintenance. It is a proximity sensor, so it does not need force or pressure to activate the device.

We also had a solution for Bluetooth problem. It turned out that HC-05 is a serial type Bluetooth module, which is able to transfer files between devices but not to receive keyboard input. We were looking for a Human Input Device (HID) type Bluetooth module, which can translate a user's input to keyboard and mouse function. Adafruit Feather 32u4, which we previously used in another course, is a HID module. Therefore, it was decided that we would use that module.

There were also comments on the questionnaire. We realised that there were irrelevant questions on the first draft. Our project was clearly intended for ICT access, but we included unrelated questions like asking for other activities that requires assistance. Questions need to be generated carefully so we do not breach ethical considerations regarding personal data. Personal data is regulated under Data Protection Act, which is a translation of European General Data Protection Regulation (GDPR). Therefore, the questionnaires were revised and the final document can be seen in Appendix I of group report. I also learned that engaging stakeholders should be the earliest thing to do to define the problem and user requirements.

By the end of this week, Federico managed to make the capacitive sensor to work. He tested the device by himself without any measurement. Therefore, we designed a test to measure the minimum distance for the sensor to activate (Figure 1). I designed several boxes with different thickness: 2, 4, 6, 8 and 10 mm (Figure 2), in Autodesk Inventor.

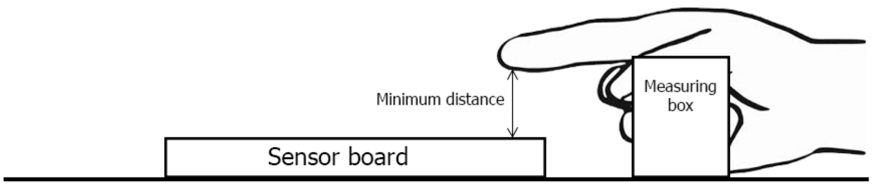


Figure 2. Test to measure the minimum activation distance of capacitive sensor.

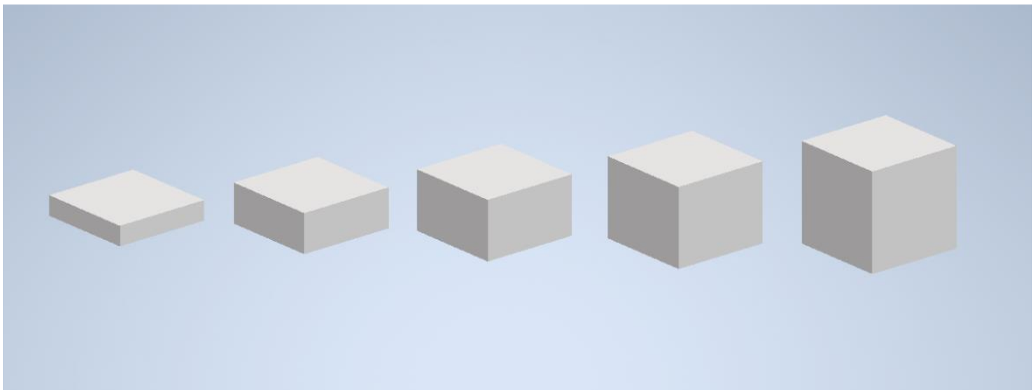


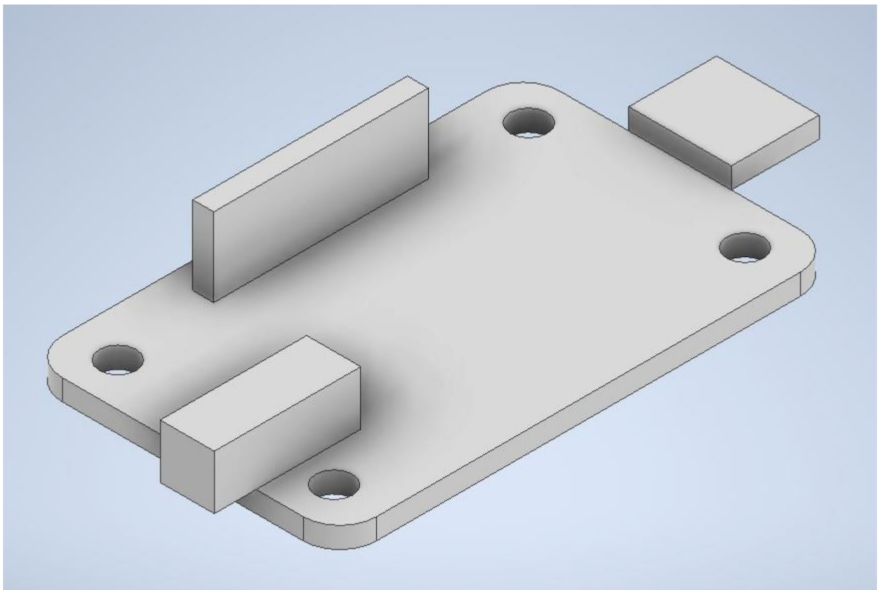
Figure 3. Measuring boxes.

In the end, we did not do the test because the voice recognition module arrived and we started to focus on that. I started to design the case for the device by modelling each component, voice recognition module and Bluetooth module.

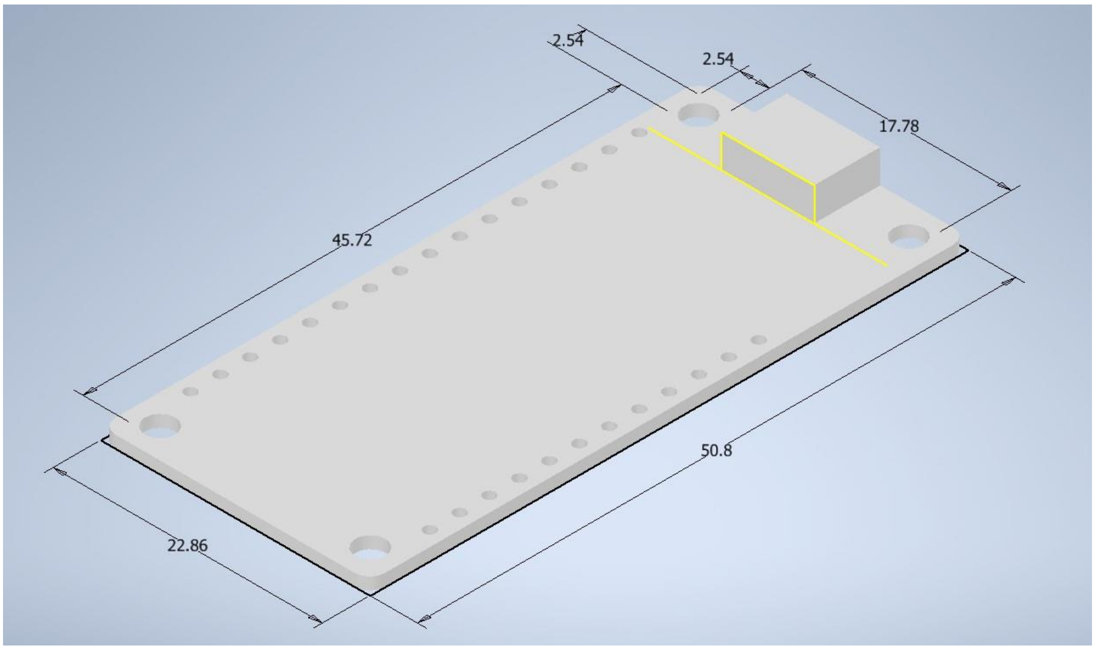
<u>Week 9</u>

Federico finished the voice recognition module connected to Arduino board and powered using a computer. The device could record 3 set of commands, each contains 5 commands, but we had only been able to use 1 set. Using his own voice recorded, Federico was able to activate the device repeatedly from long distance. When the others tried to test it, there were true negative results even in close distance. There were several ways to increase the sensitivity of the device. Possible solutions were using a better microphone and installing another module to attenuate the signal. But due to time limit, we could not further developed it.

I was able to build a simple model of voice recognition module and Bluetooth module, only showing the major parts (Figure 3). Although in the final assembly, I did not use these models. I downloaded template models instead to illustrate them more realistically (Figure 5).



(a)



(b)

Figure 3. (a) Model of voice recognition module. (b) Model of Bluetooth module.

Week 10

The initial design of the case was comprised of a base and a cover. On the base, there were two spaces for Feather and the voice recognition module (Figure 4). The base and its cover were to be connected using screws, hence there were four holes on each side of the board. On the cover, there was a small curvature each on the left and right sides. This was added to help people who wants to open the box, to put their fingers into.

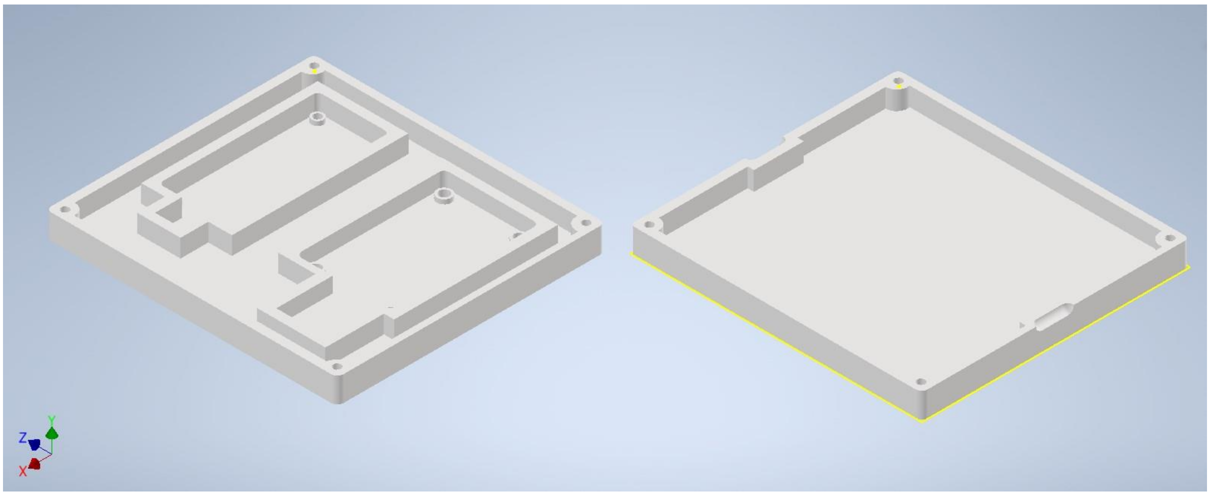
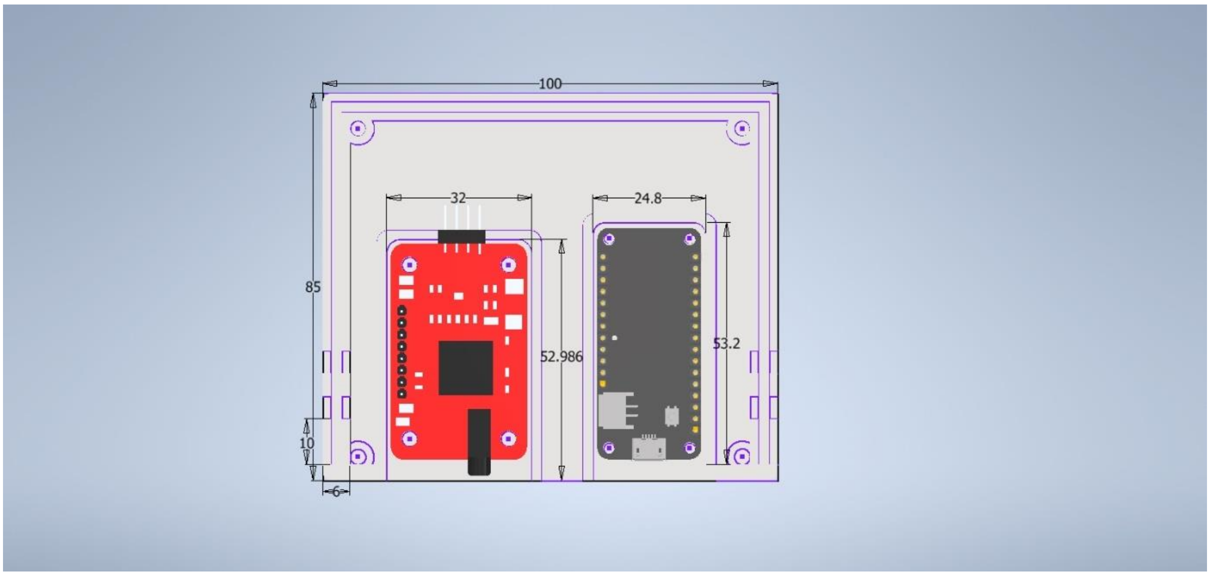
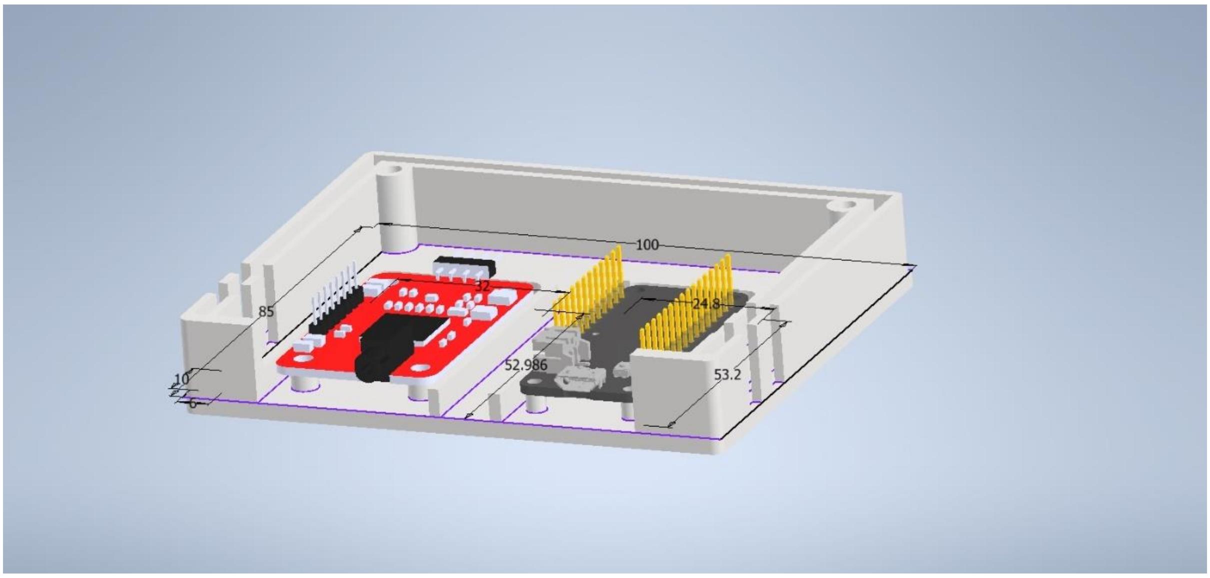


Figure 4. Initial design of case, comprised of a base (left) and a cover (right).

I revised the design after several considerations. There should be more space for battery and cables. The edges of the cover was protruded and the edges of the base was extruded to attach both boards together (Figure 5). This was done because we have predicted that drilling the screws in may not be done in time. Two supports were made on the left and right sides of the base to attach a strap (Figure 6). Case was printed in Ultimaker 2+ Extended 3D Printer, using acrylonitrile butadiene styrene (ABS). The final product weighed 65 g (Figure 7).



(a)



(b)

Figure 5. Design of the base part of case in (a) orthographic view and (b) perspective view, with Bluetooth module and voice recognition module represented inside. Measurements in mm.

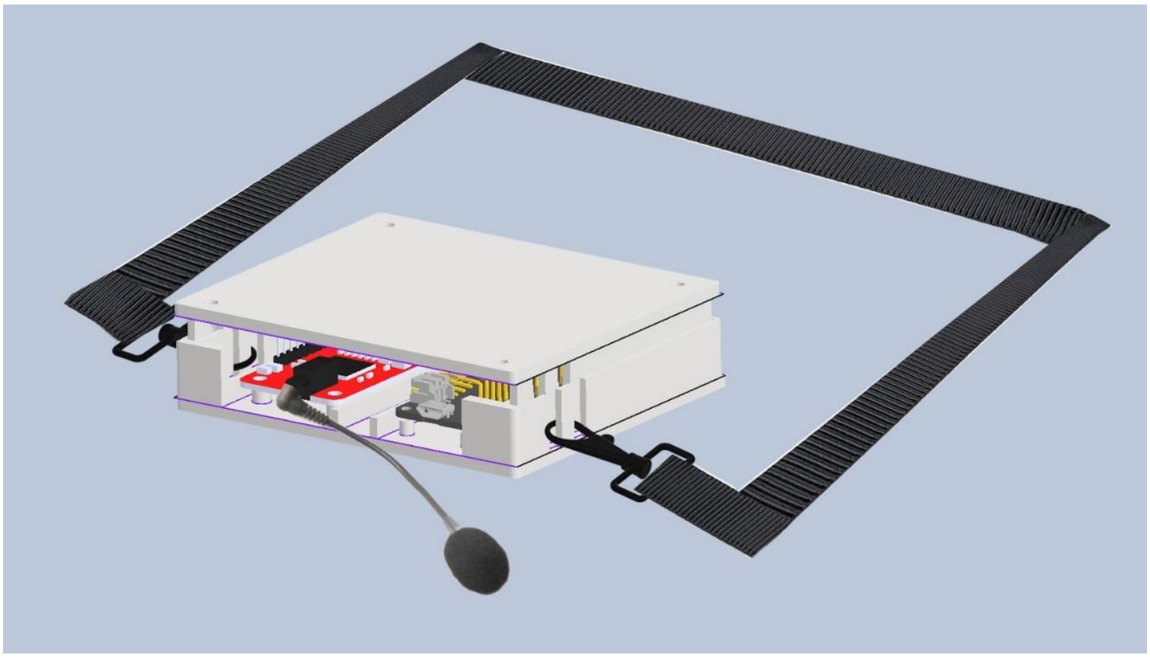


Figure 6. Design of device.

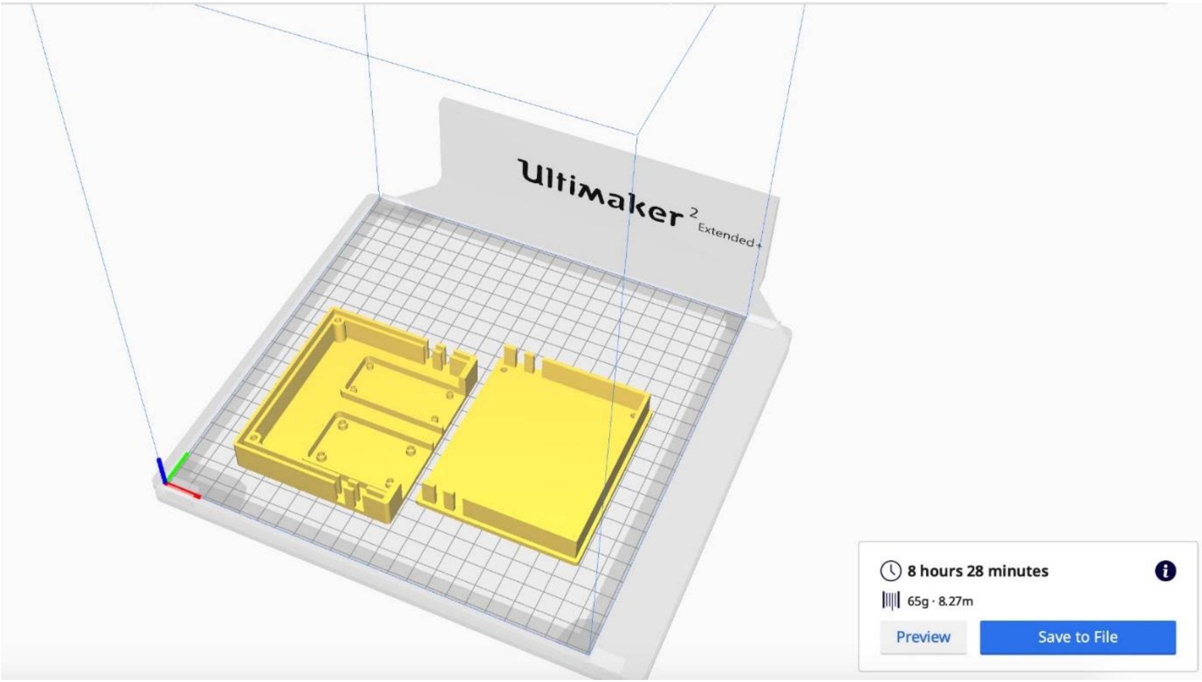


Figure 7. The setup of the case in Ultimaker Cura before being printed.

It turned out that the final device incorporated additional components, namely two batteries, a logic converter and a voltage converter (Figure 8). A logic converter was needed because the Bluetooth module uses a 3.3 V supply and could not define the voice recognition which uses a 5V supply. A voltage converter reduced the voltage from the 9V battery so the voice recognition module and logic converter received suitable values.

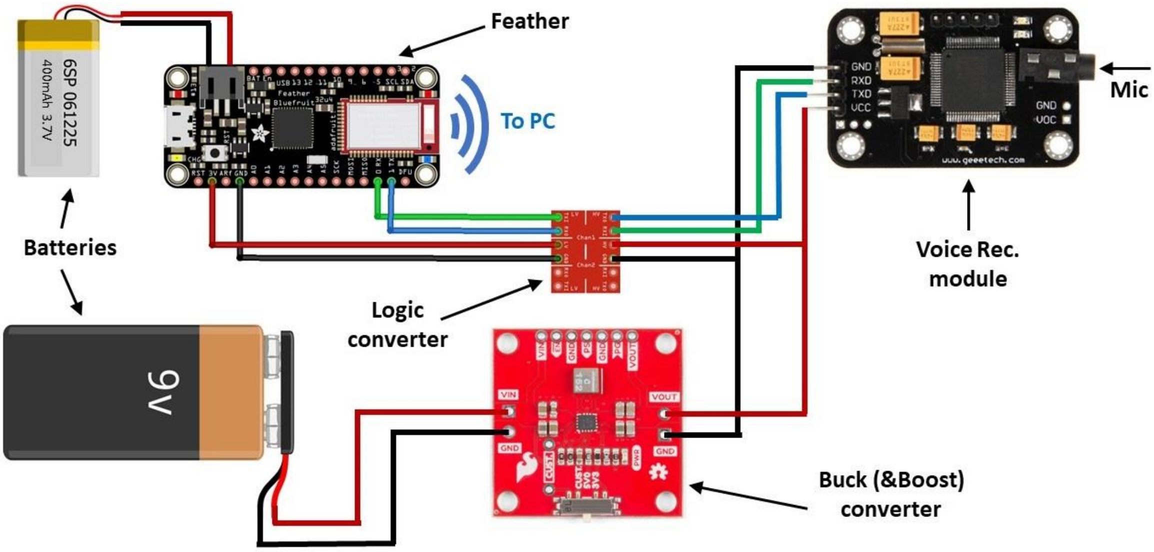


Figure 8. Circuit diagram of the device.

The case design did not leave adequate tolerance for space, so we had to fit everything inside. The 9V battery was placed outside. Ideally, the case shall be completely enclosed, leaving only holes for a microphone and a USB cable. The base thickness should also be increased to allow screws inside. Future iteration of this device shall also have a display of battery level, with an increased dimension in mind due to additional component. Overall, planning should be done in advanced and other factors like facility opening times should be predicted. It took about 8.5 hours to print one set of case, so the printing process alone already takes one to two days.

In the same week, Paporn and Alina set some experiments to test the functionality of the device. In all tests, each command was tested 5 times.

a) Experiment 1. Each person recorded 5 short commands and tested each command in 12 cm distance from the device. Then the other people who did not have their voice recorded tested the commands, in closest distance and 12 cm distance.
b) Experiment 2. This was similar to experiment 1, but the commands were longer.

From these two experiments, it was found that shorter commands have higher accuracy, sensitivity and precision than longer commands. That was why the final prototype used shorter commands. We used two words instead of one word because it will unlikely appear in our conversation. The commands were defined as follows:

- Left mouse – corresponds to left click
- Right click – corresponds to right click
- Open file – corresponds to double click
- Drag and drop – corresponds to left click and holding it for 0.5 seconds
- Email reader – corresponds to opening email

The following tests were developed to test the final commands:

c) Environmental testing. This test was done by one person who recorded the voice, and tested in 12 cm distance. The only variable was environment: controlled and non-controlled. In controlled environment, noise level was kept to minimum. In non-controlled environment, several settings were used: street, coffee shop, bus stop, bar and classroom. In general, the results for non-controlled environment were less accurate and less sensitive than controlled environment.
d) False Positive Testing. We used 2 different sets of command which were similar in sound to the original set of command. The device still activated even if it was not the original command, so it still could not distinguish between similar words.
e) Distance between Bluetooth and computer. We tested the device 1 m and 2 m away from the computer. The results showed that closer distance (1 m) produced higher accuracy and sensitivity.

REFERENCES

[1] Origin Instruments, “Sip and Puff Switch Solutions”, url: https://www.orin.com/access/sip_puff/
[2] Control Bionics, “Neuronode Trilogy”, url: https://www.controlbionics.com/neuronode/
[3] GSPK Design Ltd., “Emego”, url: emego.co.uk
[4] Thought-Wired Ltd., url: https://getnous.app/
[5] D. J. C. Matthies, B. A. Strecker, B. Urban, “EarFieldSensing: A Novel In-Ear Electric Field Sensing to Enrich Wearable Gesture Input through Facial Expressions,” CHI Conference on Human Factors in Computing Systems, pp. 1911-1922, 2017.
[6] RehabMart, LLC, “The Twitch Activated Assistive Technology Switch”, url: https://www.rehabmart.com/product/the-twitch-activated-assistive-technology-switch-32088.html

APPENDIX I
SURVEY OF ASSISTIVE TECHNOLOGY FOR TETRAPLEGIC USER

1. What is your age?

   - 20 and below
   - 21 - 30
   - 31 - 40
   - 41 - 50
   - 51 - 60
   - above 60

2. What is your current living situation?

   - Living alone
   - Living with family
   - Living with caregiver
   - Living with other, please specify: ____________

3. Do you need any assistant in performing activities of daily living?
   - o Yes
   - o No

4. If yes, please indicate activities that require an assistant

   - Personal hygiene
   - Dressing
   - Eating
   - Toileting
   - Transferring/Mobility

   - Environment controlling e.g. turn on the light
   - Accessing ICT
     e.g. using mobile phone
   - Other, please specify: ___________________

5. Please indicate if you have difficulty in the following functions

   - o Head movement e.g. nodding
   - o Eye twitching or blinking
   - o Mouth gripping
   - o Speaking

6. What is your current method to trigger a switch action e.g. turning on computer?
   ____

7. Why you decide to use the current method?
   ____

8. Are you aware of assistive technology that can allow you to trigger a switch action by yourself?
    - Yes
        - If yes, have you ever try it?

          ____
    - No
        - If no, are you interested in trying it?

          ____

9. Do you have any design preferences of an assistive device for accessing information? e.g. monitor that can detect eye blinking

   ____

10. What are the main factors affecting your choice?

    ____

11. Have you ever used voice recognition technology to trigger some action?
    - Yes
        - If yes, what do you think about it?

          ____
    - No
        - If no, are you interested in trying it?

          ____

12. What are the advantages and disadvantages in your opinion?

    ____
    ____

13. How often do you think the battery of the assistive device should be charged?

    a. Daily
    b. 2 - 3 days
    c. 4 - 5 days
    d. Weekly

14. How much would you be willing to spend on a voice recognition device?

    ____

15. Do you have any other comments?

    ____
    ____
    ____

SURVEY OF ASSISTIVE TECHNOLOGY FOR RELATIVES AND CLINICIANS

1. Please indicate who is completing this survey

- Patient's family/relatives
- Caregiver
- Doctor
- Other health professional, please specify: _________

2. What is your age?

- 20 and below
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- above 60

3. How long have you been working/living with tetraplegic patient?

- Less than 1 year
- 1 – 2 years
- 3 – 4 years
- 5 years and above

4. Do you face any difficulty working/living with tetraplegic patient?
- Yes
  - If yes, please specify the difficulty
    ____
- No

5. Does tetraplegic patient require any assistance from you?
- Yes
  - If yes, please indicate the activities that require your assistance
    ____
- No
  - If no, is there any other assistant for the patient?
    ____

6. Have you ever heard about assistive technology?
- Yes
  - If yes, please specify what you know about it
    ____
- No

7. Do you think assistive technology is necessary for a tetraplegic patient?
- Yes
  - If yes, please elaborate why you think it is necessary
    ____
- No

  - If no, please explain why you think it is unnecessary

    ____

8. Have you ever use assistive technology with your patient/relative?
   - Yes
     - If yes, please specify the type of assistive technology used

       ____
   - No

9. Do you think it is good to enable tetraplegic patient to trigger some action by themselves using assistive technology instead of an assistant?
   - Yes
   - No

10. Are you aware of assistive technology that can allow patients to trigger a switch action by themselves?
    - Yes
      - If yes, have you ever used it on your relative/patient?

        ____
    - No
      - If no, are you interested in trying it with your relative/patient?

        ____

11. What do you think is the most challenging issue for tetraplegic patient in terms of triggering some action by themselves? e.g. turn on the light

    ____

12. Do you have any design preferences of assistive technology to trigger an action? e.g. monitor that can detect eye blinking

    ____

13. What do you consider in choosing an assistive technology to trigger an action for your patient/relative?

    ____

14. Have you ever used voice recognition technology to trigger some action?
    - Yes
      - If yes, what do you think about it?

        ____
    - No
      - If no, are you interested in trying it?

        ____

15. What are the advantages and disadvantages in your opinion?

    ____

    ____

16. How often do you think the battery of the assistive device should be charged?

    - Daily
    - 2 - 3 days
    - 4 - 5 days
    - Weekly

17. How much would you be willing to spend on a voice recognition device?

18. Do you have any other comments?