Assistive Technologie Challenge

EPFL 2021- Team ATC communication interface 2021

Open Access Report

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1 Introduction

The device is a communication interface for an 8-year-old child that cannot speak but is eager to interact with his environment. His medical condition is characterized by motor impairments and dyskinesia. The user can currently communicate with someone nearby by two means: first, by pointing at pictograms present on his board with the left hand (see Figure 9 in Annexes), second, by controlling a computer using an eye tracking system. The latter is problematic: it is not adapted to the user's motor abilities and thus, it works only in rare occasions. The goal is to facilitate his communication with people by developing an efficient and adapted controller to interact with his tablet (computer) effortlessly. The challenges are first of all to create a device easy to use for a child, that does not increase his fatigue and is in phase with the communication tools he uses. We have to consider the low precision of the movements as well as an unstable head hold. In order for this project to be successful it is also crucial that the device meets the criteria of safety, biocompatibility and that it is easy to use for both the family and the therapists. In addition, we aim to produce an object that is easily reproducible, open-source and within a reasonable budget.

2 Motivation

Due to his medical condition, the user is limited in the precision of movements. He is in a wheelchair. He can move his forearms, however when he gets tired, he can only control his left hand accurately. Similarly, he has difficulty holding his head and his upper-body still. Often during the day, he tends to completely lean on the table. Moreover, he gets rapidly tired. The principle sources of fatigue that have been identified are the following: making wide movements, staying still, frustration and stress due to a crowded environment.

2.1 Actual Device and Challenges

The user currently uses a low-tech board in front of him that is fixated to his wheelchair, similarly to a tray table (as shown in Figure 9 in Annex section). On this transparent board, several pictograms are taped which are essential to communicate with people around him. The user points to one or to a sequence of pictograms. Moreover, several sheets of paper with additional pictograms are attached to the side of the board, and are placed over it if additional vocabulary is needed.

The user has at his disposal a tactile computer (tablet). This screen is placed in front of him. On this tablet, the software Grid3 allows to communicate with a sound feedback, also via a system of pictograms (see Figure 10). When a pictogram is selected on the tablet, a voice command orally repeats the corresponding word or sentence. The latter tablet have a Tobii eye tracking camera which is not very effective for the user case. He is not able to control it by having his head still all the time. Maintaining such a position requires a huge effort for him. The only remaining option when exhausted is the usage of his left arm on the board to express himself throughout the pictograms. Also, the user cannot use the tablet in its touch functionality due to his random movements and fatigue caused by the frustration of not being able to handle it properly.

Accurate and efficient tablet control is important because it is what the user is likely to use the most as he grows older and it would give him more independence. This is exactly why BR4VE has been created.

2.2 Current Existing Solutions

Eye tracking: The solution allows one to control the tablet by detecting the direction of his gaze. In other words, by looking at one pictogram for a short period of time, this pictogram will be selected. This solution has proven to be successful for many disable person that can stay immobile, facing the tablet computer. However, as mentioned before, our user cannot sit still for a prolonged period of time. Whenever the user is tired, he leans on the low-tech board in front of him and his not able to control the tablet anymore, since his eye gaze cannot be detected. As a result, this solution is not optimal as the user is not able to use it throughout the day.

Hand tracking: This solution has also been implemented in HackhaHealth Geneva 2021. It allows to control the tablet by computer vision, and recognition of the movement of the user's hand. The drawbacks here are that the signal corresponding to the movement of the user would include noisy signals and that such an implementation would need a more complicated and bulky setup for the family when fixating the camera above the user hands.

Tactile screen: By placing the tablet on the board of the wheelchair, the tablet could in theory be controlled by finger touch. However, the user's forearms are always placed on the board, and his movements consist of sliding on the tablet. This would make it impossible to control the tablet, as any pictogram placed between his hand and the one that is targeted would be selected during the hand movement. Raising his forearm and hand between pictogram selection is not something that can be performed repeatedly, due to the very fast fatigue.

3 Product Concept and Technical Solutions

3.1 Device presentation

Given the information mentioned above, our implementation consists of a board that can be fixated to the user's wheelchair exactly as the board he currently uses (see front cover). The board includes a tablet controller based on capacitive sensing. This type of sensors can be activated without applying any force, and therefore presents the advantage of not requiring any tiring movement and additional force for the user. The controller is composed of seven sensors: four arrows indicating the direction (up, down, left, right), one sensor to confirm the selection of a pictogram, an additional sensor for drawing attention by emitting a specific sound and the last one allows the user to turn on or off the sensing system. The controller is connected to the tablet controller via bluetooth connection and is compatible with the Grid3 software. On both sides of the controller two sheets of pictograms are placed. The main reason to have a non-interactive part for the board, is to keep the user current benchmarks in the way of communicating with his surrounding. It also allows him to communicate even when the tablet is turned off, thus its ability to communicate will not be stopped when the tablet is charging or the device has no power left. Moreover,it is important to note that the user will need to train in order to be able to use perfectly and easily the controller connected to the tablet computer. At the beginning, he may be tired by this exercise, and may not be able to use it all throughout the day. Having the pictograms on the board thus allows for a smooth transition from his current device to the one we will implement. For this part of the board, we need to take into account that the pictograms are changed when the user learns new vocabulary. More details about the requirements quantitative are presented in a Table in the Annex section.

3.2 Compatibility Requirement

Computer connection: The device has a Bluetooth module made to be connected to a computer or tablet.

Grid3 compatibility: Our device must be compatible with the Grid3 software [3]. It is a common used software to implement an Augmentative and Alternative Communication (AAC) method. Those systems permit a functional communication when natural speech methods are insufficient to provide the essential daily communication needs [2]. The communication proposed by the software is by means of a matrix of pictograms or words that the user can select. The later software offers higher flexibility on the number of communication icons to arrange on the grid and their disposition. The order of the pictograms is defined by the user according to his needs. This software allows the user to control his tablet using accessing devices such as a pointing device, hand or eye tracking, a scroll system or switches. The software is illustrated on Figure 10 in Annexes.

Wheelchair fixation: As the device is attached to a wheelchair, a compatible fixation for the board is necessary. Steel bars are used to attach the device to the wheelchair and those elements are fixed to the other parts of the board using 3D printed elements. Special care has been taken to create a system that is relatively modular and adaptable to the wheelchair.

3.3 Technology Used

This section exposes how the implementation is being considered. In the sensing technology part, the capacitive technology is explained and discussed. The following section describes the visual feedback embedded in the controller. The communication section describes the connection system between the tablet and the board. Finally an electronics section explains the different systems and components that we will be used.

Sensing technology: Projected capacitive technology is used to detect the user's selection on the board. The detection is done by means of scanning and measuring the amount of current passing through each electrode, then establishing a steady current state. The user finger creates a current draw in the initial circuit (illustrated on Figure

8 in Annex). A MPR121 module connected to the controller using I2C communication protocol is used [8]. This module allows the signal filtration and simplify the Micro Controller Unit (MCU) pin occupancy.

Visual feedback: Having LED components on the top of each sensing rectangle, permits to add more interactivity with the board. Based on the user feedback, it has been determined that this element was essential in the user's learning process because it clearly indicates whether an action was detected or not.

Tablet communication: Taking into consideration that the tablet is using Windows 10 as an Operating System (OS), the choice of technology is turned towards Serial communication via Bluetooth connection. The HC-05 module is implemented in this case and is connected directly to specified Tx and Rx pins of the arduino [11]. The idea behind controlling the tablet using our sensors is really to imitate the usage of the keyboard on the tablet. This means that when a sensor on the controller is touched, the MCU sends to the tablet a message telling that a specific key on the keyboard should be activated.
Electronics : The electrical system contains the following components:

Electrical components	Supply voltage (V)
Microcontroller (Arduino Nano)	5 DC
MPR121 module	3.3 DC
Metallic sheets of copper electrodes	-
Bluetooth module HC-05-4 Arduino	5 DC
Addressable LED strip WS2813	5 DC

A power bank is used to supply the system [9]. It is a relatively user-friendly source for both charging and connection and this solution avoid hazardous risks by having a very safe solution. As calculated in Annex section, the current consumption is not more than 1 Ah and the voltage needed is 5V.
An other module connected to the Arduino is a communication module. It is used to establish the communication between the board and the tablet via the nano micro-controller [10] as presented on Figure 12 in Annex is used. This micro-controller is easy to program and compatible with the current application.
Two additional modules are implemented: First, between the Arduino and the copper electrodes is placed a proximity capacitive touch sensor control module called MPR121 (see Figure 13a). The Bluetooth module HC-05-4 [11] is similar to the one in Figure 13b. The MPR121 module can handle 12 inputs and outputs at the same time.
A RGB addressable LED system has been chosen for the visual through different light colors as shown on Figure 14 in Annex. The WS2813 LED [12] are in a strip form. Finally, for the well functioning of the device, a simple LED to indicate if the device still has power and an On/Off button are pinned to the system. A buzzer [13] connected to the MCU emits a melody to draw attention.

To summarize, the electronic system is quite simple and efficient and is represented below in Figure 1.

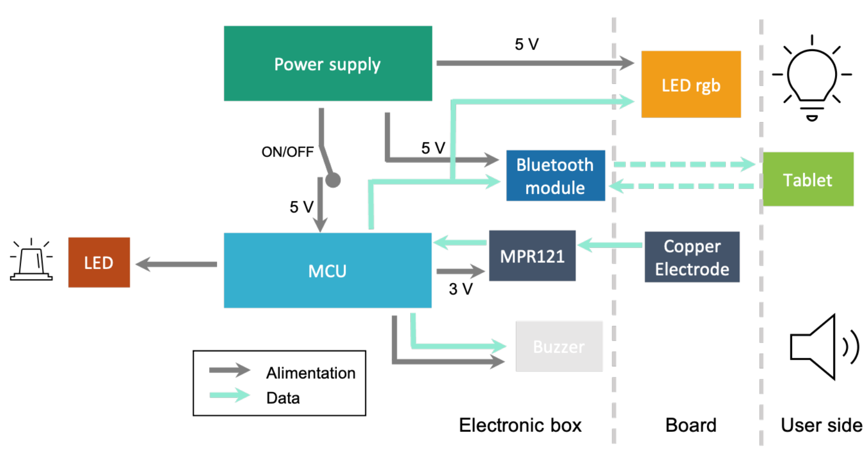

Figure 1: Electronic diagram of the device

3.4 Chosen Design

Layering system : For the design consideration, the device is divided in several layers as illustrated on Figure 2.

The first layer (exterior, closest to the user interface) is a cover window with a 3 mm thickness. Its purpose is to protect the sensors (and pictograms) and to create a smooth interface for the user. The extremities are folded upward to prevent objects from falling off. Also, the controller arrows have been engraved on it to provide additional sensory guidance to the user. An encapsulation have been created over the entire board and guarantees a more waterproof system.

The second layer is composed of the pictograms. A plastic map system allows the user to insert two A4 pages previously printed with the desired pictograms on each side of the board. A system of magnets keeps the pictogram pages in place at the desired location. The cover window and the support layer are attached to each other using magnets. Those permit to easily detach and attach the cover window and allow easy access while remaining waterproof.

The third layer is the sensing layer. This where the capacitive technology lies (ie. one sensor per pictogram) which is a copper sheet stuck on the top support layer.

The last layer is the support. That is to say, it will support all the above mentioned layers and also insulate the device from below. In this support, tracks are machined to leave room for the LEDs and the cables and to remain flat. This layer makes the system more rigid, insulated and safe.

The last element of the device is a box in which all the electronics and the power supply are located. This box has no sharp edges and is very well isolated from the environment. A magnetic cap system ensures an easy to use closure. The user only has access to the power bank. A tab system allows the power bank to be easily removed and instructions for recharging are printed on it. Rails are located on the inside of the electronics box and allow the user to plug the power bank safely once charged. On the side of the box there is a switch to turn the system on and off and also a LED to make sure the system is powered. Being splash-proof and hidden from the user is very important. It is still possible to access the electronics by removing the box in case of technical problems. However, there is also a USB A female output on the side of the box to flash new code without having to open the box.

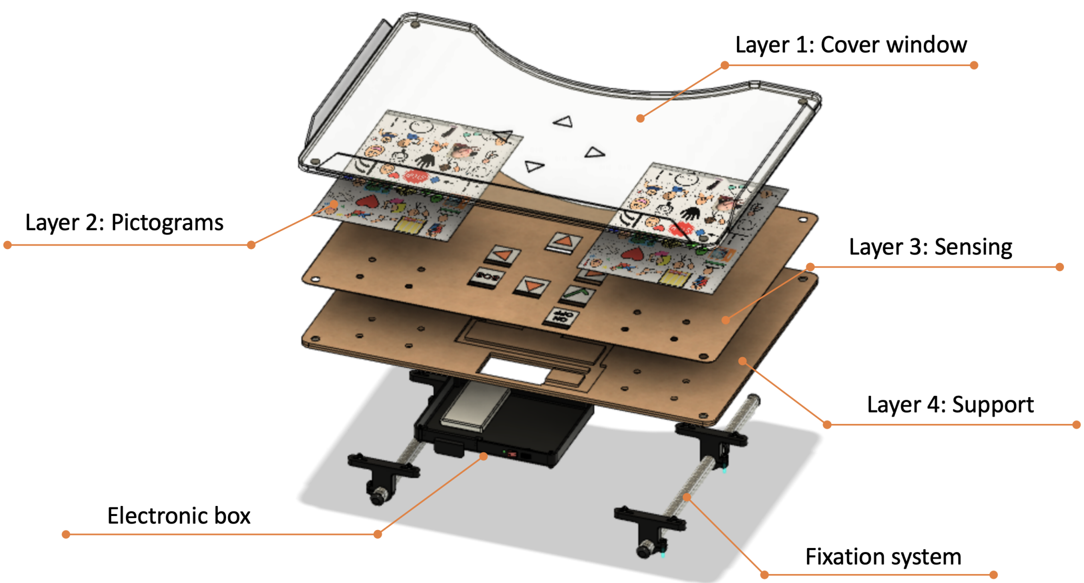

Figure 2: Layer by layer illustration of the device

Top View : Concerning the top view of the board, different access zone have been established for the user (main zone, secondary zone and difficult to access zone), as shown in Figure 15 (see Annex section). This allows the controller to be placed in the most suitable location for the user (ie. easy to access and visible). It should be noted that this analysis is entirely dependent on the user.

4 Device Manufacturing Instruction

n plsrs elements tout doit s'assembler à la fin et faire ref au tableau de matériaux To ease the construction of the device, we propose to consider it as an assembly of several elements. Therefore, the device consists of a board support, a cover window, capacitive sensors, an electronic part, and other small elements considered as diverse. It should be noted that the device presented here is adapted to a specific user. It was built by an iterative process, several prototypes were created and improved according to the needs of the user. Some procedures must therefore be adapted according to the user for whom the device is designed.
As detailed in the Budget section in annex, the estimated budget for building the device is approximately 320 CHF. The price may vary as it depends on where the device is manufactured.
According to our estimates, the manufacturing time to build the whole device is about 10 days. In each section the manufacturing time is specified. This is based on the time we took to produce the device. This obviously depends on the work space available and the experience of the manufacturer.

4.1 Board Support

Estimated time for manufacture : 9-12 h
Materials : The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- Laser cutting machine [32]
- Iron clamp [33]
- Wood glue [34]

Steps to follow :

1. Load the dxf files (support_3_MDF_4mm.dxf and support_2_MDF_4mm.dxf) on the laser cutter and choose the appropriate parameters for 4mm MDF in the library for each support layer (bottom and middle).
2. Load the dxf file (support_1_CP_aviation_1mm.dxf) on the laser cutter and choose the appropriate parameters for aviation plywood in the library for the top layer.
3. Glue the middle support to the bottom support with wood glue (support_1 and support_2). Once aligned, clamp the two layers together with Iron clamps.
4. Wait approximately 20 minutes.
5. Glue the small elements that form the channels for the electronics with the wood glue.

Remarks: Do not hesitate to make several passes with a laser cutter to be sure that the wood has been cut properly.
The following pictures illustrates the major steps described above.

4.2 Cover Window

Estimated time for manufacture : 8 h
Materials: The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- Laser cutting machine [32]
- Iron clamp [33]

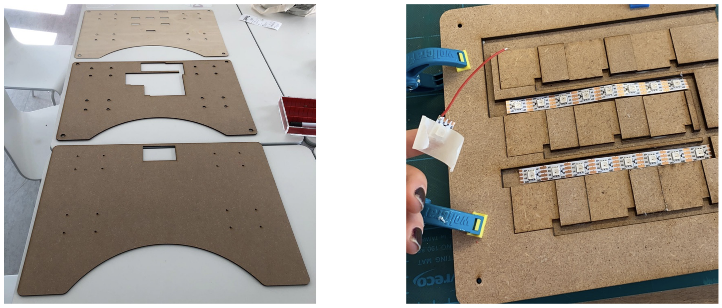

Figure 3: Illustration of the two major steps to make the board support

- Methylene chloride glue [35] and a syringe for the application
- heat bender machine

Steps to follow:

1. Load the dxf files (cover_window_PMMA_3mm.dxf and frame_window_PMMA_8mm.dxf) on the laser cutter and choose the appropriate parameters for 3 mm PMMA in the library for the cover window and 8 mm PMMA for the encapsulation. For the windows cover make engravings for the arrows as done on the dxf.
2. Clean the engraved area with pressurised air and finish the work with water and a soft sponge
3. Bend the edges of the cut sheet by heating the areas to be folded according to the illustration provided using the heat bender.
4. Glue with methylene chloride the encapsulation around the board, use a small syringe and tighten with clamps all along.
5. Wait approximately 10 minutes.

Remarks: Do not hesitate to do some tests beforehand to choose the depth of the arrows. Be careful not to scratch the window when working. The arrows engraved in the board should match the sensors of the controller. The following pictures illustrates the major steps described above.

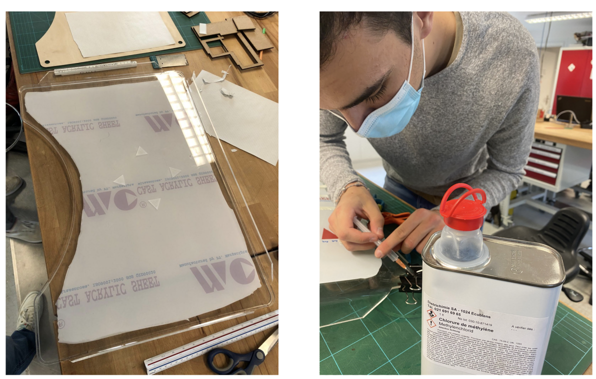

Figure 4: Illustration of two major steps to make the cover windows and encapsulation

4.3 Sensors

Estimated time for manufacture : 4 h
Materials : The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- Sticker machine [36]
- Adhesive vinyl film [37]

Steps to follow :

1. Insert the copper sheet in the cutting machine and draw 7 rectangles on the software sized by 40 x 50 mm.
2. remove the excess copper and keep only the sensors.
3. Stick transfer tape on the copper sensors.
4. Cut with scissors flush with the sensors (cut only the sides).
5. Glue the sensors on the top support (made of aviation plywood previously cut out as explained above) and fold the protruding strip to the other side. The wires will be soldered on this part.

Remarks: The procedure for cutting the sensors was based on this tutorial [5]. Do not remove the transfer immediately to protect the sensor during handling.
The following pictures illustrates the major steps described above.

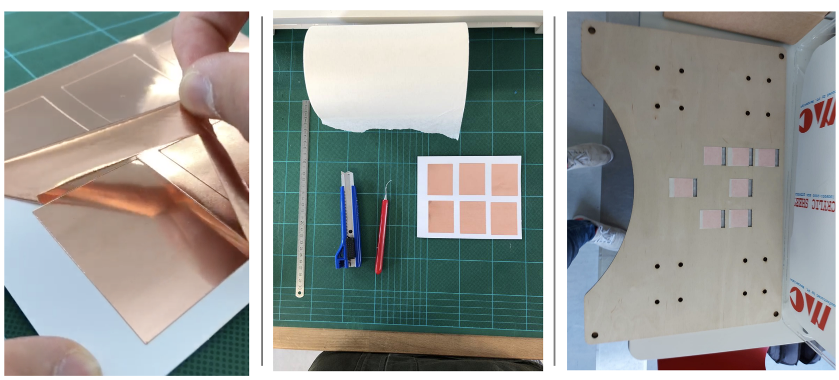

Figure 5: Illustration of three major steps to make the copper sensors

4.4 Electronics

Estimated time for manufacture : 18-20h
Materials : The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- Soldering iron

Steps to follow :

1. Veroboard

   1.1. Cut the veroboard in the right dimensions (cut the tracks with a cutter + bend the board and it should break where it is cut). Clean the copper tracks with acetone

   1.2. Scrape tracks as shown in the Figure 6 with a sharp tool.

   1.3. Solder all the stripped cables, using flat and sharp pliers to pull the cables along the veroboard.

   1.4. Solder the three resistors.

   1.5. Solder pin to fix the modules (MPR, arduino, bluetooth and buzzer). Be careful during soldering. The modules should be clipped on the pins to be well aligned and make possible to add or remove the modules afterwards.

   1.6. Solder the connectors for the sensors, power, LED, and RGB LED cables.

2. General

   2.1. Solder cables on the USB male connection (1 5V and 1 Gnd) and connect by soldering the 5V cable on the on/off module.

   2.2. Cut a USB mini cable and solder the cables to a USB female connection where the connectors are shown in Figure 16.

   2.3. Solder cables to both pins of the green LED.

   2.4. Cut the rgb LED strips three by three and solder the cable according to the length of the tracks on the support.

Remarks : When scraping the copper tracks, do it gently. Leaving some length to the wires can be useful. The following pictures illustrates the major steps described above.

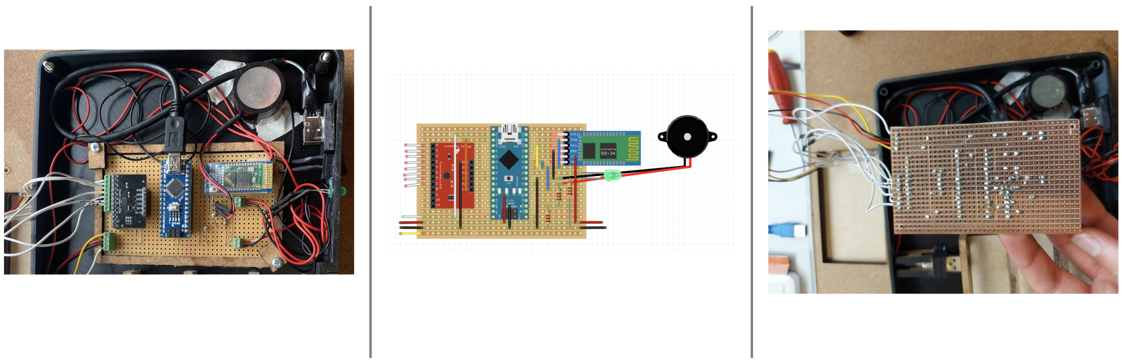

Figure 6: Illustration of the practical and theoretical veroboard with all the elements

4.5 Diverse

Estimated time for manufacture : 16 h
Materials : The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- 3D printer [38]
- Laser cutting machine [32]
- Araldite Adhesive glue [39]
- Strong glue contact [40]
- Polyethylene Terephthalate Glycol (PETG) Filament black [41]

Steps to follow :

1. Fixation wheelchair

   1.1. 3D print the four fixations, two safety rings and four tube caps, in accordance with the files in the folder named STL_3D_printing.

   1.2. Saw two steel bars to a length of 450 mm and glue (Araldite) the caps at the extremities.

2. Cushion

   2.1. Glue the two cushions together with extra strong contact adhesive.

   2.2. Insert the cushion on the previously formed cover windows and cut the edges of the cushion.

3. Electronic box

   3.1. 3D print the electronic box, according to the files from the folder named STL_3D_printing.

3.2. Glue the magnets (Araldite) at the places provided on the closing and on the box.

3.3. make rails to adjust the insertion of the power bank, make a bracket to lock the USB A male connection and a structure to block the veroboard.

3.4. Glue all this with Araldite on the plastic box.

Remarks: It is not necessary to print the fixation with supports when 3D printing. When gluing the two cushions together, be careful to align them. Care should be taken to ensure that the magnets are positioned to attract each other when gluing. Before gluing, make sure that the USB A and the power bank are aligned.
The following pictures illustrates the major steps described above.

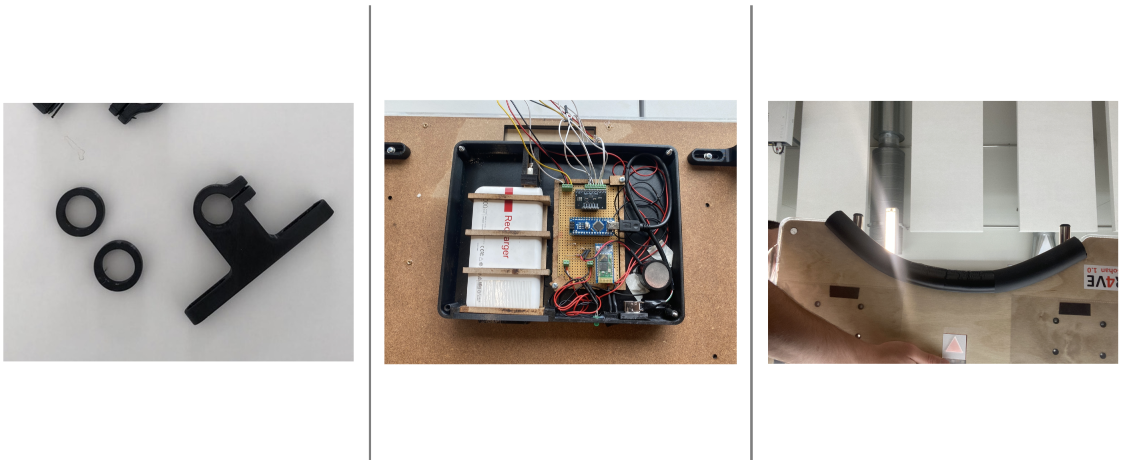

Figure 7: Illustration of three major steps to make diverse elements

4.6 Final Assembly

Estimated time for manufacture : 24 h
Materials : The materials needed are listed in the table in the Annex section.
Manufacturing machines and tools :

- Soldering iron
- Hot glue gun [42]
- Double-sided tape
- Araldite Adhesive glue [39]
- Linseed oil [43]

Steps to follow :

1. Solder the wires to each sensor (adapt the length of the wires) and tape them to the top support.
2. Stick the rgb LED to the base with double-sided tape and glue the wires with a hot glue gun.
3. Tape the top bracket to the bottom bracket using double-sided tape.
4. Paint the top and bottom of the board with linseed oil. Let it dry for at least one day.
5. In the electrical box, attach the electronic modules to the veroboard and insert the cables from each element into the connectors.
6. Fix the verobord on its support.

7. Screw the electronic box on the support below.
8. Screw the fixation on the support below.
9. Insert the steel bars into the fixings and adjust with the nut.
10. Insert the plugs at the end of the bar and glue the security ring near the fixation.
11. Remove the transfer on the sensors and put stickers indicating the function of each sensor.
12. Glue with Araldite the large magnets in the holes of the support and on the cover window.
13. Stick flat magnets on the pictogram map and on the base.
14. Close the device with the cover window.
15. Put the cushion in its place.

Remarks: Take some margin in the length of the wires for the sensors and LED. Be careful not to overflow with the glue when attaching the magnets to the base. The support may need to be sanded a little to fit the cover window.

4.7 Computing Part

Devices: The needed device is a tablet having bluetooth connection (Here using Windows as an OS)

Used software

- Grid 3: As mentioned above, it is very useful tool for implementing AAC methods [3].
- Arduino IDE: It is an easy to handle software for writing C codes and upload them easily on any arduino board [6].
- Python IDE: A recent version of python is used to process the MCU serial messages and control specific keys of the tablet keyboard.

Implementation logic and open access files: In this section there is two main parts, first is exposed the sensing logic behind choosing which sensor is activated and second is shown how to use python toolboxes for the aim of controlling Grid 3.

1. As shown in the Figure 17 in Annex and according to the user needs four different arrows are designed to be able to navigate through the Grid 3 matrix. A validation button (upper left) confirms the user choice on the grid. Taking into account that the user deploys only his left hand to point toward the passive pictograms, a priority (Table 1) table between the sensors is really helpful in order to have at each time only one sensor detected and spiking.

   To define if a sensor is activated and to advance on Grid 3 matrix, the detection is made considering a specific threshold (Table 1). In order to navigate easily, some considerations were made:

   - The activation time: This time is crucial to be chosen according to the user needs. In the default case, it is chosen to have 1 second of waiting time before detecting that a sensor is activated.
   - The scrolling time: For a better use of the tablet when spending more time on an arrow then the activation time. There will be periodic steps to be able to scroll all the Grid 3 matrix easily.
   - The time between steps in sweeping: This can be changed to have a different velocity in going from case to another on the tablet.

   The controller stops sending a command if the user stays more than 5 seconds on the same sensor. This avoids false manipulations if for example the user falls asleep with one hand on the sensor.
   In this part, there is a further more developed feature where the user can change those values when executing the python code. We can either chose to keep the default set values or change manually those values to have better user handling. A better user interface is needed to make changing those parameters easier.

2. The main advantage of using a python file is that it offers with its pyserial library a very intuitive way to read the serial messages sent by the arduino. Those received values are converted to simple keyboard inputs using pyautogui library. In here it's crucial to set up for the bluetooth connection the right COM port. That information can be found when opening the control panel and in devices you can find the properties of your peripheral device (HC-05). In Grid 3 it's crucial to assign to the different simulated keyboard keys a specific switch of the joystick mode.

Both the C files and its dependencies as well as the python file are given in the Github made for the project [7]

5 Conclusion

BR4VE have been a motivating and inspirational project. The human dimension present throughout the project drove us to achieve our best. We learned a lot in the development of user-centered devices. We are very happy that this device can be used to improve the user's daily life. With the help of this open access report, we hope that this project will continue to be improved or even developed for other users with similar motor abilities as our user. We plan to continue this project with our user. Following his feedback, we will be able to adapt new features and offer him an improved version this summer. Through the whole device development, each member of the team has contributed to the realisation of the project and learned a lot. The realisation of the project allowed us to gain new skills in a large variety of disciplines, as soldering, 3D printing, mechanical assembly, coding, testing, CAD design and graphical design. As said before, this particular project has given us a great human dimension and we have learned a lot from it. We also had to manage our group organisation which went very well. We are very optimistic with our project because we have already seen the user validate the prototypes made before this device.
We insist on making a special mention of SKIL that made the project possible. To conclude we would like to address a huge "Thank you" to all the people who have been involved in the BR4VE project from near or far. They gave us motivational support, advices and pushed us to give the best of ourselves.

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6 Annex

6.1 Figures and Images

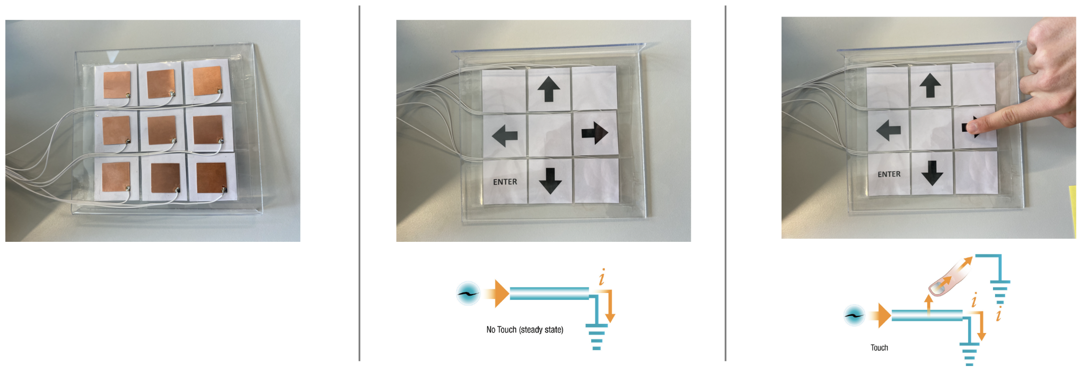


Figure 8: Diagram and illustration of the capacitive sensing system that we have prototyped [1]

Figure 9: The current Low tech board of the user

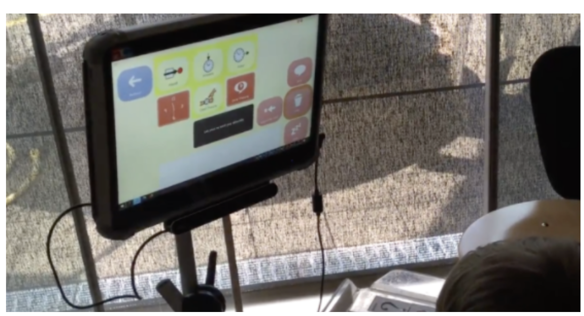


Figure 10: Example of Grid3 software used on a tablet [3]

Categories	Target	Reality
Controller Area	< 300 x 300 mm	200 x 200 mm
Weight	< 5 kg	3.6 kg
Powering	5 V	5 V
Entire size	< 700 x 450 x 100 mm	630 x 440 x 80 mm
Sensor size	< 40 x 50 mm (more sensitive)	40 x 40 mm

Figure 11: Quantitative requirement table

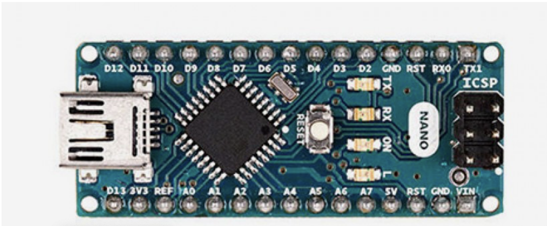
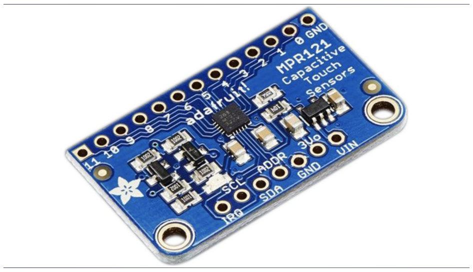
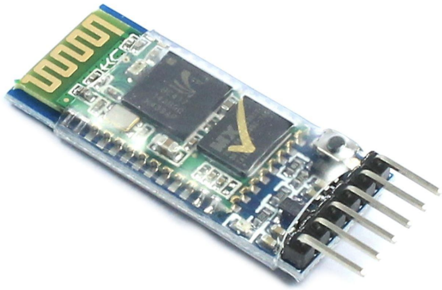


Figure 12: Arduino Nano [10]



(a) MPR121 capacitive control module, Adafruit [8]



(b) Bluetooth module HC-05-4, Arduino [11]

Figure 13: Complementary modules

Figure 14: LED WS2813 [12]

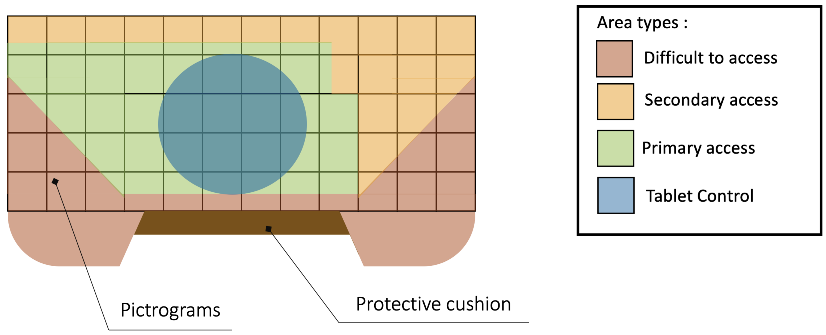


Figure 15: Top view of the board with the different area access levels

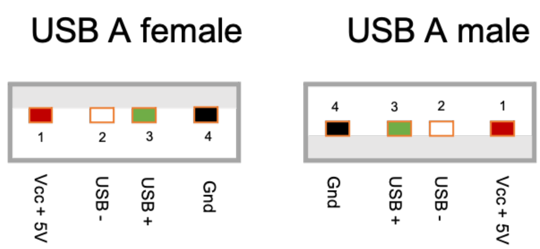


Figure 16: USB A female and male pin identification adapted from [4]

6.2 Computations

Device autonomy :
To compute the current consumption in the electronic system some assumptions are needed. Fist we know that no more than 3 rgb LED will turned ON at the same time. As each color in the rgb LED have a consumption of 18 mA. So the global consumption for one LED can be approximated as 60 mA. So for the approximation made, the consumption for 3 LED is 180 mA. For the micro-controller part, according to the datasheet its current consumption is lower than 20 mA. If we now assume that the user will turn on the device for 5h per day, we arrive to 1 Ah. As the power bank placed in the device have a capacity of 5Ah this means that the device can be used 5 days without being charged.
Processing :

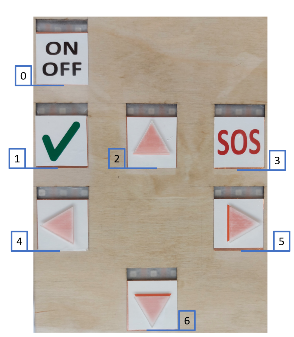


Figure 17: The disposition of the capacitive sensors

Sensors	0	1	2	3	4	5	6
Priority	rank 1	rank 5	rank 4	rank 2	rank 6	rank 3	rank 7
Threshold	4	3	3	2	2	2	4

Table 1: Table of the priorities assignments from highest priority to the lowest priority and thresholds values for each sensor (Relative values).

6.3 Budget

The total manufacturing cost of the device is about 320 CHFs. The estimated price of the device has been separated into four categories, see Figure 18. The biggest one is the board manufacturing part. This consists of the purchase of materials to make the board support as well as the cover windows, the cushion and the 3d printed box for the electronics. The second category requiring about a third of the budget is the electronics. In fact, adding sensing and feedback to the current board requires additional components such as a microcontroller, LED and other modules as described above. The copper electrodes represent only a small part of the budget. We have added a margin considered as "other" for components like glue, tape and any other non-categorize purchase. Our estimates are based on the orders we already had to place for the manufacturing of the prototype as well as the prices of big classic suppliers like *Distrelec* or *Reichelt*.
It should be noted that this budget is not entirely accurate because the purchases made for the prototypes were made through makerspaces located at the EPFL campus. We therefore cannot guarantee the accuracy of the prices if it were to be manufactured in another workspace.

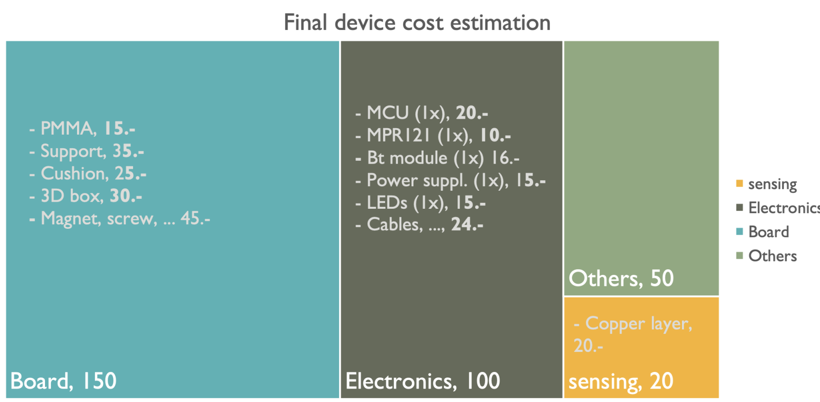


Figure 18: Detailed cost estimation for the final device

Material	Usage	Supplier	Thickness	Area	Remark	Price [CHF]
			SUPPORT LAYER			
MDF plate	Bottom support	[21]	4 mm	600 mm x 900 mm	could be found in professional work spaces	9
MDF plate	Middle support	[21]	4 mm	600 mm x 900 mm	”	9
Aviation plywood	Top support	[22]	1 mm	600 mm x 900 mm	”	12
			COVER WINDOW			
PMMA plate	Cover window	[23]	3 mm	600 mm x 900 mm	”	9
PMMA plate	Encapsulation	[24]	8 mm	600 mm x 500 mm	”	5
			CAPACITIVE SENSOR			
Copper foil	sensors	[14]	0.2 mm	A4	-	20
			ELECTRONIC			
Arduino Nano	Controller	[10]	-	-	-	20
Module bluetooth HC-05-4	Tablet-board connection	[11]	-	-	-	16
Module MPR121	Sensor signal filtration	[8]	-	-	-	10
green LED	indicator lamp	[26]	-	-	-	1
On/Off button	turn the device on and off	[27]	-	-	-	1
Connecteur USB, USB-A Fiche mâle	connection between the power bank and electronics	[16]	-	-	-	1
Connecteur USB, USB-A 2.0 Prise femelle	input to flash code	[15]	-	-	-	1
Power Bank	system powering	[9]	-	-	-	15
Veroboard	electronic connection	[19]	-	30 x 20 pin	-	4
Buzzer	sound feedback	[13]	-	-	-	3
1 resistance of 2 kOhm, 1 of 1 kOhm and 1 of 200 Ohm	electronics	-	-	-	-	1
Intallation wire stripped	connection on the veroboard	-	-	-	-	1
			DIVERSE			
Installation wire	Global wiring	[25]	-	-	-	3
rgb LED strips WS2813	visual feedback	[12]	-	-	-	12
16 screws M3	hold fixings and electric box	[28]	-	-	-	4
8 magnetic discs	support and cover window closure	[29]	2 mm	d = 12 mm	-	8
Magnetic adhesive tape	ahesion plastic map to board	[30]	-	-	-	5
4 Cubic magnets	closing electronic box	[31]	4 mm	4 mm x 4 mm	-	3
Cushion	user confort	[20]	-	-	-	25

Table 2: Tables grouping all the materials present in the device, with their respective usage and sizes.