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優勝作品專輯

作品編號 **100028**

參展科別 **工程學**

作品名稱 **Using EEG Neuro-Feedback technology to control a prosthetic hand**

得獎獎項 **大會獎：二等獎**

國　　家 **South Africa**

就讀學校 **Hoerskool Schweizer-Reneke**

作者姓名 **Farida Cajee**

作者照片

Introduction

Unaffordable healthcare and excessive plastic waste are both alarming issues that are plaguing modern society. Recent studies conducted by the World Health Organisation (WHO) report that about 15% of the world's population suffer from a form of disability, of which 50% of the demographic cannot afford adequate health care. Furthermore, 8 million metric tons of plastic annually enter our oceans (apart from the 150 metric tons that currently circulate our oceans!). In conjunction to the global plastic pollution crisis, unnecessary invasive surgery is currently being done on amputees. Many of these desperate patients are forced to pay exorbitant prices in order to live a normal life with bionic prosthetics.

The solution… Project Limbs - an EEG, 3D printed prosthetic printed from recycled plastic. Signal processors will be implemented to build an affordable and easy-to-use ‘mind controlled prosthetic hand’, that requires no invasive surgery.

The Increased Need of an Innovative Solution

Due to various political, socio-economic, scientific, and demographical reasons, the overall rates of amputees and limb dysfunction patients are increasing. There are over 10 million amputees worldwide, out of which 30% are arm amputees. Although prosthetic limbs exist since decades, they are not very natural in terms of operation and interaction with the environment. They require undergoing an invasive surgical procedure. The main goal of such complex procedures is to reassign nerves and allow amputees to control their prosthetic devices by merely thinking about the action they want to perform.

Advantages of 3D Printing in Prosthetics

3D printed prosthetics can greatly benefit children. The average lifespan of a prosthetic is five years, but in that time a child grows so rapidly that they will need a new prosthetic much more frequently. 3D printed prosthetics can also be made much quicker; a limb can be made in a day. Furthermore, consumers can easily customise their purchases, which is another enticing factor for kids. Children can pick out colours and styles to fit their wants and needs. 3D printed prosthetics use materials such as acrylonitrile butadiene styrene (ABS) plastics or forms of stronger material like bridge nylon. 3D printers are becoming compatible with other materials like lightweight titanium to increase durability and strength.

Both medicine and prosthetics have much to gain from 3D printing, however the success that 3D printing has among individuals (rather than institutions) reflects an intense change of traditional healthcare sectors. Due to the introduction of these new techniques and a collective approach to the creation of self produced prosthesis, costs have been reduced and 3D printing is proving to be an efficient solution to substitute old or faulty prostheses as well as creating new prosthetics for growing children.

This approach is thought to have been successful because of its wider scope, considering the regular and numerous prostheses that a disabled person needs to use and change between during their entire life. For example, an adult would typically need 15-20 prostheses over a lifetime, whereas a 10-year-old child would need 25 artificial limbs. The rates in which prostheses need changing also varies according to growth. A child, from 4 to 16 years old, grows up 5-7 cm per year consequently, his/her prostheses should be renewed every 6-12 months as opposed to 3-5 years for an adult.

A modern prosthesis is quite complex, typically consisting of three basic components: the socket, serving as an interface between the limb and the prosthesis, the modular section, that has the same length of the amputated limb and can include an articulation, and eventually the artificial foot/hand.

Repairing a damaged prosthetic limb may cost more than buying a new one. This may force the user to live with a malfunctioning prosthesis or to adopt an unconventional solution that could affect its calibration, causing collateral damage. 3D printing could be very useful, as it encourages the creation of singular parts at a lower price (though, only if all the plastic materials are available).

3D printing consists of the creation of a three-dimensional objects. Known as additive manufacturing, a 3D printer deposits a binder material layer by layer from a digital model. The materials used for 3D printing are various, but the most common are natural, synthetic and plastic fibres, metal, cement and glass. 3D bio-printing uses a similar process, but its aim is to create cell patterns preserving their functionality to create tissues and organs. In the future 3D bio-printing will radically change the way we perceive prostheses, but currently it is still under development and is restricted to the creation of simple and small organs.

Consequently, this research pays more attention to 3D printing and on the changes provoked by its implementation - not only in more developed countries, but also those with fewer resources.

3D printing was initially limited to the research and experimentation field, due to the large expenses required to build and maintain equipment. Today however, printing is increasingly available for the general public thanks to the spread of new portable and simple models, characterised by open-source designs (made to be easier to reproduce with no need to buy specific patents or production rights). Many enthusiasts have supported projects based on free software and hardware that allowed the creation of open-source printers, which are covered by liberal patents such as GNU Public Licence, whose aim is to keep these products free and accessible to everyone in the future. Therefore, the 3D printer market has been enriched by the presence of different and often cheaper models, including those that are customisable, or can be bought as assembled items, according to creativity or need. Some of these printers (RepRap and Ultimaker) are self-replicating, which means that their main components can be infinitely 3D printed.

Electroencephalogram “Mind-Control” Technology

An electroencephalogram (EEG) is a test that detects electrical activity in your brain using small, metal discs (electrodes) attached to your scalp. Your brain cells communicate via electrical impulses and are active all the time, even when you're asleep. This activity shows up as wavy lines on an EEG recording. An EEG can determine changes in brain activity that might be useful in diagnosing brain disorders, especially epilepsy or another seizure disorder.

Mind-controlled technology uses a brain-computer interface to establish a pathway of communication between the user’s brain and an external device. It has the potential to augment or even repair patients’ damaged hearing, sight, or movement. EEG sensors have been incorporated into gaming systems that enable a player to control what happens onscreen with a headset, EEG-controlled exoskeletons translate users’ brain signals into movements, and implanted electrodes enable patients to control bionic limbs.

Arduino Technology

Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control both physically and digitally.

Problem

Unaffordable healthcare, unnecessary surgeries and excessive plastic abundance are problems that are prominent in modern society. Despite increased demand, the cost of an "under-elbow" prosthetic is about R140 000, which is rather inaccessible to most. There is a global plague of pollutant plastic, and there is a great need for this plastic to be repurposed into something meaningful and useful.

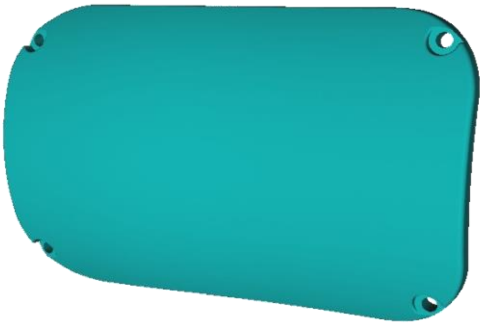
Aim

To develop an effective, affordable and versatile human-like prosthetic arm. This proposed arm will be 3D-printed using recycled plastic bottles so as to be environmentally friendly. The final prototype will also eliminate the need of invasive surgeries.

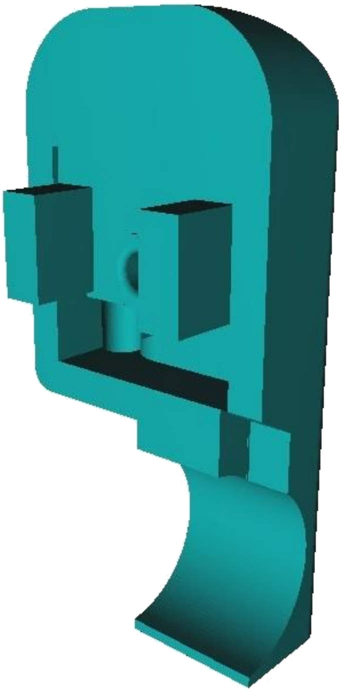
Engineering Goals

To 3D-print a human-like prosthetic from recycled plastic bottles that is controllable via brain activity using EEG neuro-feedback technology. Furthermore, the design is to be environmentally friendly (made from recyclable materials) and be affordable than what is currently available on the market.

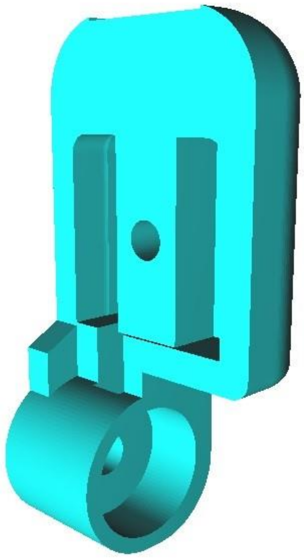
3D Concepts Created by Farida Cajee (Using Autodesk Fusion 360)



Arm Door

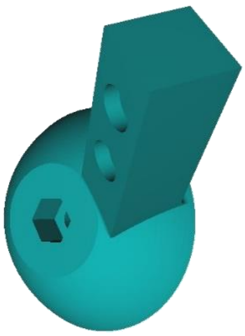


Fingertip Upper



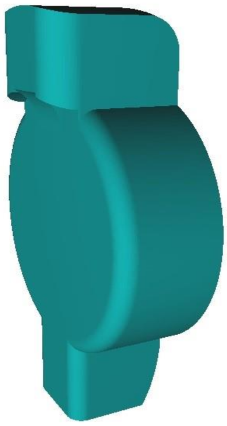
Fingertip Lower

Ball Mount A

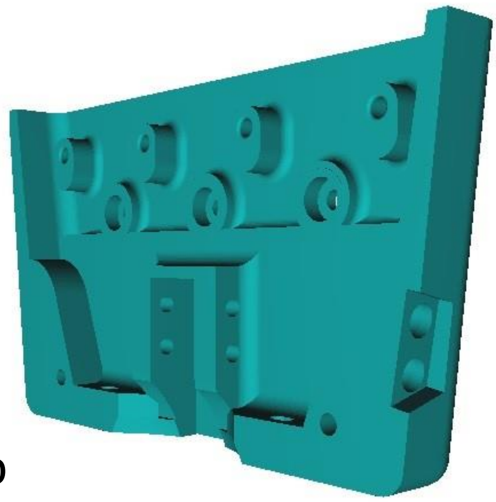


Ball Mount B

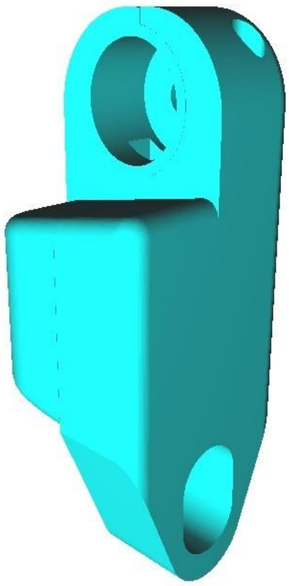
Forearm



Index Ring Cap

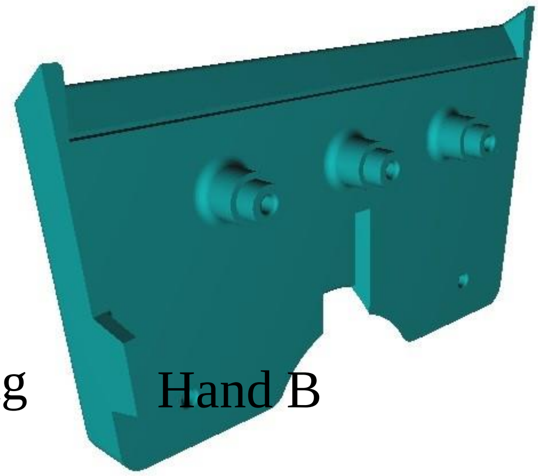


Hand A

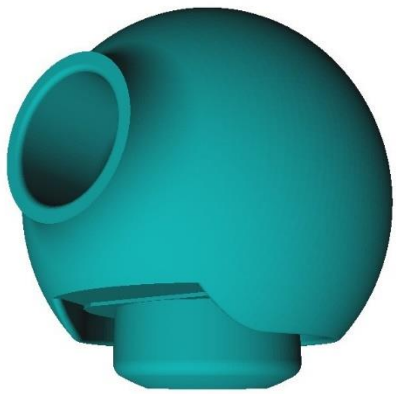


Indexing Joint

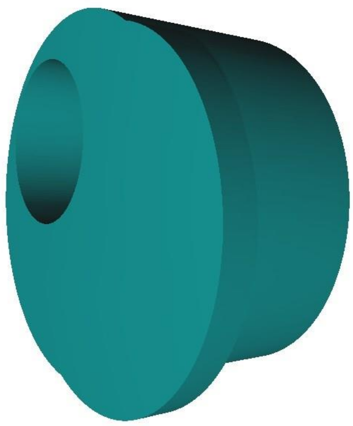
Index Ring



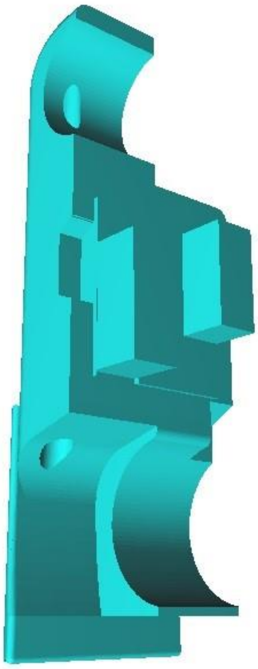
Hand B



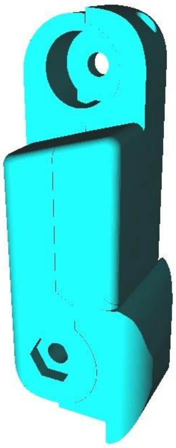
Knob



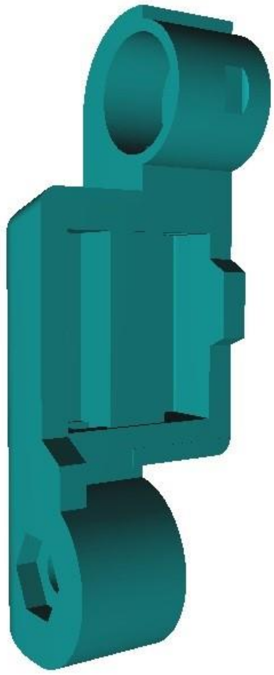
Index Finger Support



Lower Finger Dual Extrusion B

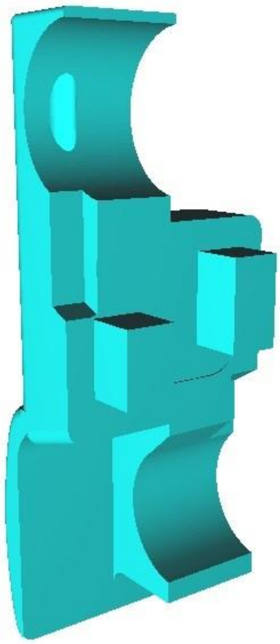


Lower Finger

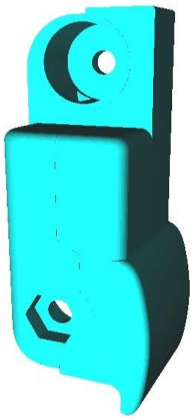


Lower Finger Dual Extrusion A

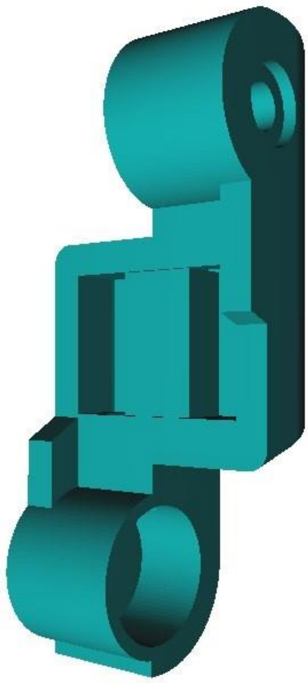
Lower Ring



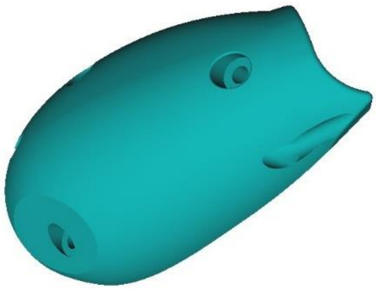
Middle Finger Dual Extrusion A



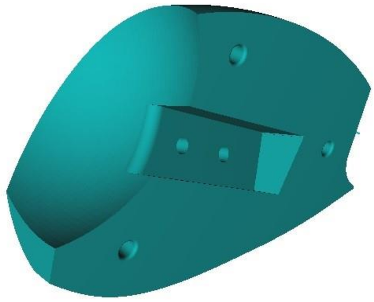
Middle Finger



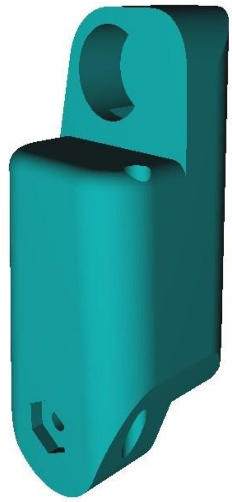
Middle Finger Dual Extrusion B



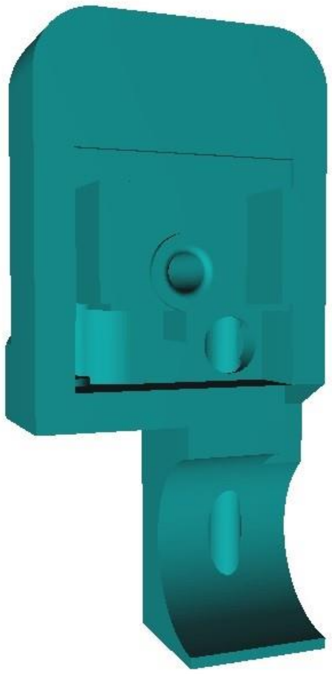
Thumb A



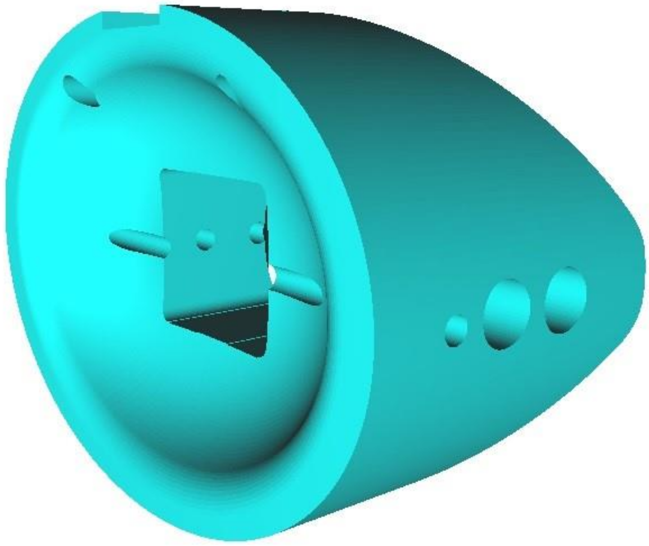
Thumb B



Thumb Mid



Thumb Tip



Wrist Insert

The Plastic Recycling Process

A ProtoCycler is a machine which allows the user to turn waste plastic into 3D filament.

How A Protocycler Works

The grinder shreds waste plastic.

Shredded material is fed into the top to create recycled filament.

MixFlow technology delivers extrusion with quality

Active diameter feedback ensures high precision filament

Filament is automatically spooled (wound) and ready to use

(image of ProtoCycler used, taken by Farida Cajee)

The Protocycler was used to create recycled filament which was used to print prototype 1,2 & 3. A total of 165 PET bottles were collected and fed into a *ProtoCycler* to create the filament.

Prototype 1

Proof of concept

Assembling 3D printed pieces

Materials:

- 3D printed hand (original design)
- 3 rubber/elastic bands
- 2m of gut line
- Super glue
- Bead clamps (available at craft store)
- Tools: pliers, knife, screw drivers, scissors
- 1 pack of 2mm diameter nut & bolts

Assembling procedure:

First assemble the 3D printed parts in the form of a three fingered hand, secure each part with a nut and bolt. From the top of the hand to each finger gut will be threaded through, each line of gut will differ in length just keep in mind that it will later be threaded around a servo arm. Over each gut from joint to tip elastic bands must be threaded and glued in place but still allow movement in all three fingers.

Control system of prototype 1:

Materials:

- EEG headset
- 3 servos
- Motor
- Bluetooth transmitter
- Joystick

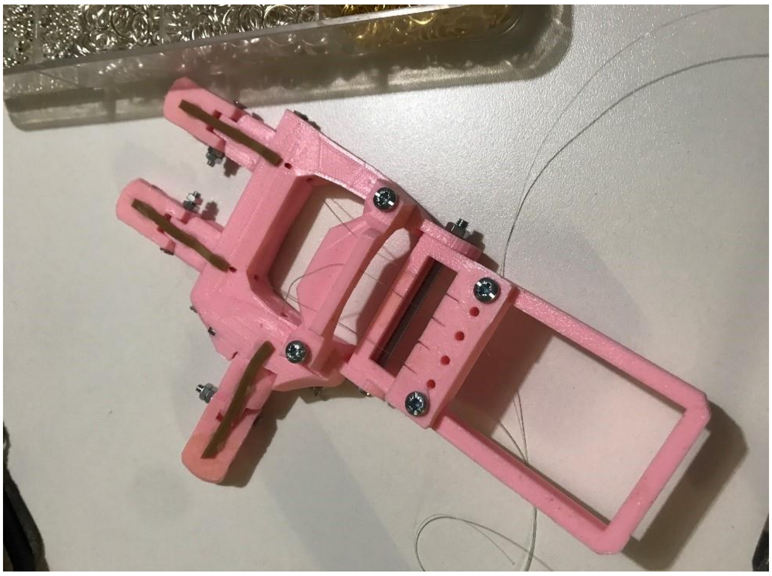
Procedure:

Once again, the electroencephalogram headset, control panel, joystick and transmitter all come built already. Coding system used this time is the Bluetooth transmitter. Linking the headset joystick and servos to the Bluetooth transmitter allows movement via brainwave and joystick functions.

Procedure for assembly:

The forearm has a big enough opening for all the servos and motor to be glued down. Switch on everything and connect to one Bluetooth signal via the transmitter, when you move the joystick the hand should move as well.

Design



Simple 3D printed design used to test the theory.

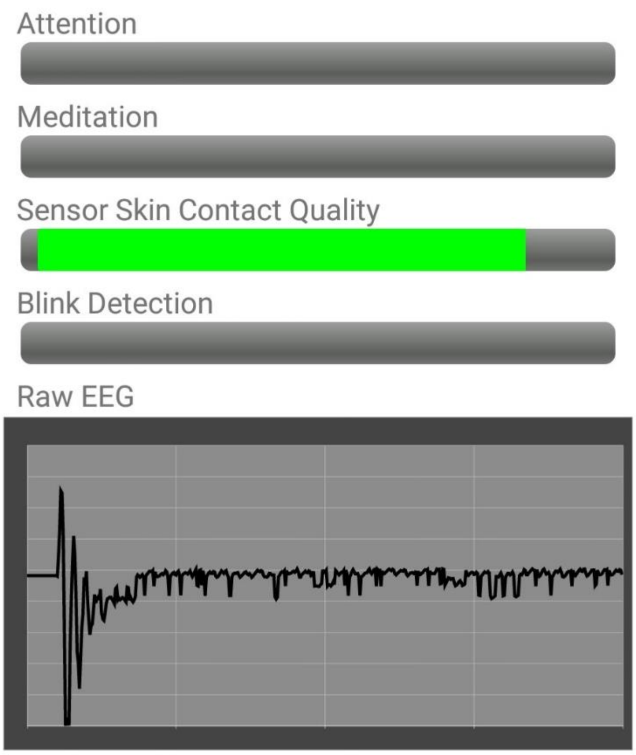
3 fingers with one joint and wires running along each finger to servo.

(picture by Farida Cajee)

Bluetooth joystick used to control Prototype 1

(Picture by Farida Cajee)

Testing prototype 1



Signal is detected.

Movement is at little to none.

Prototype 2

Assembling 3D printed pieces

Materials:

- 3D printed hand (original design)
- 3 rubber/elastic bands
- 2m of gut line
- Super glue
- Bead clamps (available at craft store)
- Tools: pliers, knife, screw drivers, scissors
- 1 pack of 2mm diameter nut & bolts

Assembling procedure:

First lay out the 3D pieces in the form of a 3 fingered hand, secure each part with a nut and bolt, from the top of the hand to each finger gut will be threaded through, each line of gut will differ in length just keep in mind that it will later be threaded around a servo arm. Over each gut from joint to tip elastic bands must be threaded and glued in place but still allow movement in all three fingers.

Controlling the hand

Materials:

- EEG headset
- Bluetooth transmitter
- Coding software
- 3 servos
- Motor

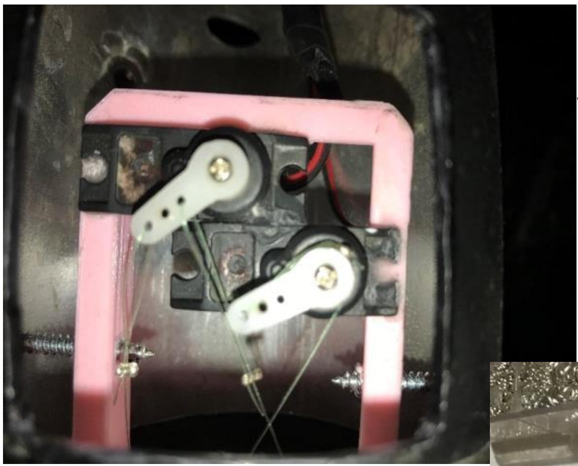
Procedure:

The gut line threaded earlier should wrap around each servo (1 strand per servo) all three servos run off a power source in this case the motor & batteries. Assembly of the motor to servos should be done by following package instructions. The headset is already coded and ready when removed from its box, so every coding that takes place should be done to suit the headset. Coding software can be downloaded from the Nuerosky website and each finger should be coded to grip when concentrating and loosen when relaxing. When the EEG and software in linked on the same signal as the transmitter it gives power to the hand and brainwaves will be detected thus causing the movement of the hand. When you concentrate the hand grabs, when you relax it will loosen. This is similar to the coding used in joystick drones. Concentration = up, whilst Relaxation = down

Finally, secure the servos into the forearm using glue. To make the project more presentable for judging add a board and piping as the arm.

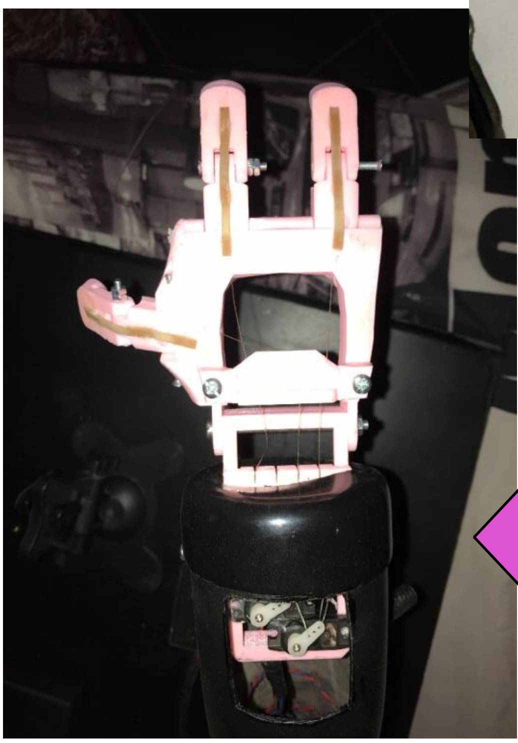
Design

Edited by Farida Cajee



Servo bed with final wiring

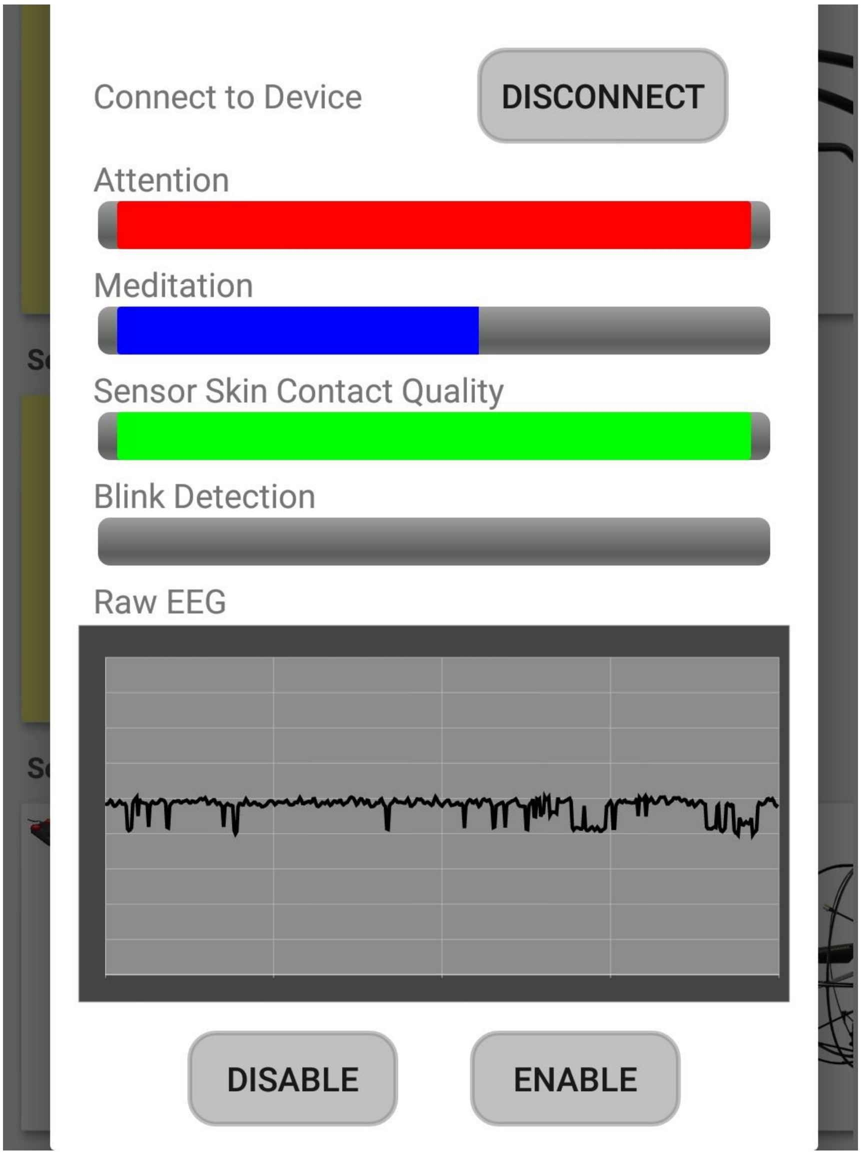
3D printed hand used for prototype 1 & 2.



Final model of the working prosthetic

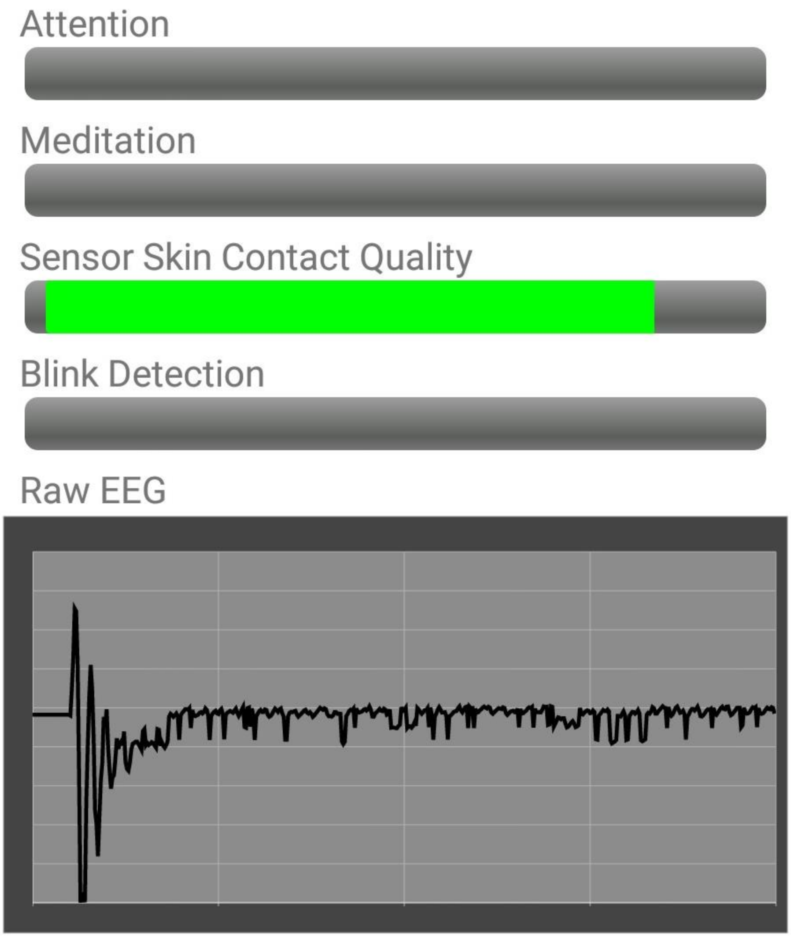
Testing prototype 2

Test 1: immediately after putting on EEG



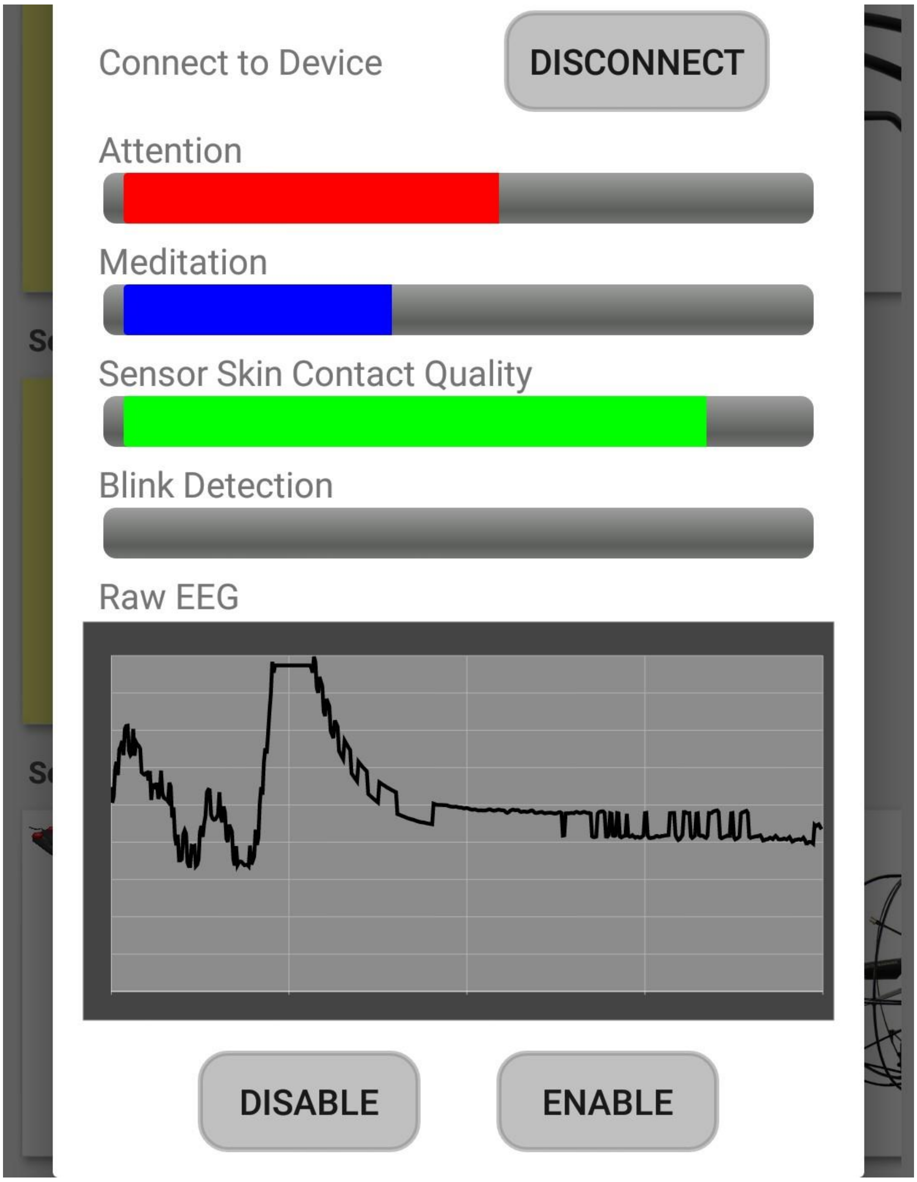
In the above one can see that the sensors are ready to detect brainwaves and are 100% functional.

Test 2: first test 30 minutes after waking up.



In the above movement is VERY strong and brainwaves are harvested extremely well.

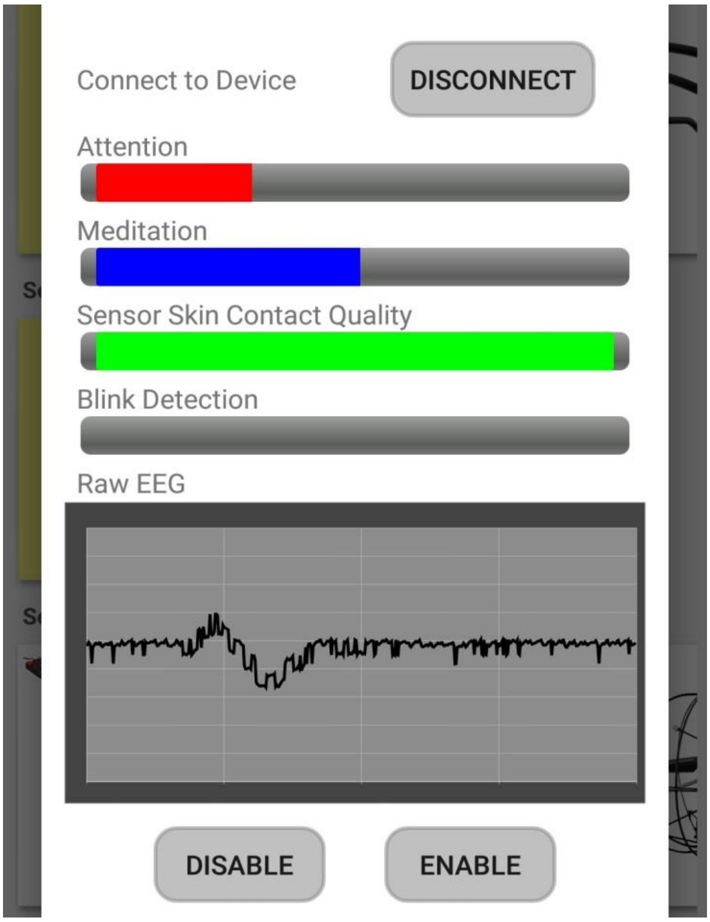
Test 3: taken at 5pm



In this the test subject is seen to be less interested but the brainwaves are still strong enough to create movement.

Test 4: 12am

!



Here we see the test subject meditating/sleepy, but the brainwaves are still detected and still promote movement.

Analysis of Results *Prototype 1&2:*

Prototype 1 was a ‘proof of concept’.

- showed little to no movement and did not work as predicted.
- The joystick had to be removed in the later improved prototypes.

Prototype 2 showed great improvement.

The components used in prototype 2 have shown great results. The battery life of the system is short and needs recharging every 4 hours. Prototype 2 cannot lift objects due to the amount of fingers and also the small servos and lack of torsion springs.

Final Prototype

Procedure for the Mechanical Unit

Materials:

- 3D-printed arm/hand (original design)
- 1 pack 2x25mm screws
- 1 pack 4x40mm screws
- 1 pack 3x9mm screws
- 1 pack 3,5x25mm screws
- 1 pack 3x25mm screws
- 1 roll of tiger tail string

1. The 3D printed pieces were laid out in the form of a left hand.
2. The screws were matched to visible holes.
3. Each piece was secured with the required screw.
4. The holes running from the top to bottom of hand were located, ie. where the guitar wire fitted in.
5. Four pieces of guitar string were measured and cut to fit along each finger besides the thumb.
6. The guitar string was threaded through each finger except the thumb.
7. The ends of the string were later tied onto servos

Interface unit

Materials:

- 1 x Arduino UNO R3 OEM
- 1 x USB cable
- 1 x breadboard
- 1 x IR receiver
- 1 x temperature sensor
- 2 x servo
- 1 x 9v battery + connector
- 1 x USB bluetooth receiver

Procedure:

1. Connect servos to Arduino UNO R3 OEM.
2. Connect interface unit to a laptop.
3. Code the interface using C++ language.
4. Testing unit to see if servos correspond to input.
5. Servos are placed in forearm and connected to corresponding wires in each finger.
6. Servos tested again to see if there is still movement.
7. Pairing EEG headset to bluetooth receiver on interface unit.
8. Testing to see if arm moves using EEG signals.

Design Specifications

A: forearm, 30cm. Long enough for component storage.

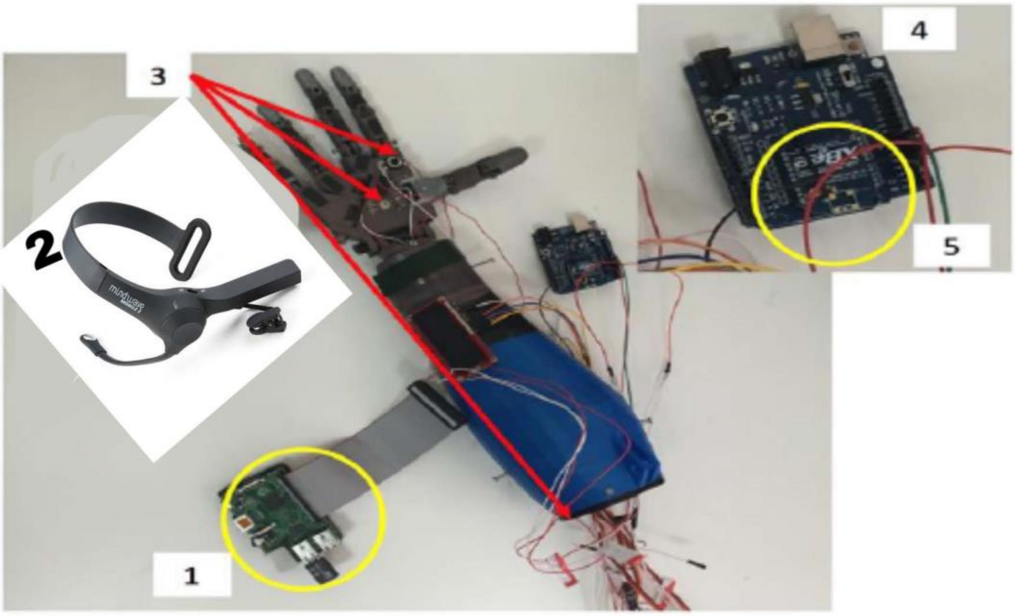
B: fingers' width, 10cm.

To ensure easy

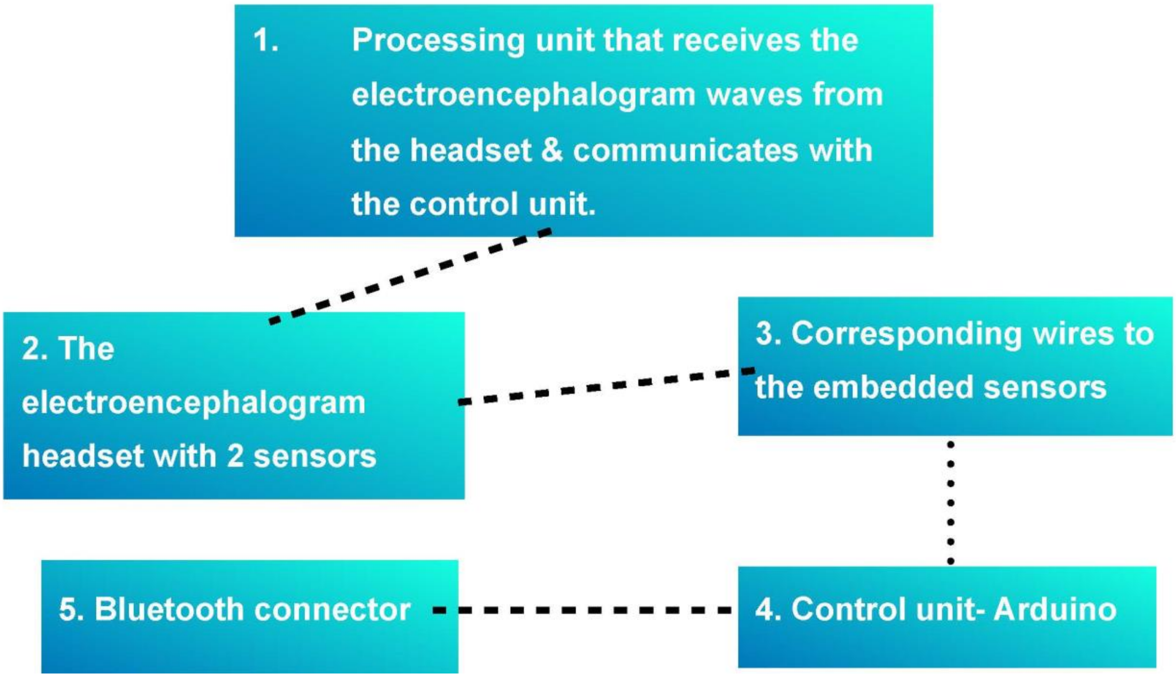
grip ability fingers had to be thick.

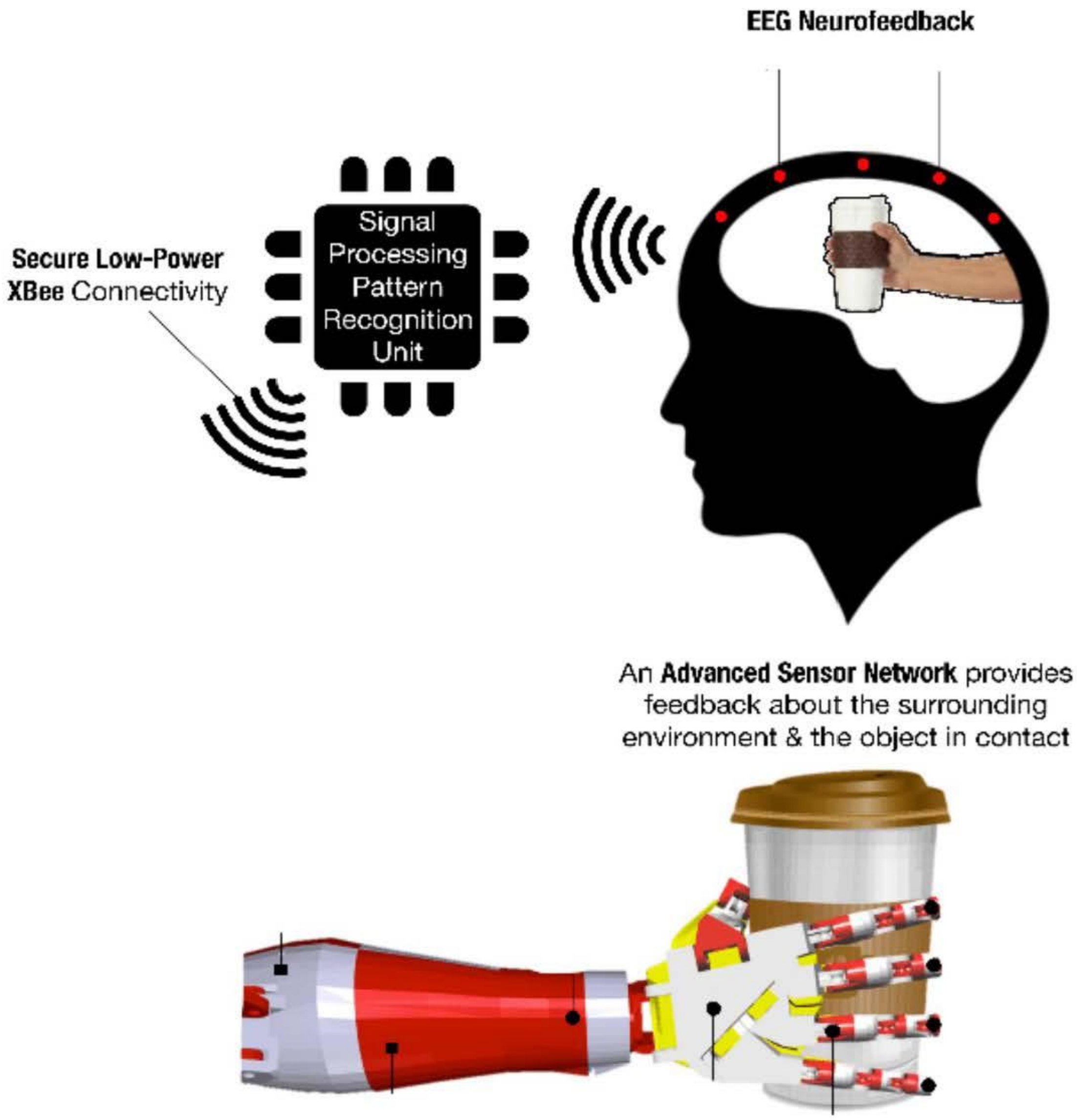
C: hand, 14cm. Efficient grip and easy lifting ability. 3D printed prosthetic

Photo and edits by Farida Cajee



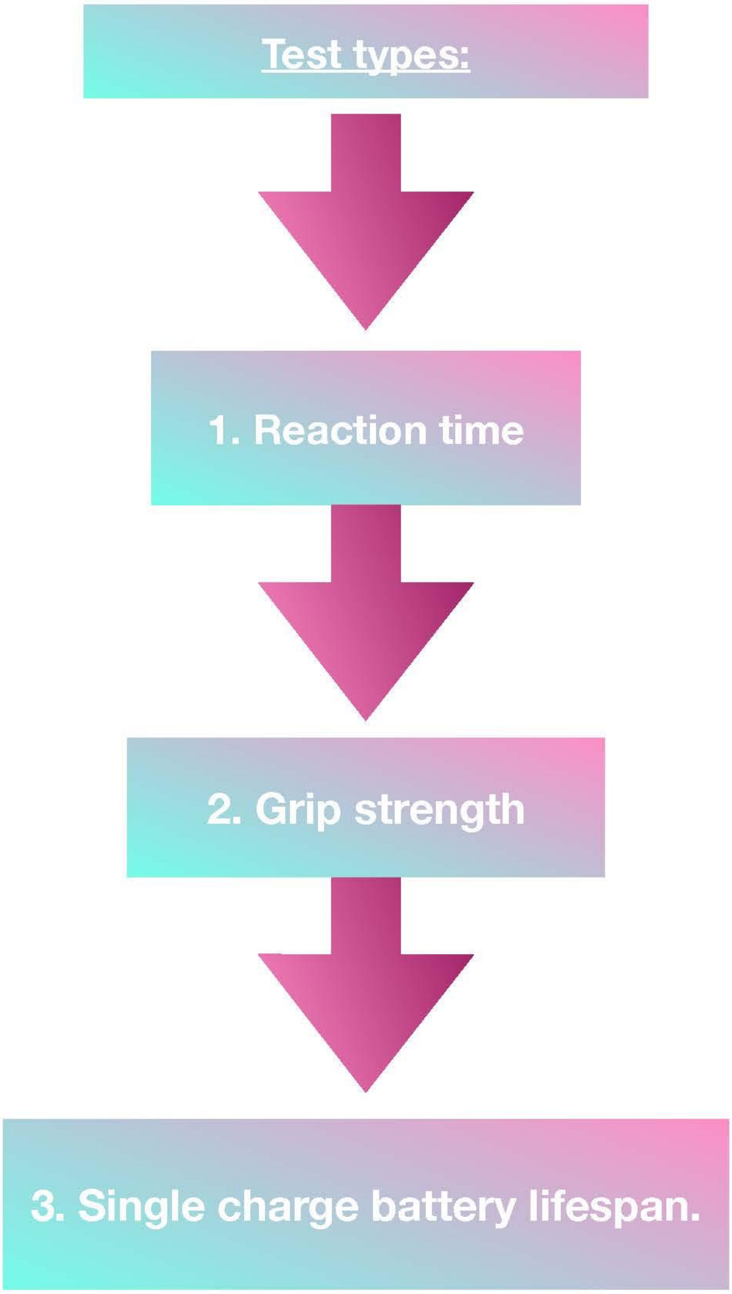
(Design and edit by Farida Cajee)





Edited by Farida Cajee

Testing: Final prototype



Test 1: Reaction time

Testing the reaction time between the EEG and Prosthetic. Test is repeated at different times of the day over 5 days for accurate results.

Use a stopwatch to measure time from the minute concentration begins until first movement made by prosthetic.

Table Showing Results from Test 1 – the reaction time of the prosthetic

Alertness level	Time (s)
High	3
Moderate	4,7
Low	9

Test 2: grip strength

Using a PVC pipe with rope attached to the end. Hand will be placed in an elevated position while holding PVC pipe, incrementally different sized weights will be attached to pipe to test grip strength. The grip strength is controlled by adding more bolts to avoid super tight grip.

Table Showing Results from Test 2 – the grip strength of the system

Weight (KG)	Able to lift
1	Yes
2	Yes
3	Yes
4	Yes
5	Yes
6	Yes

Usage level	Single charge lifespan (h)
Low	13
Moderate	9
Heavy	5

Test 3: battery life

A new battery is inserted into the headset and hand is fully charged. Test is timed on three usage conditions: low, moderate and heavy.

Table showing results from Test 3- Battery Life

Discussion and interpretation of results

Prototype 1 & 2:

Prototype one was used as a proof of concept, the electroencephalogram was tested to see if it could successfully measure brainwaves & concentration levels.

Prototype 2 showed great results but battery life and quality was poor. Only 30 (estimated) PET bottles were used to print the hand used. Grip was little to none as only 3 fingers are present. Only picks up reliable signals when fully charged and when subject is very alert.

Final prototype:

An estimate of 135 PET bottles were used to print the prototype. Grip strength is perfect for household activities e.g. pouring a drink, the reaction time has improved to 5 seconds minimum and battery life has improved to 13 hours on low usage.

Errors and limitations

All of the three prototypes were printed using recycled plastic. Although this is great for the environment, this recycled material does not allow for the prototypes to be the best quality. The battery life of the hand and headset decrease rapidly when heavily used, a bigger battery could solve the problem but the space to store all components is compromised.

The hand does not have a realistic look and this could draw a lot of attention.

Thee hand cannot lift more than 6kg, but most daily/household activities can be carried out using ProjectLimbs.

Conclusion

The Project Limbs project was a resounding success. Not only was the final prototype affordable, it implements state-of-the-art technologies, communicating protocols, control systems and human interfacing. By using PET bottles in the production of the hand, plastic pollution in my area was reduced. The use of recyclable material is a great way of reducing a global carbon footprint – the concept of converting what was considered 'trash' into something that can change a person's life is absolutely astounding.

Compared to other 'below elbow prosthetics', the final prototype costs *R131 000 less* than an ordinary bionic arm in South Africa. Another benefit of Project Limbs is that it removes the need for any costly invasive surgical procedures.

Overall, Project Limbs was holistically successful in utilising PET bottles into creating an affordable and effective "below-elbow" prosthetic that could change the lives of many people around the world. Project Limbs allows for what was once thought to be trash, morph into something that can forever improve the life of someone.

Future research

The project requires several improvements – such as creating a more realistic, skin-like appearance and feel to the outside, getting each finger to move individually and increasing the grip strength. More research will help to improve this project and upgrade it to its fullest potential.

Costing

3D printed hand:	R5500
Arduino mega kit:	R1200
EEG headset:	R1000
Extras:	R1300
GRAND TOTAL:	**R9000**

Market competitor pricing in South Africa is upwards of R140 000!

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The project involves detailed mind controlled prosthetic hand. One additional advantage is to use waste plastic material as raw material by proper recycling. 3D printing technology has also been cleverly adopted.