Bionic Robotic Hand Controlled by Myo-electric signals

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Dedication

" I dedicate this work to my family. A special thank to my loving parents, Ferrooudja and Hamid Douki,who brought me endless support and encouragement throughout my academic journey. My little brother Idir who has never left my side and never failed to encourage me.

I thank my friends for their support especially Sarah who was with me from the beginning ."

Thiziri.

" I would like to dedicate this work to my beloved parents especially my father, a strong and gentle soul who taught me to trust Allah and believe in hard work.

I would like also to thank my friends Moussa, Nazim, Brahim and all DIKI Members who helped me and supported me along all the way."

Ayoub.

Acknowledgement

First and Foremost, praise is to ALLAH, the Almighty, the greatest of all, on whom ultimately, we depend for sustenance and guidance. Special appreciation and gratitude goes to our supervisor, **Dr.B. Metidji** for his supervision and constant support. His invaluable help of constructive comments and suggestions throughout the experimental and thesis works have contributed to the success of this research. Furthermore, we would like to highlight our gratitude to all our teachers of the institute for their work and their support during these past five years.

We are highly indebted to Wameedh Scientific Club for providing us with the material and help when needed.

We thank our colleagues and people whose assistance and contributions are greatly acknowledged.

Abstract

Several designs and products are currently available online as complicated limbs and hands for amputees, however many of these can be costly and heavy. This project has taken inspiration from these designs with the goal of reducing cost and weight without sacrificing functionality. One major advantage of our project is flexibility, easy to use and to wear.

In this project we have developed a prosthetic hand controlled by myoelectric signals captured from the forearm muscle. This signals were filtered and amplified to be easier to read by a micro-controller. The micro-controller then generated signals to control the mechanical hand based on these myoelectric input signals. This is done by the micro-controller increasing the pulse width sent to several servos making up the hand. The larger the pulse width, the more flexed the hand becomes until it reaches the maximum pulse programmed into it. In addition to that, we have developed a dynamic website for the sale of the prosthesis, where the client can find all the information related to this product.

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Chapter 1

Introduction

In some cases, people were born with birth defects such as missing limbs or finger tips and so on. Until very recently these people suffered from these disabilities for entire lifetimes. But with the rise of digital signal processing, micro-controller's technologies, and very recently machine learning. Electronics and control engineers begun developing some fairly practical solutions, using these technologies.

In our project we developed a bionic hand controlled by muscular signals captured from the forearms. We used 3D printing to print out a mechanical hand simulating a real human hand. We have used STM32 as a micro-controller, servo and stepper motors, in order to implement a control circuit for the robotic hand. Flex sensor and EMG sensor in order to capture data from the forearm muscle. We then performed signals classification to enable the user to control the hand by mimicking the desired gesture. Since we are using non reusable electrodes each time we plug new ones we will got different range of signals.

Finally, the hand will mimic the motions of the human hand. It can accomplish fine enough motions to pick up objects and not destroy them. The hand has enough strength to hold a cup upside and down, and not too much strength to crush the cup. The electronic engineering concepts required to finish this project are numerous and cover many areas of the subject. Analog systems are necessary for the construction of the driver circuitry and data collection. Digital systems exist in the programming of the micro-controller.

On top of that, we have a dynamic website dedicated to the sale of our product. It is design to make ordering simple for the client as well as the management of all the data for the administrators.

Chapter 2

Theoretical Background

2.1 Brief history of prosthesis

The first prosthesis dates to Egyptian times, but it was not an artificial arm or a leg as you might expect. It was a big toe suggesting that early prosthetics were used for identity and aesthetic purposes. Egyptians traditionally wore sandals, so it is interesting that these were an important enough fashion staple 3,000 years ago to warrant the creation of a prosthetic toe!. Possibly the first 'disability hero' and the first documented wearer of a prosthetic limb was Roman general "Marcus Sergius". He reportedly lost his right hand in battle and was given a prosthesis made of iron to allow him to hold his shield and carry on fighting. It worked, he went on to have a long military career [1].

The early 16th century was significant advances in prosthetic limbs as well as amputation surgery started to happen. A doctor named "Ambroise Pare" was the first to introduce a hinged prosthetic hand shown in figure 2.1 [1] and a leg with a locking knee joint, and his techniques are still used today. His colleague, a locksmith named "Lorrain", also made an important contribution to the field of prosthetics by using leather, paper, and glue in place of heavy iron. The next advance in technology didn't come until 1946 when researchers developed a suction sock for lower-limb amputees. Similar attachment technology is still in use today.

Figure 2.1: Ambroise Pare's prosthetic hand

In the 1970s around the time Fish Insurance was established an inventor by the name of "Ysidro M. Martinez" (who was an amputee himself) developed a lower-limb prosthesis that focused on improving movement and reducing friction. It relieved pressure and made walking more comfortable, which improved the lives of many future patients. Further advancements have meant that nowadays devices are much lighter, usually made of plastic, aluminium and composite materials.

2.2 Electromyography (EMG)

2.2.1 Anatomical and physiological background

Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes [1], EMG is performed using an instrument called Electromyography. The electromyography detects the electric potentials generated by muscle cells. Electromyography has been used for medical research and diagnosis of neuromuscular disorders, however with the powerful micro-controllers and integrated circuits, EMG circuits found their way into prosthetic, robotics and modern control systems. The raw EMG signal is the unfiltered and unprocessed signal detecting the superposed MUAPs (Motor unit action potentials).[2]

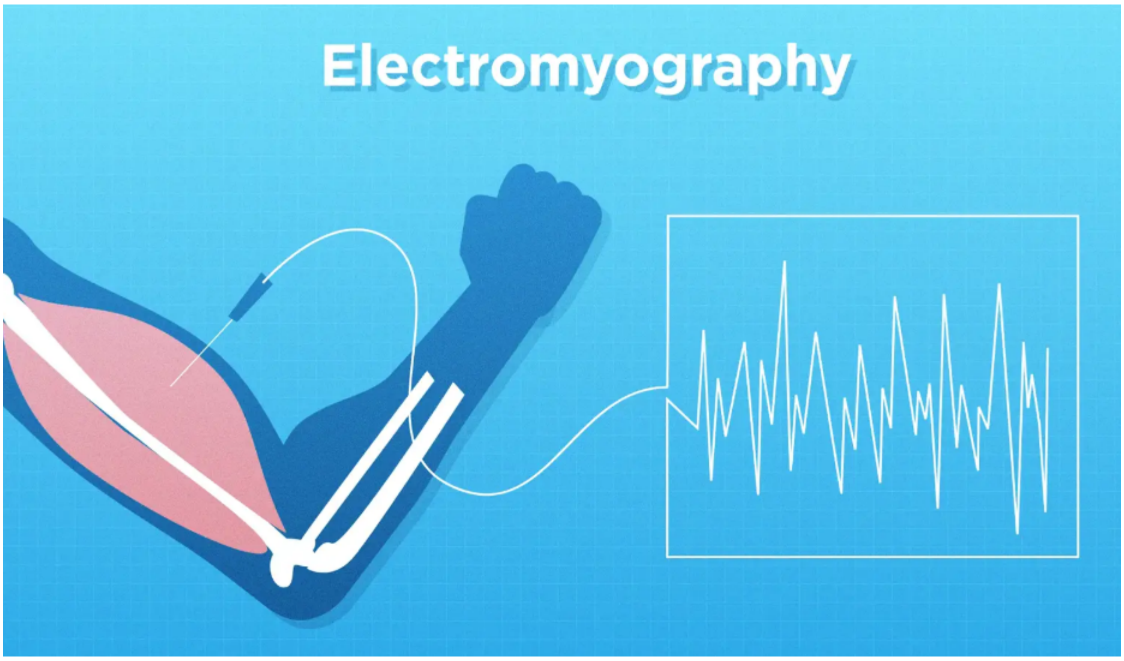

Figure 2.2: Electromyography

Two types of electrodes have been used to acquire muscle signal: invasive electrode and non-invasive electrode. When EMG is acquired from electrodes mounted directly on the skin, the signal is a composite of all the muscle fiber action potentials occurring in the muscles underlying the skin. These action potentials occur at random intervals. Therefore, at any moment, the EMG signal may be either positive or negative voltage. Individual muscle fiber action potentials are sometimes acquired using wire or needle electrodes placed directly in the muscle. The combination of the muscle fiber action potentials from all the muscle fibers of a single motor unit is the motor unit action potential (MUAP) which can be detected by a skin surface electrode (non-invasive) located near this field, or by a needle electrode (invasive) inserted in the muscle . Eq 2.1 shows a simple model of the EMG signal:

$$x(n) = \sum_{r=0}^{N-1} h(r)e(n-r) + w(n) \tag{2.1}$$

where x(n), modeled EMG signal, e(n), point processed, represents the firing impulse, h(r), represents the MUAP, w(n), zero mean addictive white Gaussian noise and N is the number of motor unit firings[2]. There are a lot of factors influencing the EMG signal, and can be grouped as follows:

- **Tissue characteristics :** The electrical conductivity of the human body varies with tissue type, thickness, physiological changes and temperature. This can affect the magnitude of the EMG signal.
- **Physiological cross talk :** The neighboring muscles may produce a significant amount of EMG that is detected by the local electrode site. Typically, this "Cross Talk" does not exceed 10-15 percent of the overall signal contents or isn't available at all.
- **Changes in the geometry between muscle belly and electrode site :** Any change of distance between signal origin and detection site will alter the EMG reading.
- **External noise :** A care must be taken to the electrical environment and noisy electrical devices.
- **Electrode and amplifiers :** The selection/quality of electrodes and internal amplifier noise may add signal contents to the EMG baseline.

2.2.2 Techniques of EMG signal analysis

Several techniques are used for EMG analysis, the most common of them are detection, processing, classification and applications

- **Detection :** Precise detection of discrete events in the EMG (like the phase change in the activity pattern associated with the initiation of the rapid motor response) is an important issue in the analysis of the motor system. Several methods have been proposed for detecting the on and off timing of the muscle. The most common method for resolving motor-related events from EMG signals consists of visual inspection by trained observers. The "single-threshold method," which compares the EMG signal with a fixed threshold.The method can be useful in overcoming some of the problems related to visual inspection. However, this kind of approach is generally not satisfactory, since measured results depend strongly on the choice of threshold. This kind of method often rely on criteria that are too heuristic and does not allow the user to set independently the detection and false alarm probabilities. In “single-threshold method,” the relationship between the probability of detection Pdk and the probability P that a noise sample is above the threshold is given by :

$$P_{dk} = \exp\left(\frac{\ln(P_{\gamma})}{1+10^{SNR/10}} \right) \tag{2.2}$$

In 1984, ”Winter” observed that this approach is generally unsatisfactory, since it strongly depends on the choice of the threshold. To overcome the “singlethreshold” problems, ”Bornato et al.” introduced “double-threshold detection” method in 1998. Doublethreshold detectors are superior to single-threshold because they yield higher detection probability. Doublethreshold detectors allow the user to adopt the link between false alarm and detection probability with a higher degree of freedom than single-threshold. The user can tune the detector according to different optimal criteria, thus, adapting its performances to the characteristics of each specific signal and application. The sEMG signal recorded during voluntary dynamic contractions may be considered as a zero-mean Gaussian process s(t)N(0,s) modulated by the muscle activity and corrupted by an independent zero-mean Gaussian additive noise n(t)N(0,n). If the probability of detection is Pd then the double-threshold method is given by :

$$P_d = \sum_{k=r_o}^{m} \binom{m}{k} P_{dk}^{k} (1 - P_{dk})^{m-k} \tag{2.3}$$

The behavior of the double-threshold detector is fixed by the parameters: the threshold ro, and the length of the observation window, m. Their values are selected to minimize the value of the false-alarm probability and maximize Pd for each specific signal-to-noise ratio (SNR).

EMG signals are the superposition of activities of multiple motor units. It is necessary to decompose the EMG signal to reveal the mechanisms pertaining to muscle and nerve control. Various techniques have been devised with regards to EMG decomposition. Decomposition of EMG signal has been done by wavelet spectrum matching and principle component analysis of wavelet coefficients.

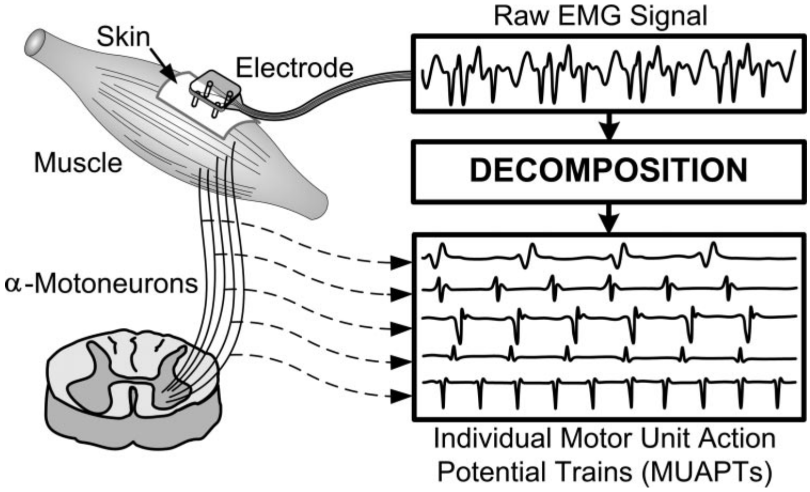

Figure 2.3: EMG signal and decomposition of MUAPs.

- **Processing :** Raw EMG offers us valuable information in a particularly useless form. This information is useful only if it can be quantified. Various signal-processing methods are applied on raw EMG to achieve the accurate and actual EMG signal.

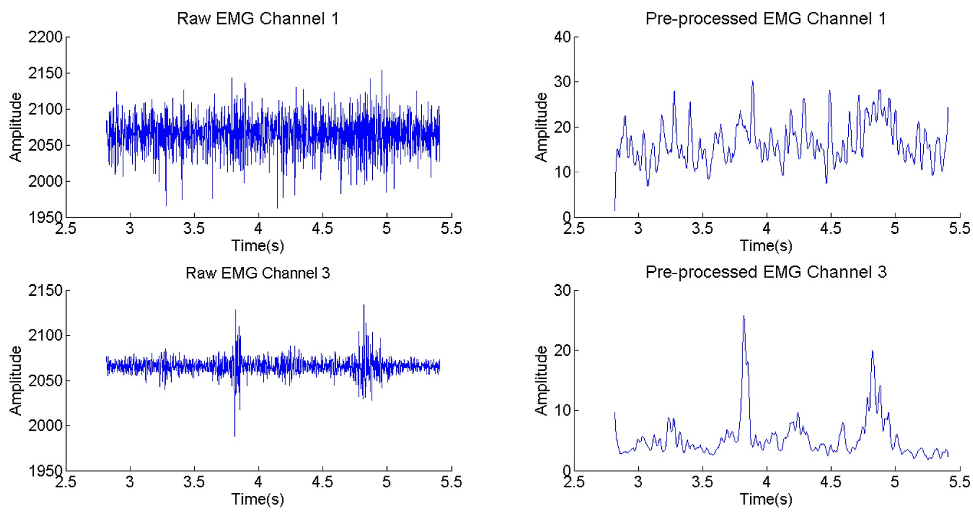

Figure 2.4: EMG signal processing.

Wavelet analysis : Both the time and frequency domain approaches have been attempted in the past. The wavelet transform (WT) is an efficient mathematical tool for local analysis of non-stationary and fast transient signals. One of the main properties of WT is that it can be implemented by means of a discrete time filter bank. The Fourier transforms of the wavelets are referred as WT filters. The WT represents a very suitable method for the classification of EMG signals.
Autoregressive model : The autoregressive (AR) time series model has been used to study EMG signal. A surface electrode will pick up EMG activity from all the active muscles in its vicinity, while the intramuscular EMG is highly sensitive, with only minimal crosstalk from adjacent muscles. Thus, to

combine convenience and accuracy there is a great need to develop a technique for estimating intramuscular EMG and their spectral properties from surface measurement. Researchers have represented sEMG signal as an AR model with the delayed intramuscular EMG as the input.
Artificial intelligence : Some Artificial Intelligence techniques mainly based on Neural Networks have been proposed for processing EMG signal. This kind of technique is very useful for real-time application like EMG signal recording and analysis.

- **Classification :** The common feature for classifying intramuscular EMG signal is the Euclidean distance between the MUAP waveforms. For clinical interests, the main feature of the EMG signal is the number of active motor unit (MUs), the MUAP waveforms, and the innervations time statistics. According to Wellig and Moschytz [3], the determination of the MUAP waveform and the number of active MUs can be considered as a classification problem.

- **Application :** EMG signals can be used for variety of applications like clinical/biomedical applications, EHW chip development, human machine interaction, etc. Clinical applications of EMG as a diagnostics tool can include neuromuscular diseases, low back pain assessment, kinesiology and disorders of motor control. EMG signals can be used to develop EHW chip for prosthetic hand control. Grasp recognition [4] is an advanced application of the prosthetic hand control.

Chapter 3

Hardware System Design And Implementation

3.1 Hardware Design

3.1.1 3D Modeling and Printing

3D Modeling :

Several designs and products are currently available, however this project has taken inspiration from these products and real human hand with the goal of reducing cost and weight without sacrificing functionality, so using these designs, we have been able to model our artificial hand using Fusion 360 software.

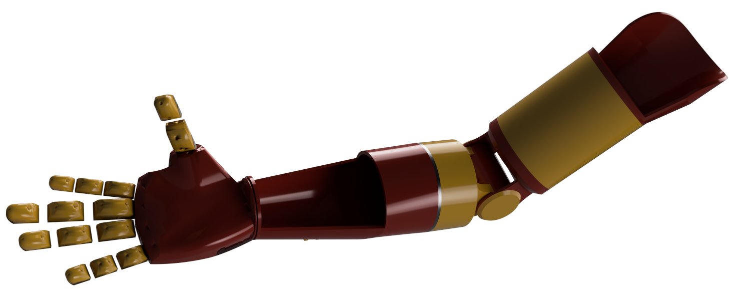

Figure 3.1: 3D design of the hand.

After finishing the design of all parts, we exported each part as STL file in order to prepare for the printing phase.

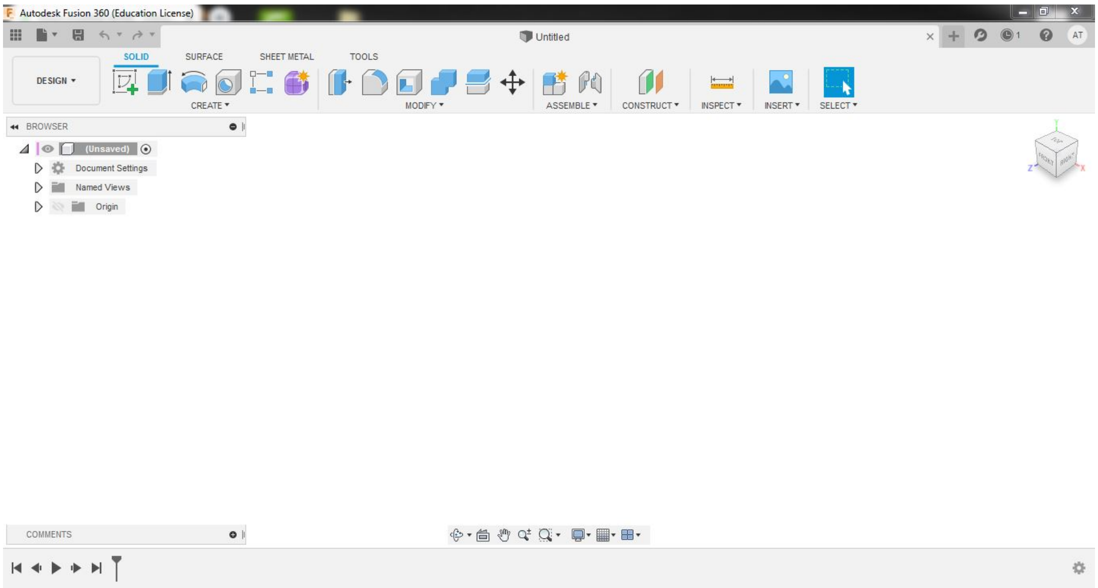

Figure 3.2: Fusion 360.

3D Printing :

In order to start printing we need first to convert STL files into G-Code Files and set all specifications needed to be used by the 3D printer, several softwares can be used. In this project we have used Ultimaker Cura v4.6.

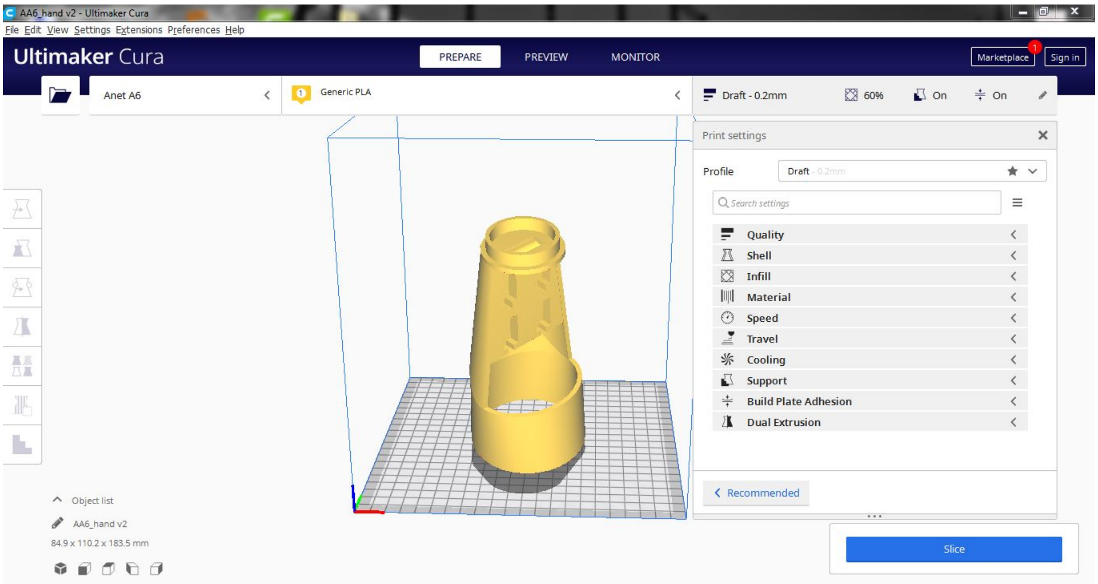

Figure 3.3: Cura Ultimaker.

For the 3D printer we have used Anet A6 model. The total printing time took about 62 hours and 32 minutes, with the following specifications:
*Filament Used : PLA.
*Speed : (100-170).
*Bed heating : 60 degree.
*Nozzle heating : 200 degree.

Figure 3.4: 3D printer.

3.1.2 Components Used

STM32F103C Black Pill board :

The STM32F103C8T6 (HCDVBD0033 / Black pill) Development Board is a low cost but feature rich STM32 MCU development board. The board features an ST Microelectronics STM32F103C8 Arm microprocessor running at a 72MHz clock speed, coupled with 64K of Flash and 20K of SRAM. This development board has 30 I/O pins, 14 of which can be configured as 12 bit ADC inputs, 12 as PWM with most pins being 5V tolerant.

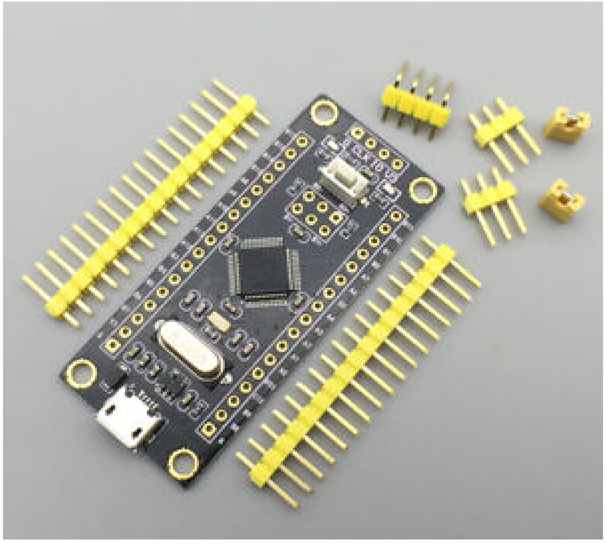

Figure 3.5: STM32 BlackPill development board.

The STM32 Black Pill board has a wide range of IO which pinout is the following

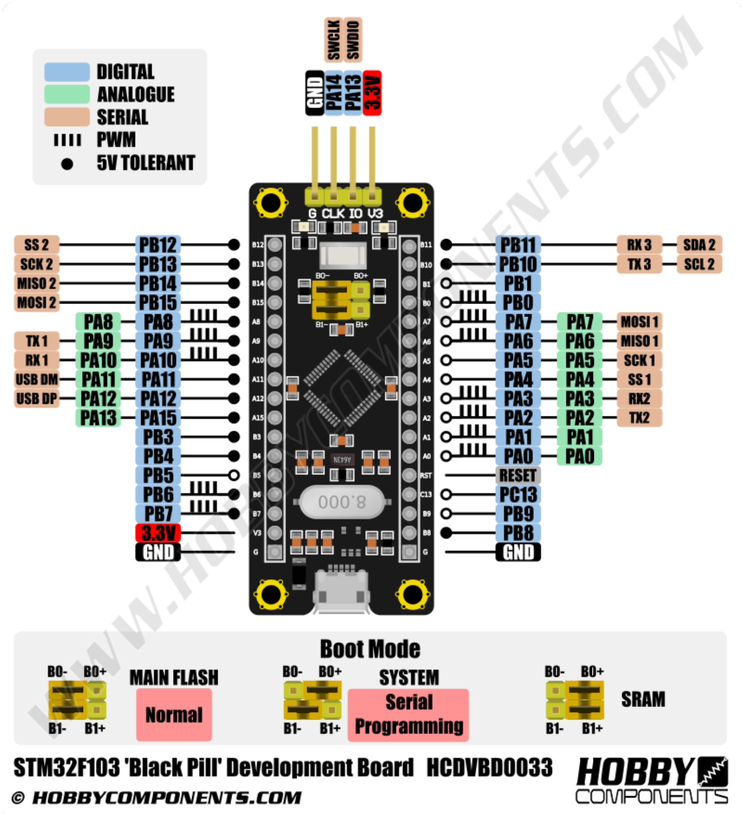

Figure 3.6: STM32 Black Pill development board Pinout.

EMG Sensor :

Muscle sensor measures the electrical activity of a muscle; outputting 0-Vs Volts depending the amount of activity in the selected muscle, it has five pins, three for power supply (+vs, -vs and GND) and two for output signal (SIG and GND), also three electrodes, one for mid muscle and the other for the end of the muscle and the last as a reference, it has an adjustable gain. The output signal of the sensor is an amplified, rectified and smoothed signal that will work well with a micro-controller. It can be used in a lot of application like Robotics, Prosthetics, medical devices and video games.

Figure 3.7: EMG sensor.

FLEX Sensor :

A flex sensor or bend sensor is a sensor that measures the amount of deflection or bending. Usually, the sensor is stuck to the surface, and resistance of sensor element is varied by bending the surface[5].

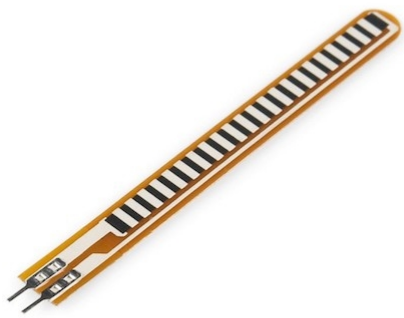

Figure 3.8: Flex Sensor.

ST-LINK :

The ST-LINK/V2 is an in-circuit debugger and programmer for the STM8 and STM32 micro-controller families. The single wire interface module (SWIM) and JTAG/serial wire debugging (SWD) interfaces are used to communicate with any STM8 or STM32 micro-controller located on an application board.

Figure 3.9: ST-LINK/V2 Debugger

FTDI FT232R chip adapter :

The FTDI FR232R is a USB UART interface Integrated Circuit Devices which was used mainly to debug and observe the serial Communication between the STM32F103C and Matlab software.

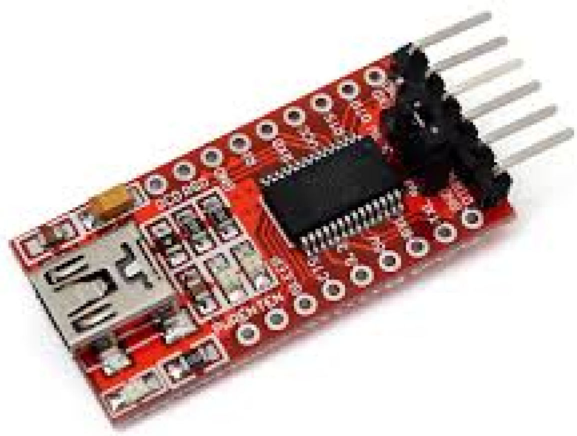

Figure 3.10: FTDI FT232R USB to Serial adapter.

Motors :

- **Servo Motor :**
  A servo motor is a rotary actuator or motor that allows for a precise control in terms of angular position, acceleration and velocity, capabilities that a regular motor does not have. It makes use of a regular motor and pairs it with a sensor for position feedback[6]. The controller is the most sophisticated part of the servo motor, as it is specifically designed for the purpose. They are used in robotics, automated manufacturing and computer numerical control (CNC) machining applications.

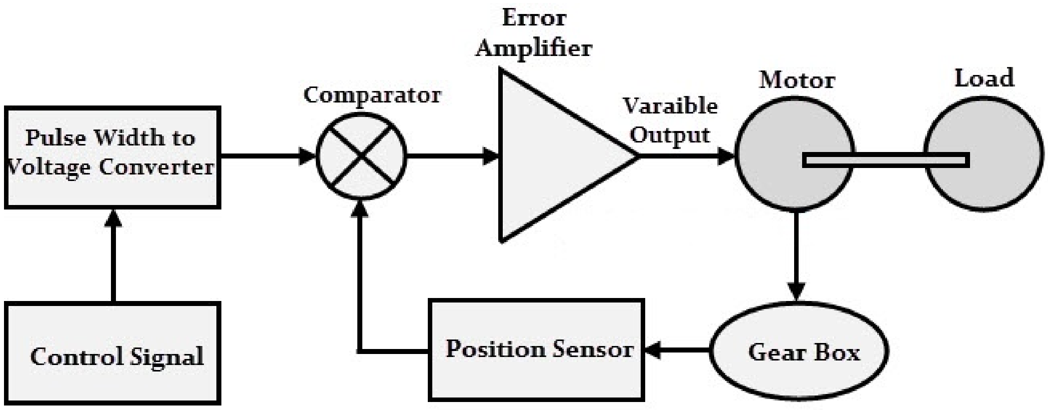

Figure 3.11: Block Diagram.

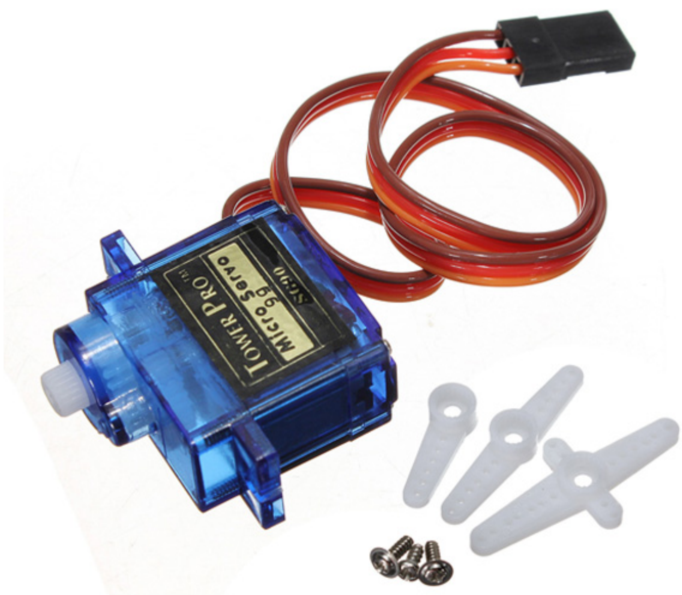

Figure 3.12: Servo Motor.

- **Stepper Motor :**
  Stepper motors are DC motors that move in discrete steps. They have multiple coils that are organized in groups called ”phases”. By energizing each phase in sequence, the motor will rotate, one step at a time. With a computer controlled stepping you can achieve very precise positioning and/or speed control. For this reason, stepper motors are the motor of choice for many precision motion control applications[7].

  Stepper motors come in many different sizes and styles and electrical characteristics.

Figure 3.13: Stepper Motor

3.2 Circuit Building and PCB Design

In this section we are going to see the overall circuit design and our EMG sensor design.

3.2.1 Overall Circuit Design

The main idea of this project is how to make the bionic hand moves according to the EMG signals extracted from the forearm muscle.The figure below shows the block diagram of the overall system.

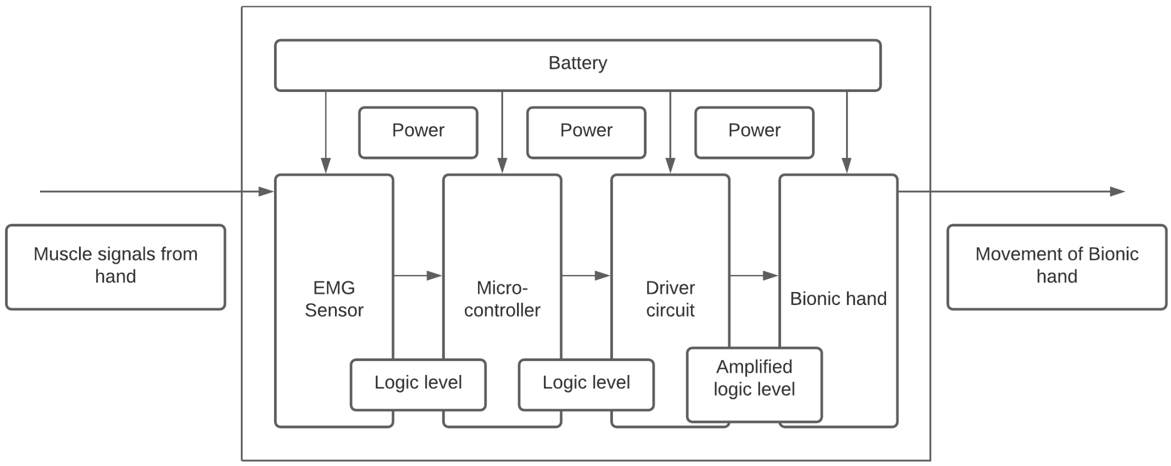

Figure 3.14: General Block Diagram.

Circuit Schematic Design :

The general circuit for this project consist of two functions:

- Controlling the stepper motor using the flex sensor input signal.
- Controlling the servo motors using myoelectric signals from the EMG sensor.

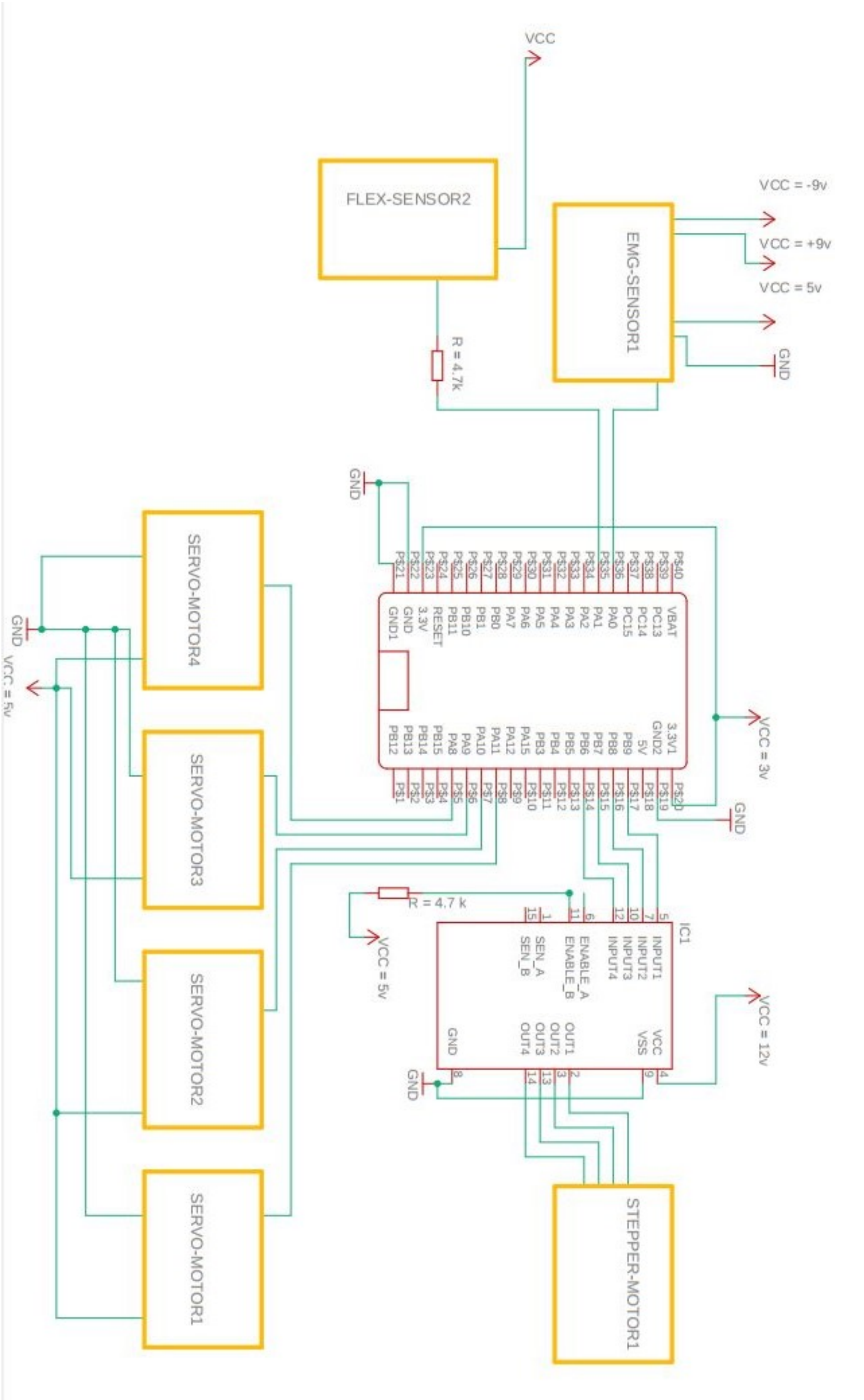

Figure 3.15: Circuit Schematic Design.

EMG sensor V3 Blocks :

For capturing the myoelectric signals we have used muscle sensor V3 which is developed by advanced technologies company. This sensor will measure the filtered and rectified electrical activity of a muscle, outputting 0-Vs Volts depending the amount of activity in the selected muscle. The EMG signal passes through 3 steps:

- **Measuring :** using 3 electrodes attached to the muscle.

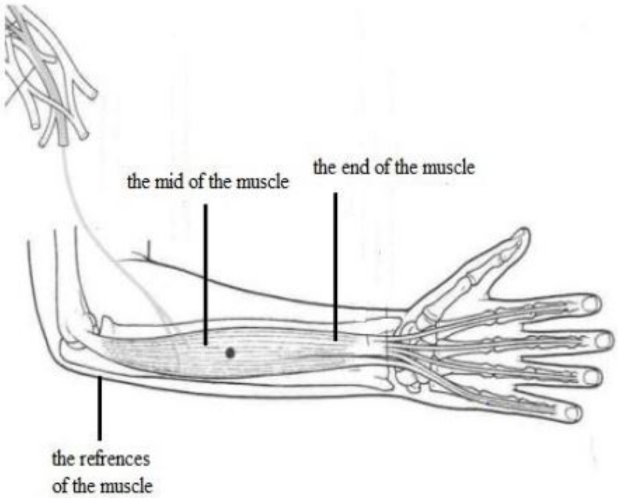

Figure 3.16: Electrodes Location.

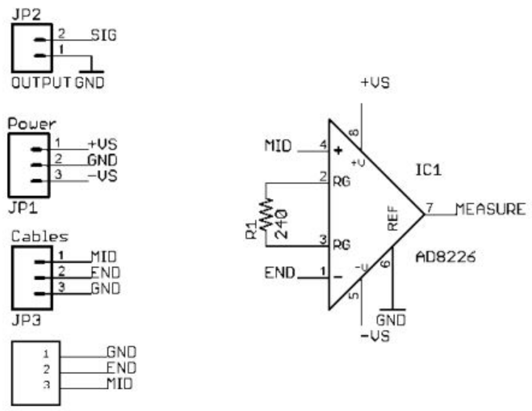

Figure 3.17: Measuring Block.

- **Rectifying :**

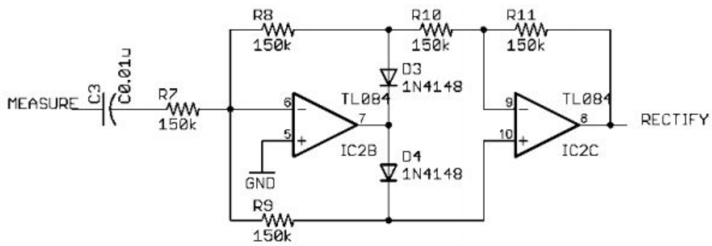

Figure 3.18: Rectifying Block.

- **Smoothing :**

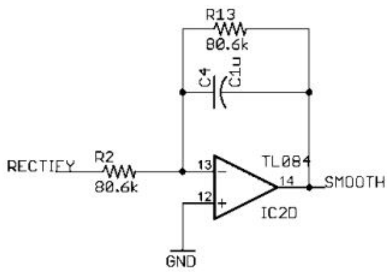

Figure 3.19: Smoothing Block.

3.2.2 BRH PCB Design

In this section we will deal with BRH PCB design which contains all blocks we need for this project including EMG sensor, STM blue pill servo and stepper motors wiring.

Software Environment :

EAGLE stands for Easily Applicable Graphical Layout Editor, it contains a schematic editor, for designing circuit diagrams. Schematics are stored in files with .SCH extension, parts are defined in device libraries with .LBR extension. This last can be placed on many sheets and connected together through ports. The PCB layout editor stores board files with the extension .BRD. It allows back-annotation to the schematic and auto-routing to automatically connect traces based on the connections defined in the schematic.

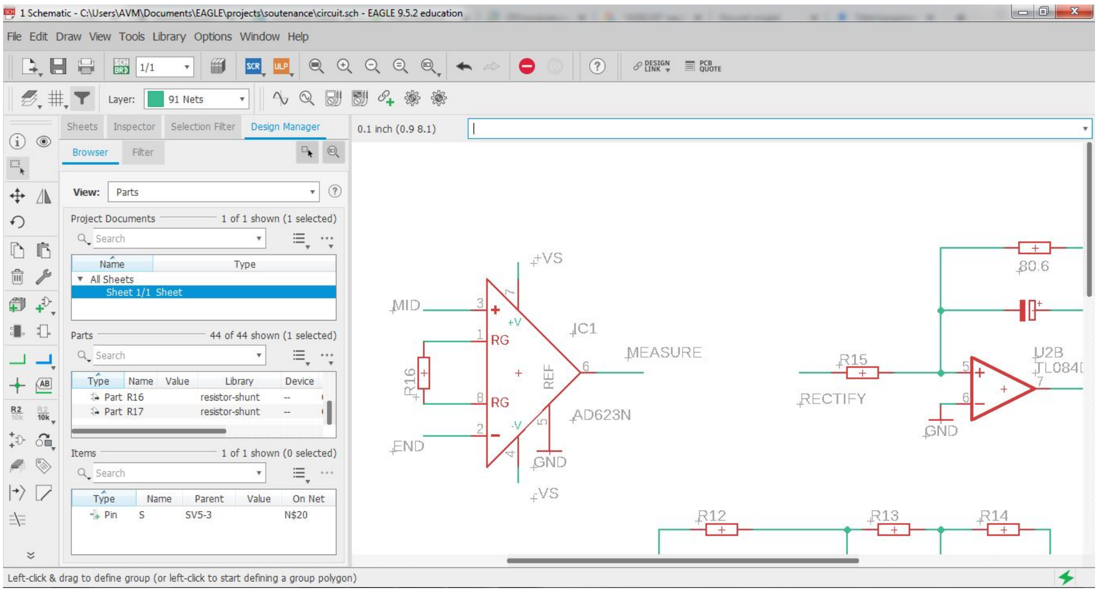

Figure 3.20: Eagle autodesk IDE.

To build this circuit we have used the same technique as the EMG sensor V3 blocks (Measuring, rectifying and smoothing). We also added STM32 Blue pill pads and connectors for servo Motors, stepper motor, flex sensor and power.

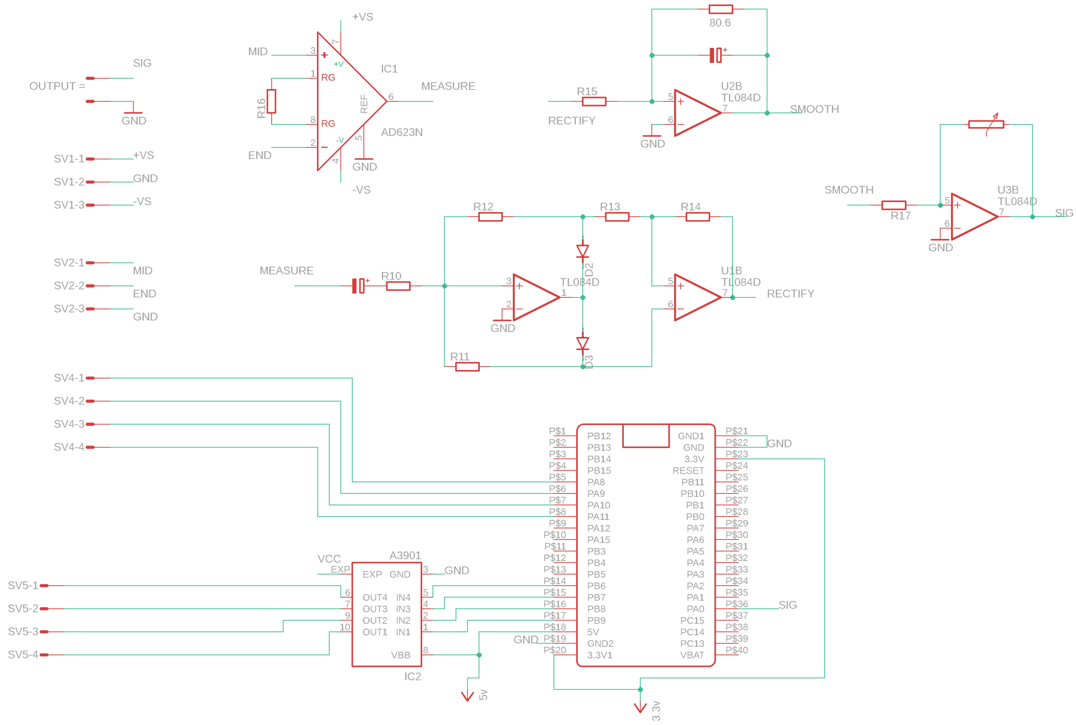

Figure 3.21: Circuit Schematic.

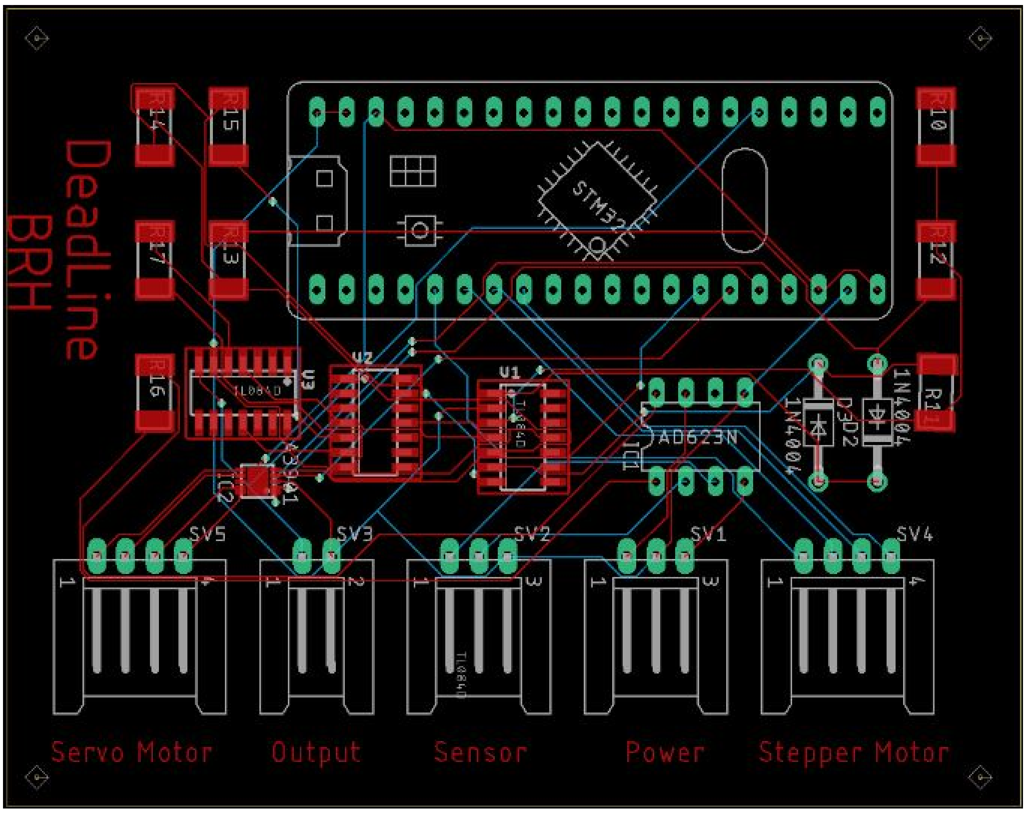

Figure 3.22: Circuit Board.

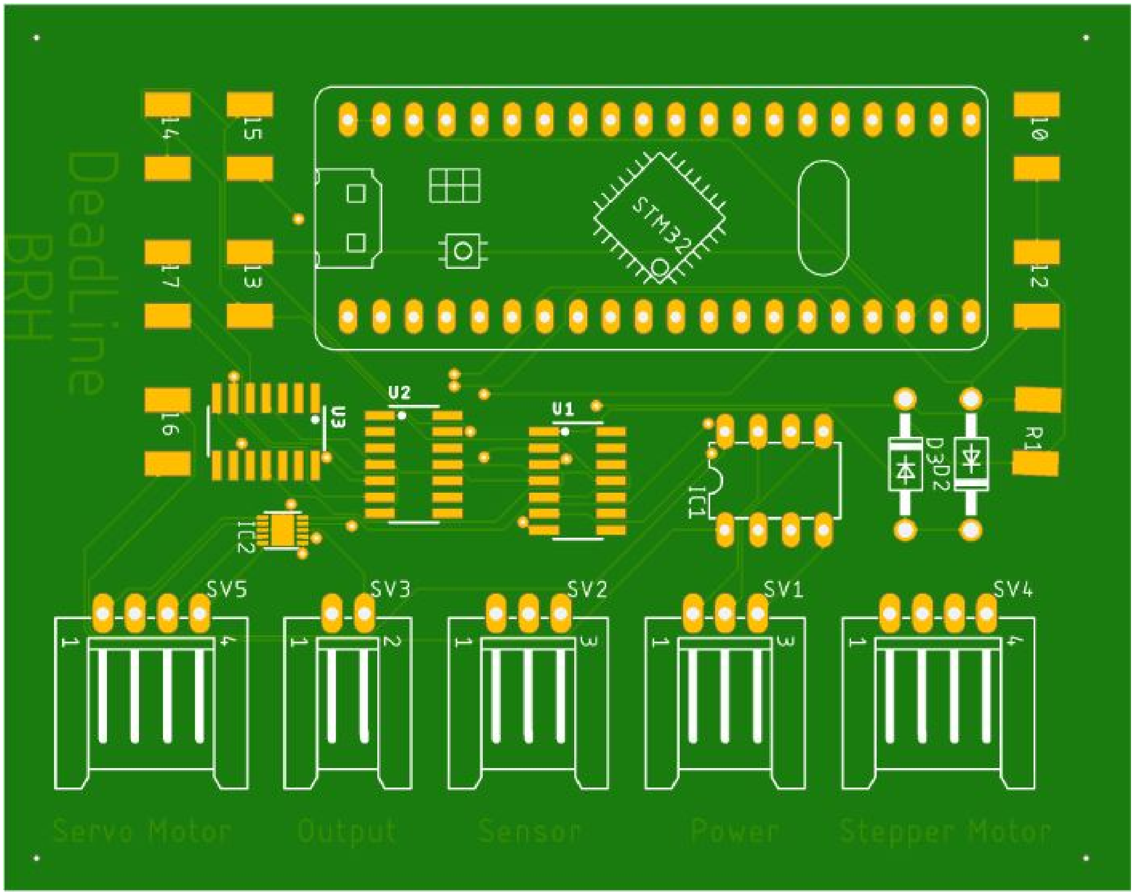

Figure 3.23: Final PCB.

3.3 Project Implementation

In this section we are going to see installations steps and the project implementation process. Our focus in this project is on building a prosthetic hand that works almost like a real human hand, and helping people with disabilities perform their daily functions.

3.3.1 Fingers and Palm Implementation :

We used two types of wires, a rubber thread at the back of the hand that passes through the fingers in order to put the hand in a relaxed state and it is an open gesture, for the other gestures we used a fishing thread that passes inside the hand connected to the servo motors so that the fishing thread is pulled when the motor rotates and the finger is closed, to open the finger we need To counter rotation of the motor and the rubber thread will open the finger automatically.

Figure 3.24: Fingers and Palm.

We used four servo motors, each finger has its motor except the ring and the pinky fingers we used one servo motor for both of them, this trick is for reducing the cost and weigh also to mimic the human hand because it is difficult for a human to move those fingers separately.

3.3.2 The Elbow Joint :

The elbow joint is the synovial hinge joint between the humerus in the upper arm and the radius and ulna in the forearm which allows the forearm and hand to be moved towards and away from the body[8].

Figure 3.25: Human Elbow joint.

For our bionic hand we attempted to make an artificial elbow joint that can mimic a human one. We used a stepper motor as a biceps muscle which is controlled using flex sensor signal.

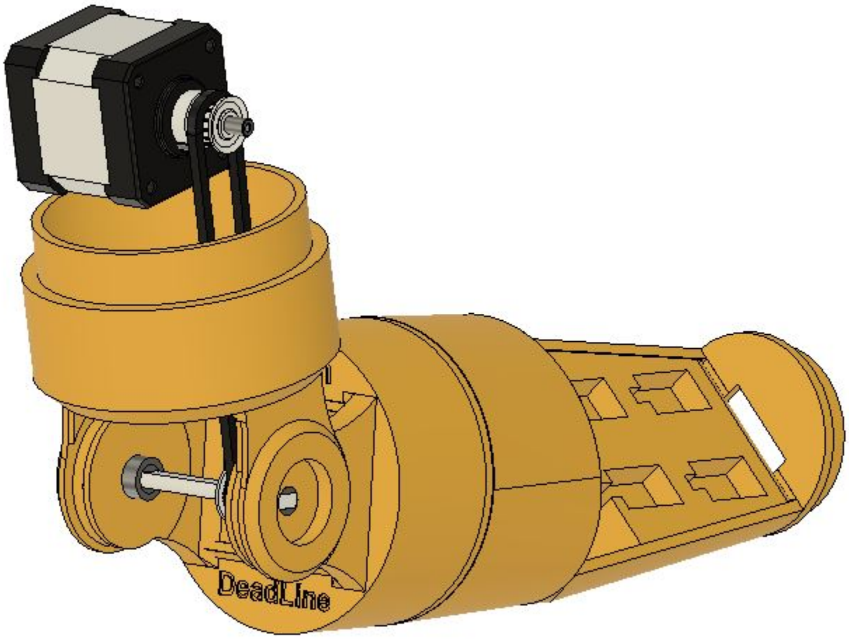

Figure 3.26: BRH Elbow.

The figures bellows shows the final implemented bionic hand.

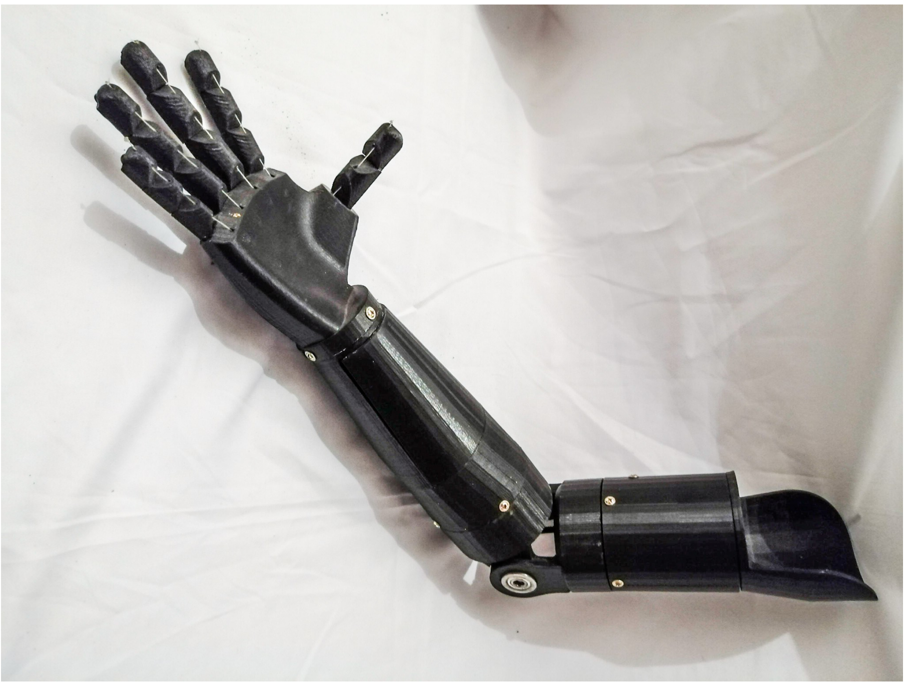

Figure 3.27: The bionic robotic hand -1-.

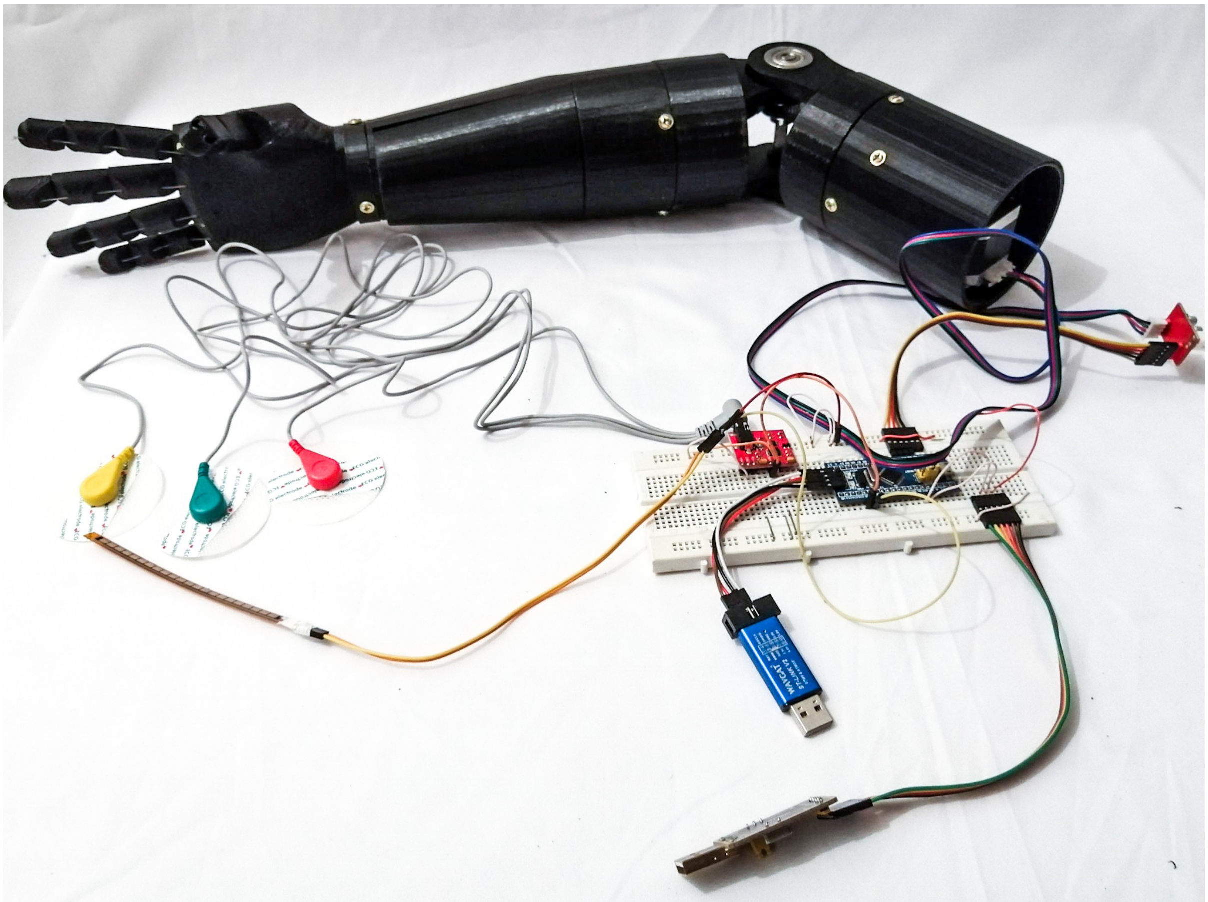

Figure 3.28: The bionic robotic hand -2-.

Chapter 4

BRH Platform And DSP

4.1 Website

4.1.1 Theoretical background

A website is a collection of publicly accessible, interlinked Web pages that share a single domain name. It consist of a front end and a back end. Front end development is mostly focused on the "client side" it manages everything that users visually see first in their browser and the back end development refers to the server side of an application and everything that communicates between the database and the browser,it refers to the server side of development where we are primarily focused on how the site works.[9]

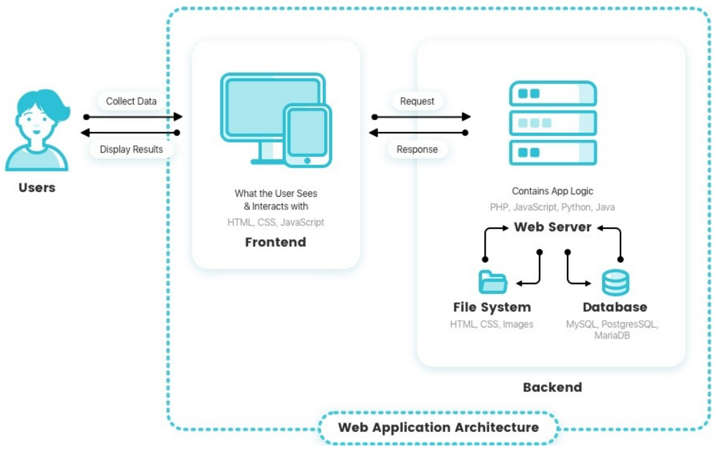

Figure 4.1: Website architecture

BRH platform :

BRH platform is a dynamic website for the sale of our Bionic Robotic Hand. The client can order a prosthesis for that it is necessary to take an appointment with a doctor in order to make some necessary measurements. The client can also fix his prosthesis in case of breaking.

Development environment:

Our web server is XAMPP which is an acronym for operating system, Apache, MySQL, PHP, and PERL.

- **Apache :** Apache Web Server is an open-source web server creation, deployment and management software. Apache Web Server is designed to create web servers that have the ability to host one or more HTTP-based websites, it has the ability to support many programming languages. [10]
- **MySQL :** MySQL is a Relational Database Management System (RDBMS) based on Structured Query Language (SQL).The most common use for mySQL is for the purpose of a web database.To handle the administration of MySQL over the Web we use **phpMyAdmin** which is a software tool written in PHP, used to perform operation as managing databases, tables, columns, relations and SQL statement can also be used directly.

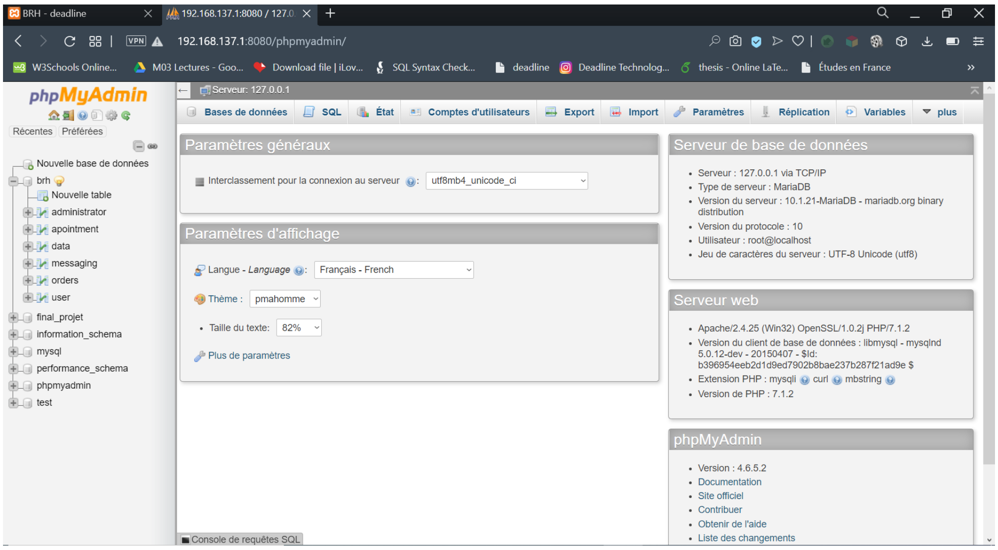

Figure 4.2: phpmyadmin preview.

- **PHP :** PHP is an open source server side scripting language that is used to develop Static websites or Dynamic websites or Web applications.

Used Languages :

- **PHP :** PHP is an acronym for Hypertext Preprocessor,it allows the connection to databases such as MySQL. PHP has the particularity of being executed directly on the server which hosts the pages and not on the user's machine.
- **HTML :** HTML stands for Hypertext Markup Language.This language is defined by the W3C (World Wide Web consortium), HTML provides a mean to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes and other items.

- **SQL :** SQL stands for Structured Query Language.It is a standard language for relational databases used for storing, manipulating and retrieving data stored in them.
- **Javascript :** JavaScript is a scripting language used both on the client-side and server-side.On the client side it is used to create responsive, interactive elements for web pages
- **CSS :** CSS stands for Cascading Style Sheets,it describes how HTML elements are to be displayed on screen.It brings style to the web pages by interacting with HTML elements.

Used Software :

- **Xampp :** XAMPP is a software distribution which provides the Apache web server, MySQL database , Php and Perl all in one package.It makes transitioning from a local test server to a live server possible.
- **Visual Studio Code :** Visual Studio Code is a free source-code editor made by Microsoft that includes basic support for most common programming languages.

4.1.2 Back end development

Identification of actors :

This website allows an interaction with several types of actors, which are defined as the direct users of the system.

We have identified thee actors:

- Visitor : represents an individual who is searching in the net for a product, he is an unknown user so not a client yet.
- Client : represents an authenticated visitor, he is logged using an identifier and a password, he can hence order the product.
- Administrator : is in charge of managing the customer order, the doctor appointment requests, the messages and the client's data.

Task Specification :

Each of the actors defined previously, performs a certain number of tasks summarized in the following table:

actor	task
Visitor	**T1:** See services **T2:** See product **T3:** Send message **T4:** Log in
Client	**T1:** Order prosthesis **T2:** fix prosthesis **T3:** take appointment **T4:** Send messages
Administrator	**T1:** Manage clients **T2:** Manage clients' data **T3:** Manage orders **T4:** Manage appointments **T5:** Manage fixing requests **T6:** Manage messages

Table 4.1: Table of tasks for each actor.

Graphic representation :

- Visitor:

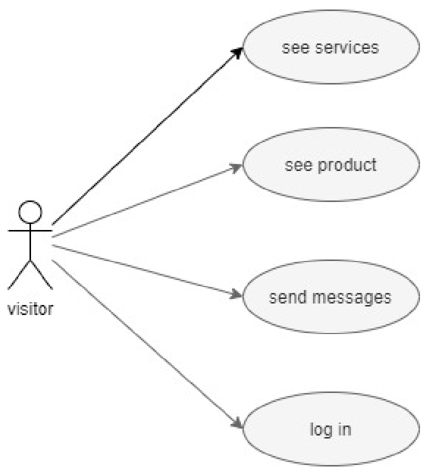

Figure 4.3: Visitor use cases

- Client :

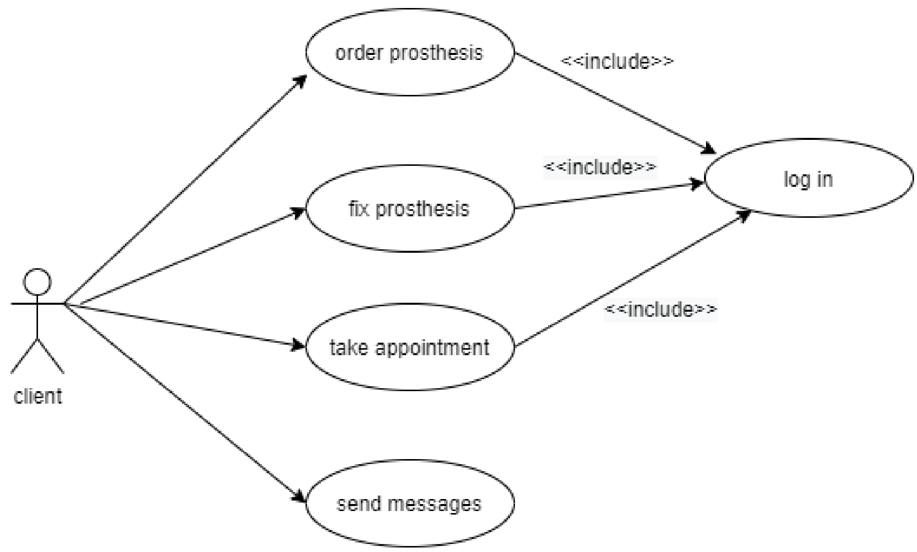

Figure 4.4: Client use cases

- Administrator :

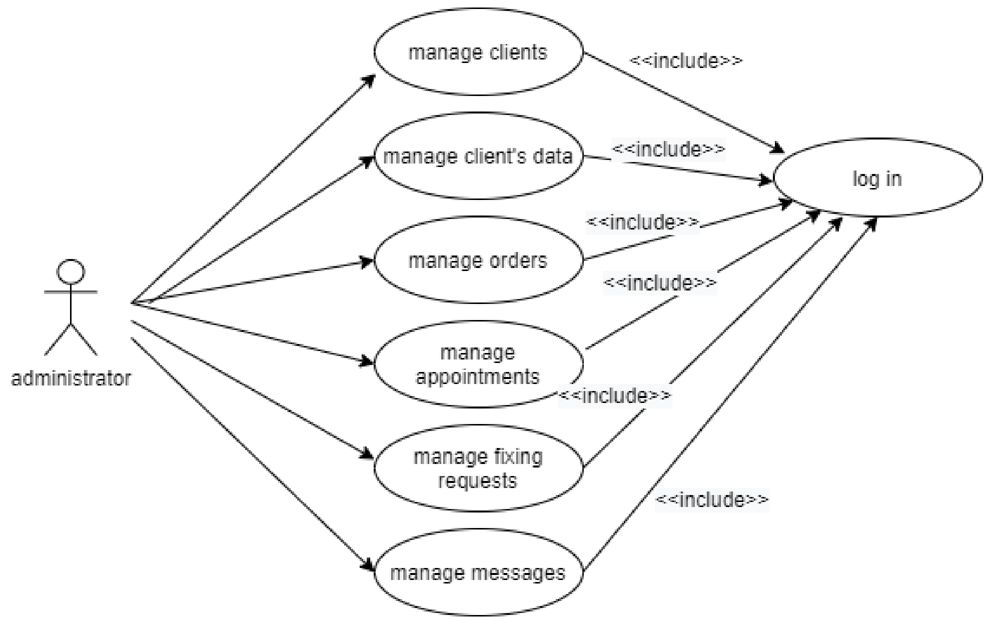

Figure 4.5: Admin use cases

Database Design :

- **The logical level of the database :** The conceptual or logical level describes what data is stored in the database and the records and relationships among each other;it has the logical structure of the entire database.

  user (id,username,Fname,Lname,email,pass,sex,birthdate)

  administrator(id,username,password)

  orders(idorder,id,Fname,Lname,date)

  data(id,link)

  appointment(id,sex,age,email,date)

  fix(id,Fname,Lname,email,part)

  messaging(name,email,phone,subject,message)

- **The physical level of the database :** The physical or internal level describes how data is stored in the database

  the user's table:

field	signification	type	key
id	client identifier	int(200)	primary
username	identification	varchar(50)	
Fname	First name	varchar(50)	
Lname	Last name	varchar(50)	
email	client's email	varchar(50)	
pass	client's password	varchar(50)	
sex	Sex of client	varchar(20)	
birthdate	client's birth date	varchar(20)	

Table 4.2: The table User

the administrator's table:

field	signification	type	key
id	administrator's identifier	int(5)	primary
username	identification	varchar(50)	
password	administrator's password	varchar(50)	

Table 4.3: The table Administrator.

the data's table :

field	signification	type	key
id	client's identifier	int(200)	primary
link	link of data	varchar(300)	

Table 4.4: The table Data.

the orders' table :

field	signification	type	key
idorder	order's identifier	int(200)	primary
id	client identifier	int(200)	
Fname	First name of client	varchar(50)	
Lname	Last name of client	varchar(50)	
date	date of the order	varchar(50)	

Table 4.5: The table Order.

the appointment's table :

field	signification	type	key
id	client identifier	int(200)	primary
sex	sex of client	varchar(50)	
age	age of client	int(200)	
email	email of the client	varchar(50)	
date	date of appointment taking	varchar(20)	

Table 4.6: The table Appointment.

the fix's table :

field	signification	type	key
id	client's identifier	int(200)	
Fname	First name of client	varchar(50)	
Lname	Last name of client	varchar(50)	
email	email of client	varchar(30)	
part	broken part	varchar(30)	

Table 4.7: The table Fix.

the messaging's table :

field	signification	type	key
name	name of user	varchar(50)	
email	email of user	varchar(50)	
phone	phone of user	varchar(20)	
subject	subject of message	varchar(50)	
object	message of the user	varchar(1000)	

Table 4.8: The table Messaging.

4.1.3 Front end development :

The website is constituted from three web pages whose are divided into section; the home page directed to any visitor on the website, the client page directed to the client so he can order and the admin page intended for the administrators in order to manage everything.

The web pages files are saved as .PHP extension.They generate HTML from a PHP engine running on a web server.The HTML content that the PHP engine creates from the code is what's seen in the web browser [11].

Home page :

After entering the home page, we find a menu which leads us to different sections :

- About us: contains information about the company.
- Product: contains pictures of the prosthesis being sold.
- Services: list the different services that the society offer including making and fixing prosthesis
- Contact: To contact in case of any enquiry.
- Log in: to log or create an account to access the client page or admin page.

The figure down below shows the home page as well as the header of the website.

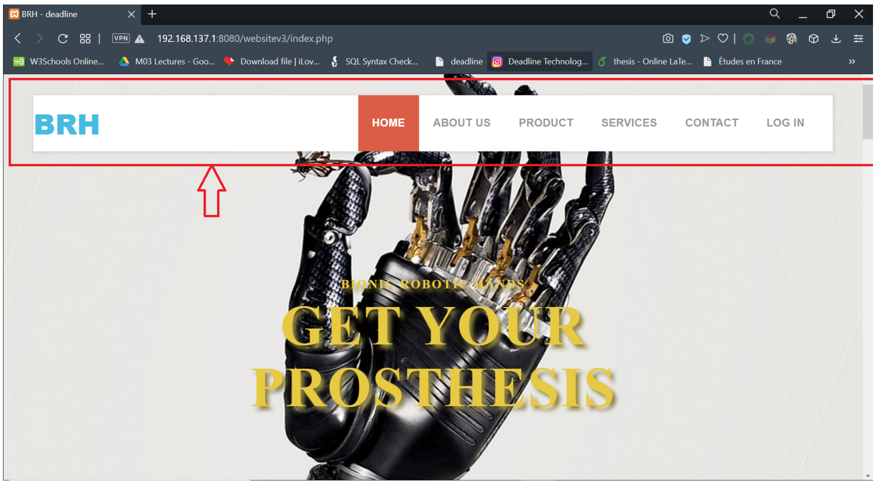

Figure 4.6: The main page overview with the header.

The product section is the section where we find some information about the prosthesis as well as pictures so that the client sees the product.

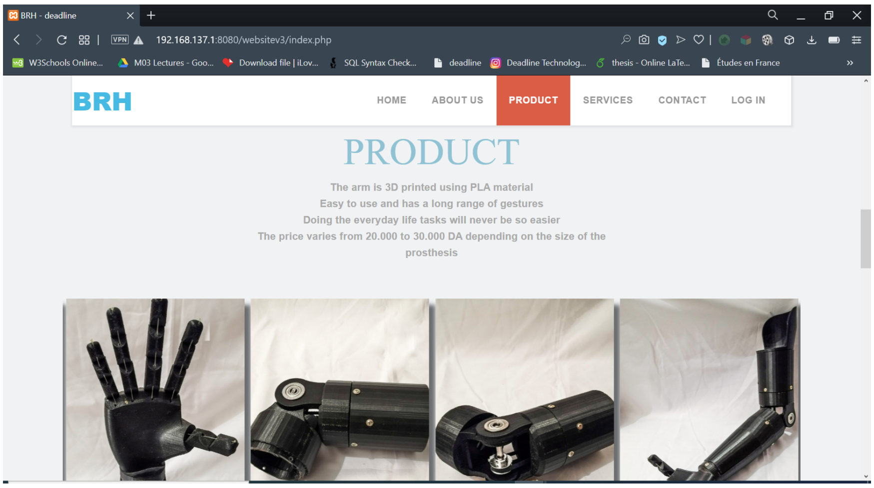

Figure 4.7: The product section.

In the services section, the visitor can see the different services that include ordering and fixing prosthesis, We can see from the figure down below that it is essential to login to make and order or fix a prosthesis.

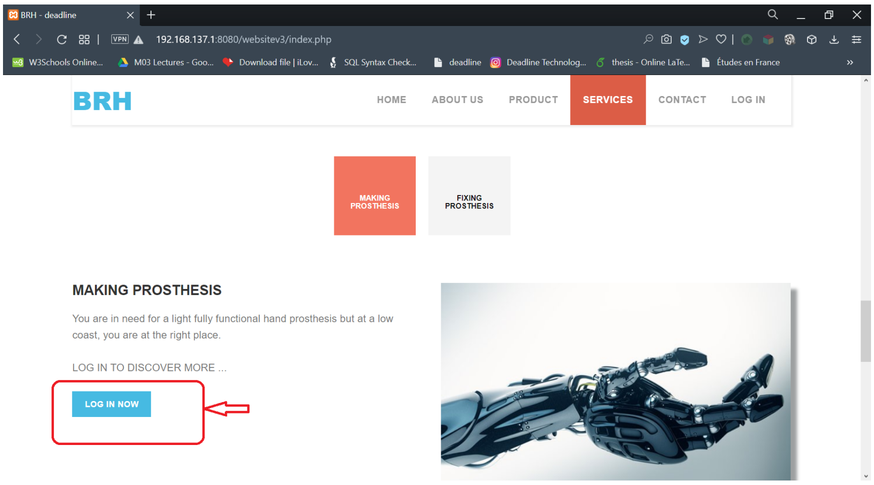

Figure 4.8: The services section.

In the contact section is found a form that the visitor fill in order to send a message for the administrator and the localisation of the BRH-Deadline society.

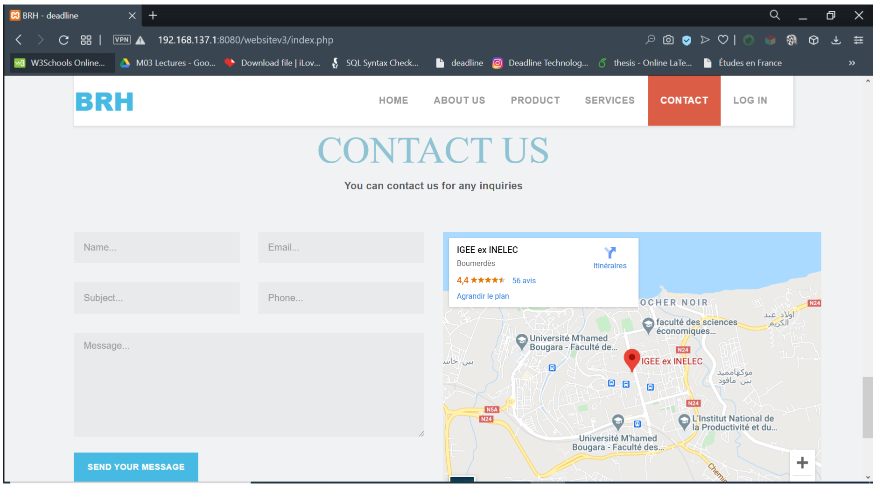

Figure 4.9: The contact section.

For the Log In section the visitor will be able to log into his account by entering his username and password. If no account, the visitor is asked to register by filling the right information.

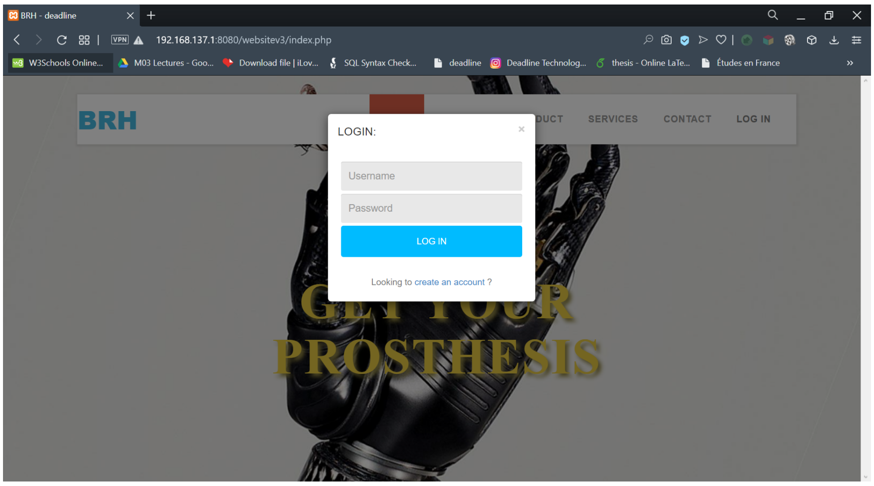

Figure 4.10: The Login form.

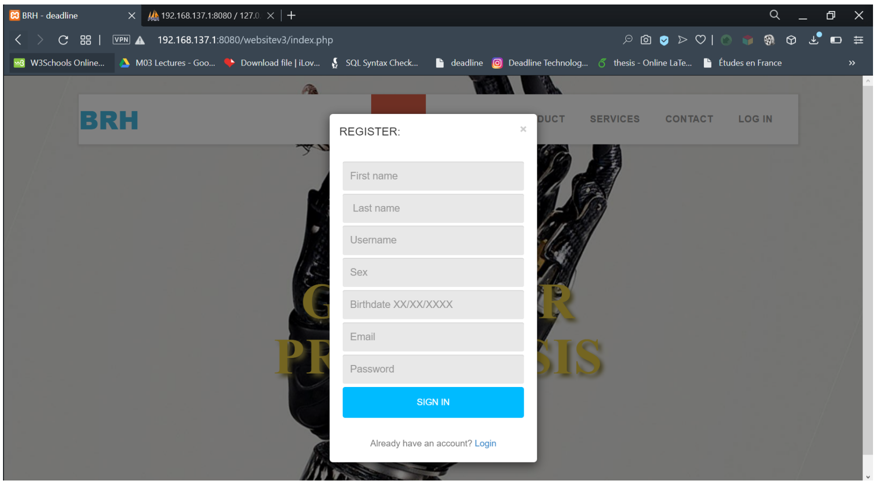

Figure 4.11: The registering form.

The Client page :

When entering the Client page, we will find a menu which leads us to different sections as well as the client's username :

- Services: Lists the offered services.
- Contact:To contact in case of any enquiry similarly to the home page.

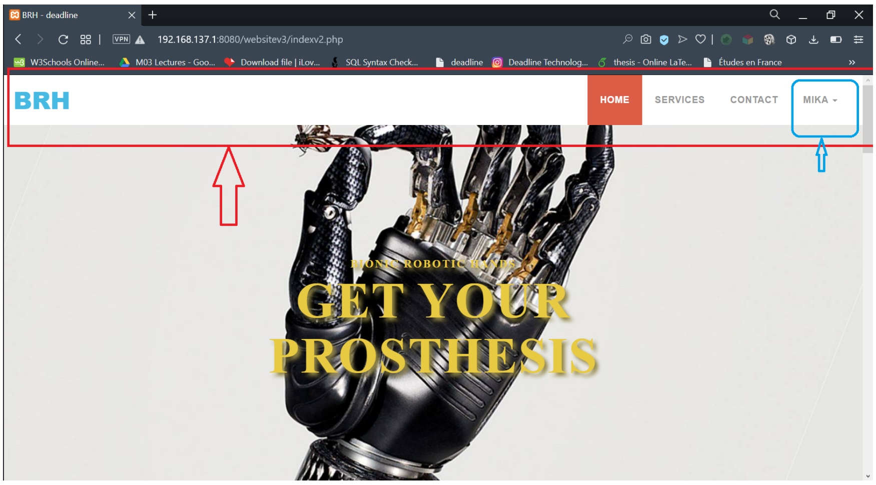

Figure 4.12: The client page overview with the header and username.

In the services section we find a part for ordering and fixing the prosthesis and also a part where a new client can take an appointment to make the required measurement.The client will be contacted later by e-mail for confirmation.

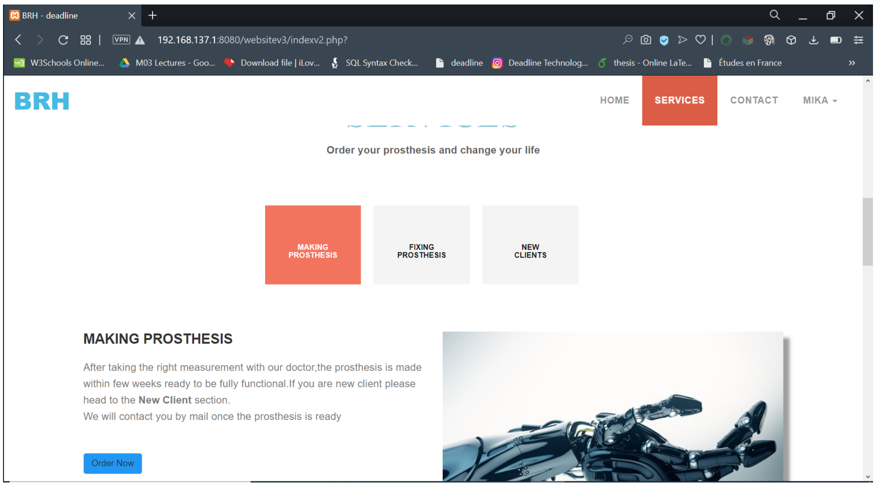

Figure 4.13: The order section.

To take an appointment the client simply need to fill a simple form and then will be contacted by email.

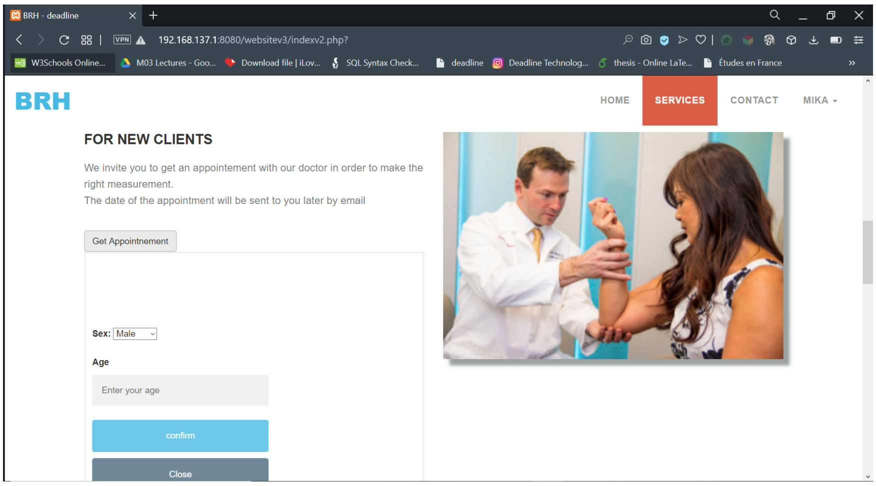

Figure 4.14: The appointment section.

The administrator page :

The administrator page is dedicated to the administrator of the company in order to manage th client, the orders, the appointment and the data.
When accessing the page, the menu lead us to the following sections:

- Clients:The list of all the clients is found.
- See data:Two operations can be made; see or insert client's data.
- Orders: The list of all the orders.
- Appointments:The list of all the appointments.
- To fix: The list of all the broken prosthesis for repair.
- Messages: The list of all the messages.

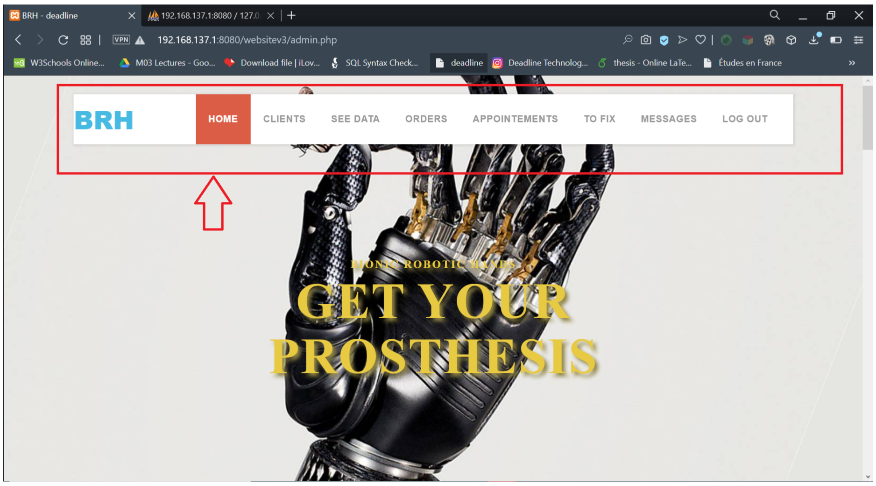

Figure 4.15: The administrator page header.

In the clients section,the administrator has access to the list of all the subscribed clients with their designated ID,name,sex,birth-date and email.

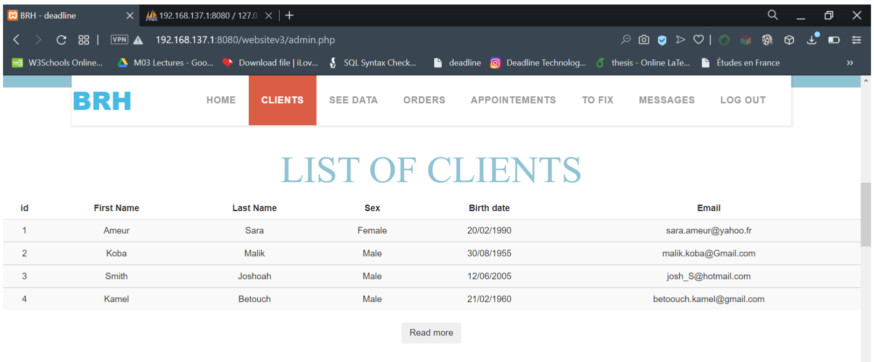

Figure 4.16: The list of clients.

In the data section the client's data can be inserted and for that the id of the client and the data link are needed. The administrator can search for a client's data using it's id, he will get a link that will directly lead him to an CSV file that contains all the client's data.

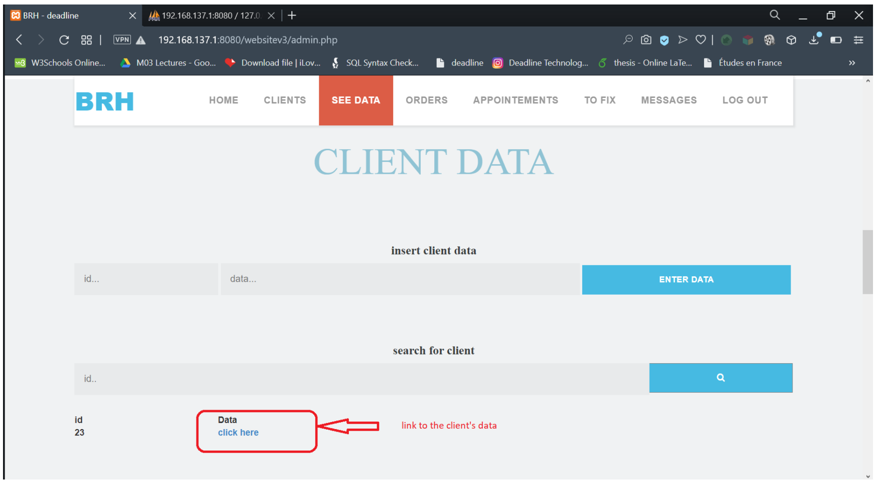

Figure 4.17: The data section.

In the orders section, we find all the orders made by the clients, with id of the order as well as the id and the name of client and the date of the order was made.

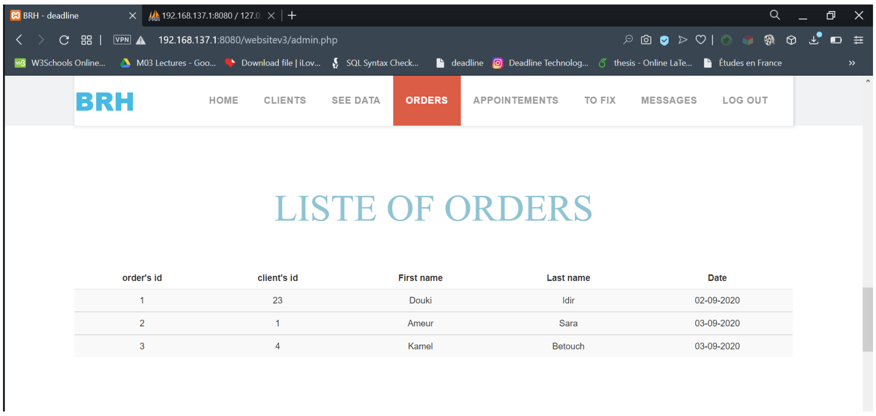

Figure 4.18: The orders section.

In the appointment section we find the list of all the appointment of the new clients along with their id, sex, age, email and date of the request .

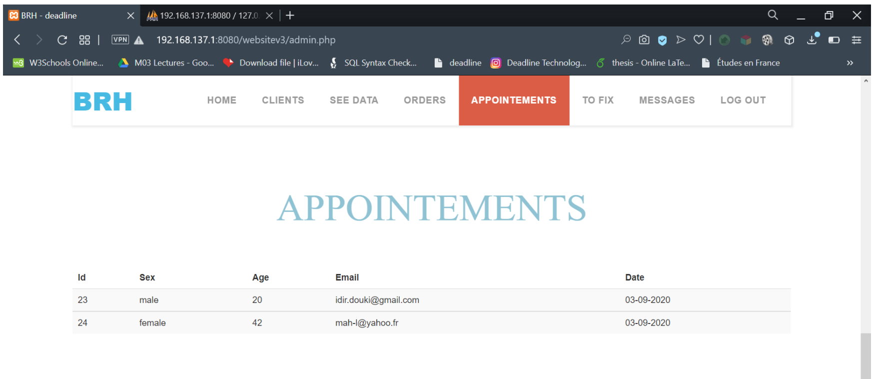

Figure 4.19: The appointment section.

In the Fix section we find the list of all the broken prosthesis of clients who demand to be fixed along with their Id, name, email and the broken part.

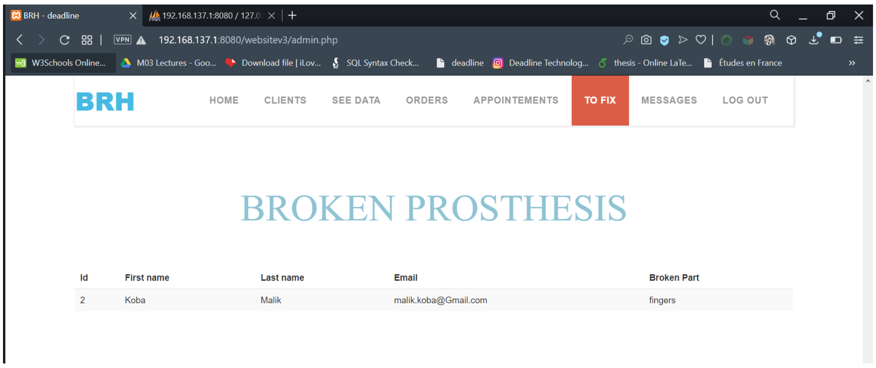

Figure 4.20: The fix section.

In the messages section we find the the messages either from clients or visitors asking for information.

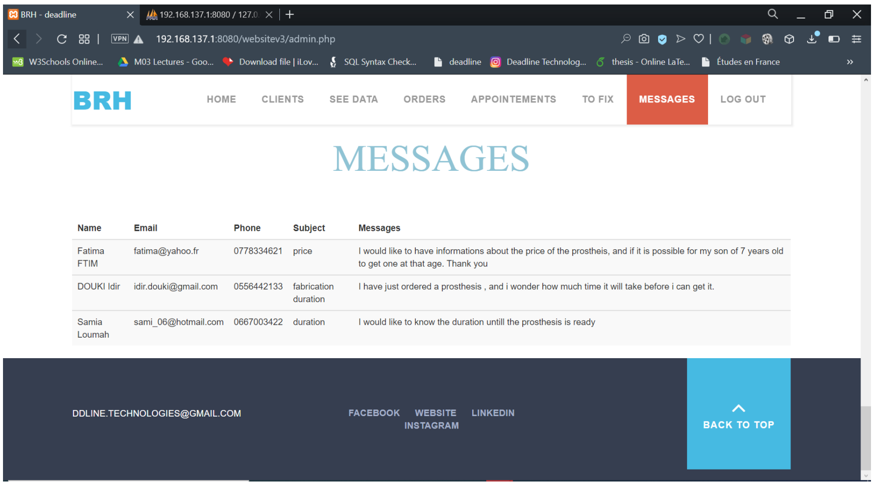

Figure 4.21: The messages section.

4.1.4 Website hosting

In this part we are discussing the steps for hosting the BRH platform. We used 000webhost, a free website hosting solution that provides an array of features, including a website builder, WordPress support, and no ads. 000webhost provides some features including 1 GB Disk Space, 10 GB Bandwidth, Free Domain Hosting and PHP and MySQL.

We start by setting the project name as **BRH-Deadline** .The website folder is created in 000webhost ready to be managed.We find as well the the URL address of the website.

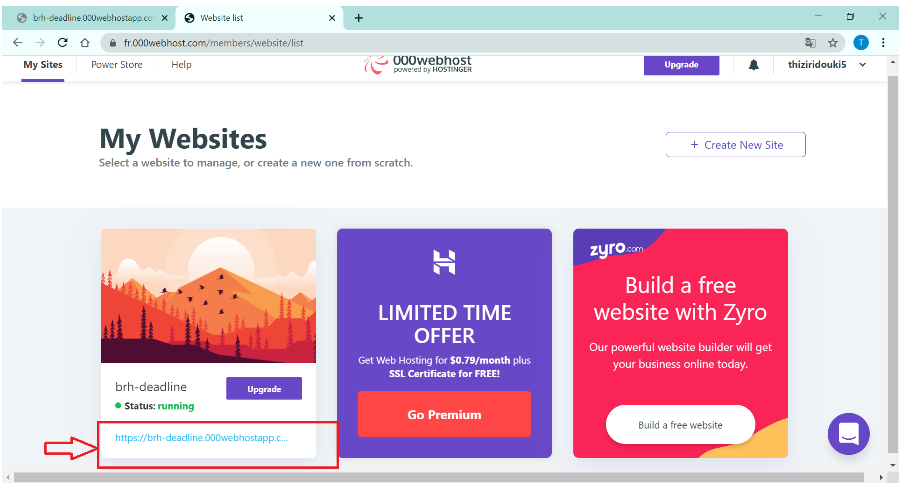

Figure 4.22: The website folder.

The next step is managing the website which consist of uploading the codes that build our website as well as the data base. The dashboard provides us with some statistics such as the monthly bandwidth quota and the disk space quota.

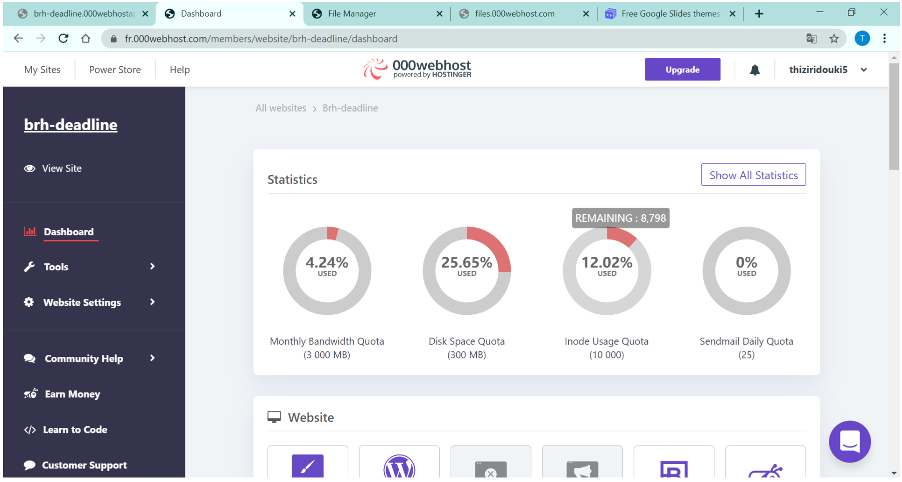

Figure 4.23: The dashboard overview.

Uploading the files that build up the website with File Manager accessed from tools.The files are uploaded in the **public-html** folder.

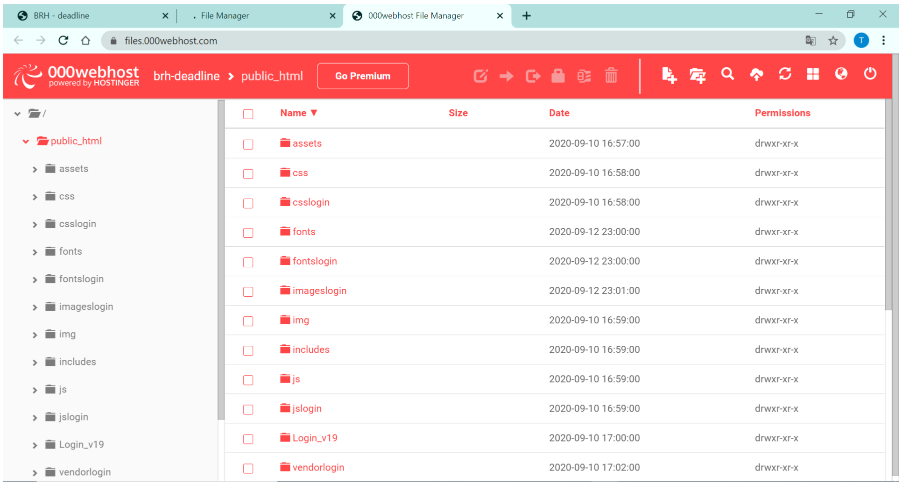

Figure 4.24: File manager.

A new data base is added, the name and ID set to id14823615-brh and id14823615-root.

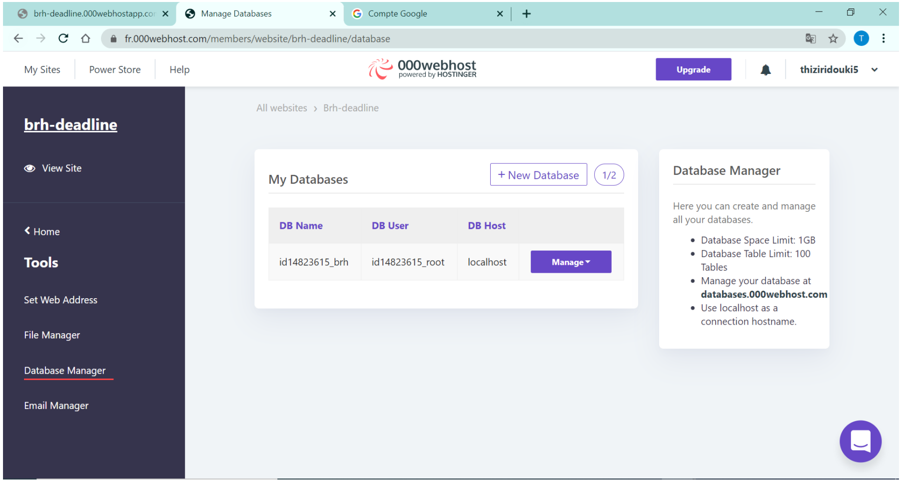

Figure 4.25: Data base setting.

After the data base is created, the table are imported from the previous data base.

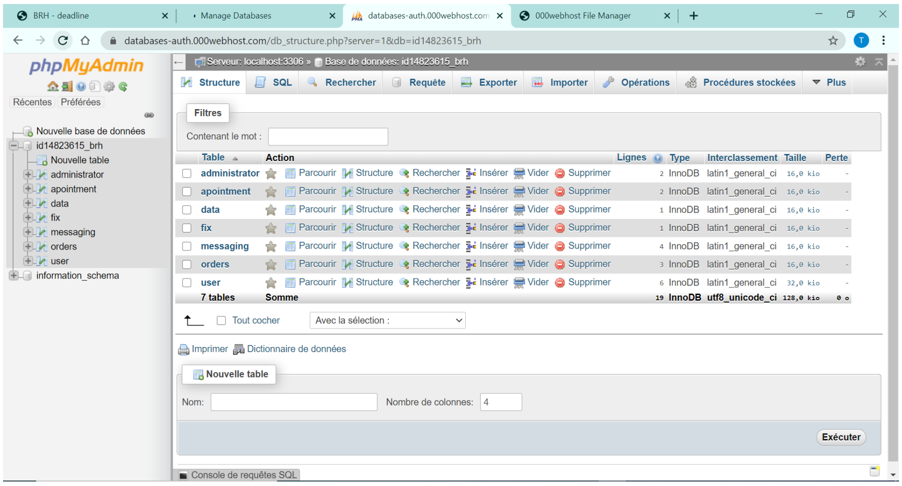

Figure 4.26: Importing the data base.

Finally, the website is hosted and ready to function under the domain name **brh-deadline.000webhostapp.com**

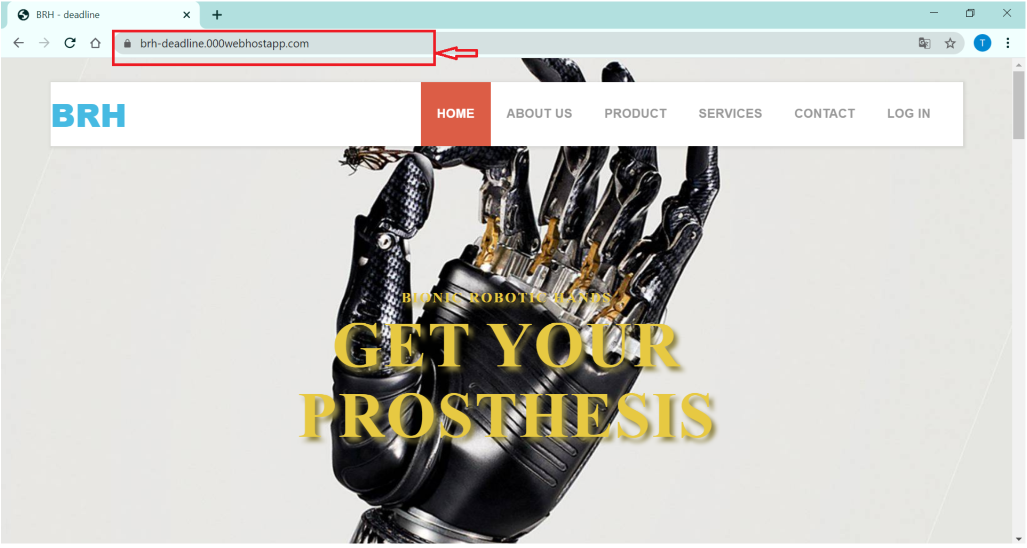

Figure 4.27: BRH platform final result.

Thus we have briefly described the making process of our website by specifying the development environment and the followed procedure for the realization as well as the presentation of some of the website interfaces.

4.2 EMG Signal Analysis

In this section we are going to deal with the followed steps during the EMG signals analysis starting from detection, processing, classification to application on the bionic hand.

4.2.1 Detection and Processing

For this two steps we have used muscle sensor v3 mentioned before, which contains 3 blocks (measuring, rectifying and smoothing). Muscle Sensors are designed to be used directly with a micro controller. Therefore, our sensors do not output a RAW EMG signal but rather an amplified, rectified, and smoothed signal that will work well with a micro controller's analog-to-digital converter (ADC). This difference can be illustrated by using a simple sine wave as an example.

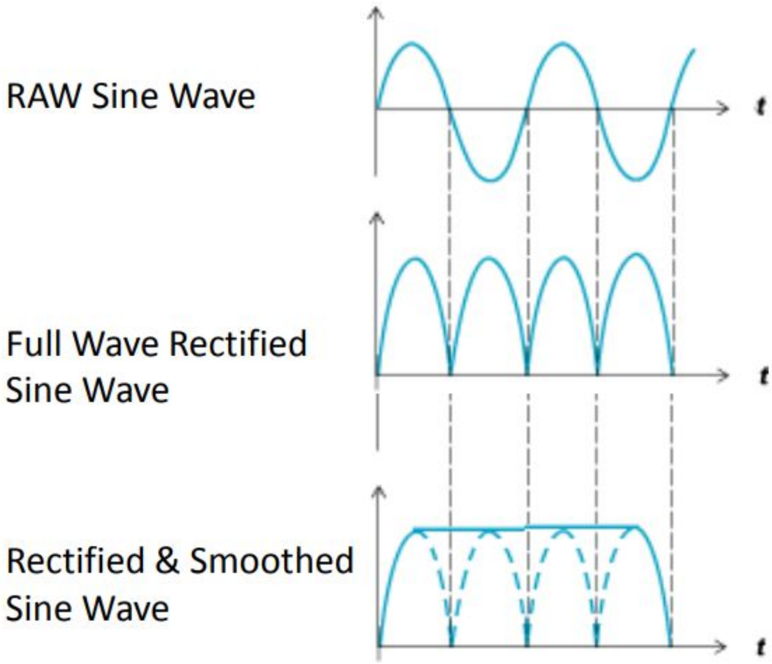

Figure 4.28: RAW EMG vs Rectified and Smoothed EMG.

Software Environment :

MikroC PRO for ARM is a full-featured ANSI C compiler for ARM Cortex-M3, M4 and M7 devices. It is the best solution for developing code for ARM devices. It features intuitive IDE, powerful compiler with advanced optimizations, lots of hardware and software libraries, and additional tools. Compiler comes with comprehensive Help file and lots of ready-to-use examples[12].

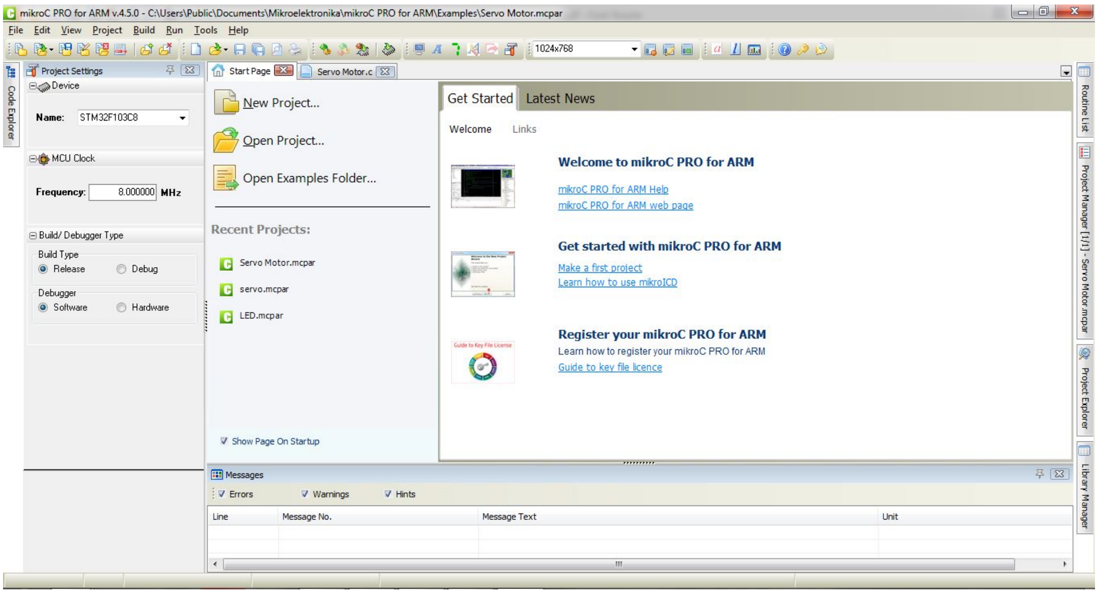

Figure 4.29: MikroC PRO for ARM IDE.

Signal Acquisition :

The classification part of our analysis is done by Matlab software, for that we have used a simple C code to read the rectified and smoothed EMG signal using STM32 12-bit ADC and then we send this data via URAT to matlab with 9600 baud Rate to be classified.

ADC.c

```
unsigned long adc_result = 0;
unsigned long relation = 0;
unsigned char lowB,highB;
unsigned  char receive;
void main() {
        GPIO_Digital_Output(&GPIOC_BASE, _GPIO_PINMASK_13);  // led 13 as output
        GPIOC_ODRbits.ODR13=0; //LED 13 ON (active low) ... used for debug
        ADC_Set_Input_Channel(_ADC_CHANNEL_0); //select ADS channel 0
        ADC1_Init();        //init ADC
        UART1_Init(9600);   // init UART with baud rate 9600
    while(1){
       adc_result=ADC1_Get_Sample(0); //ADC0 Read and put value in adc_result
       lowB= adc_result & 0xFF;       //Since ADC is 12 bit we split data in LowByte and HighByte
       highB= adc_result >> 8;

       UART1_Write_Text("ADC Value 1: ");
       UART1_Write_Text(lowB);   //print in Uart
       UART1_Write('\n');

       UART1_Write_Text("ADC Value 2: ");
       UART1_Write_Text(highB);
       UART1_Write('\n');

        }
```

Figure 4.30: ADC and UART code.

In the other hand we received the data in matlab software as follow:

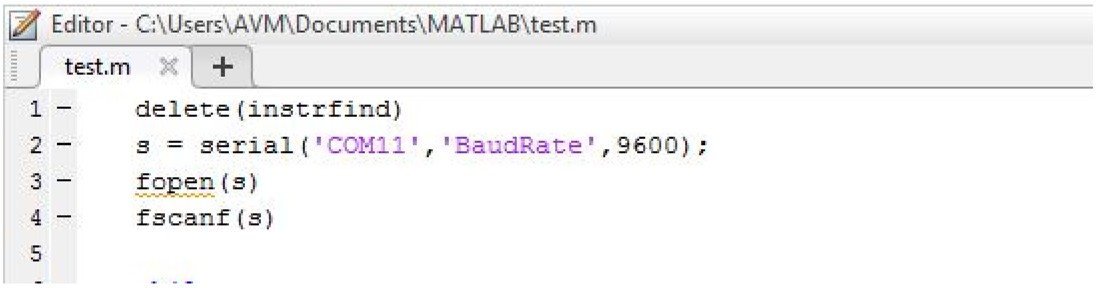

Figure 4.31: Matlab receiving code.

After receiving the data from the micro controller we plot it to get the following EMG signal:

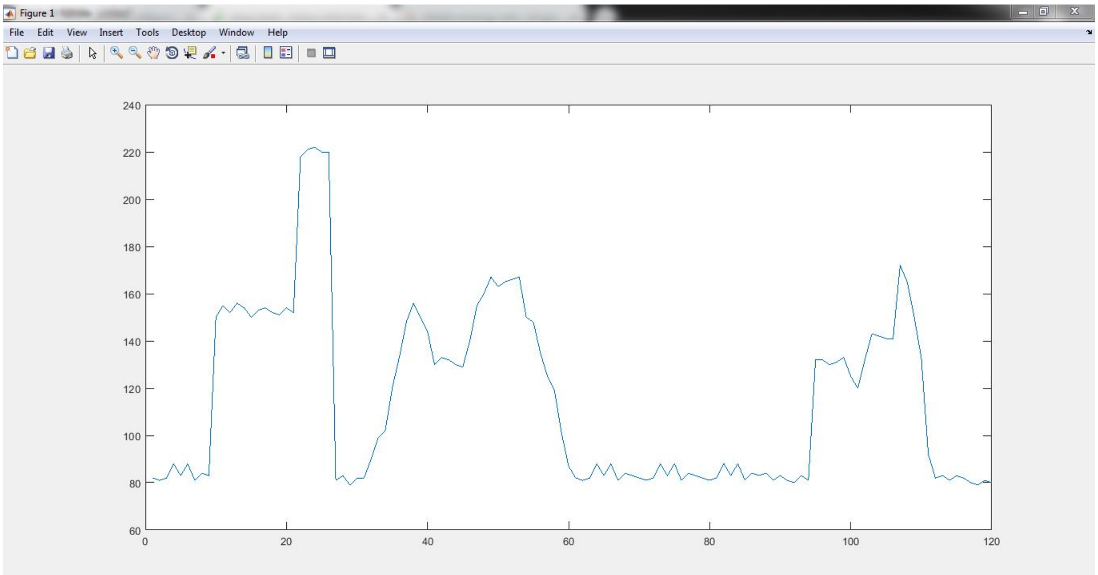

Figure 4.32: EMG signal

4.2.2 Gestures Classification

Now using this data we classify our gestures, we have used two approaches for gestures classification:

Amplitude Classification :

For this approach we are going to classify the gestures based on the amplitude and the peak of the signals obtained from the muscle sensor. For every gesture we have defined an interval of amplitude and for each interval the micro controller will generate control signals for the motors to do the appropriate gesture.

For example if we have assigned 4 gestures, each gesture has an interval. Amplitude classification approach will check for which the test signal belongs in order to generate the appropriate control signals for the motors.

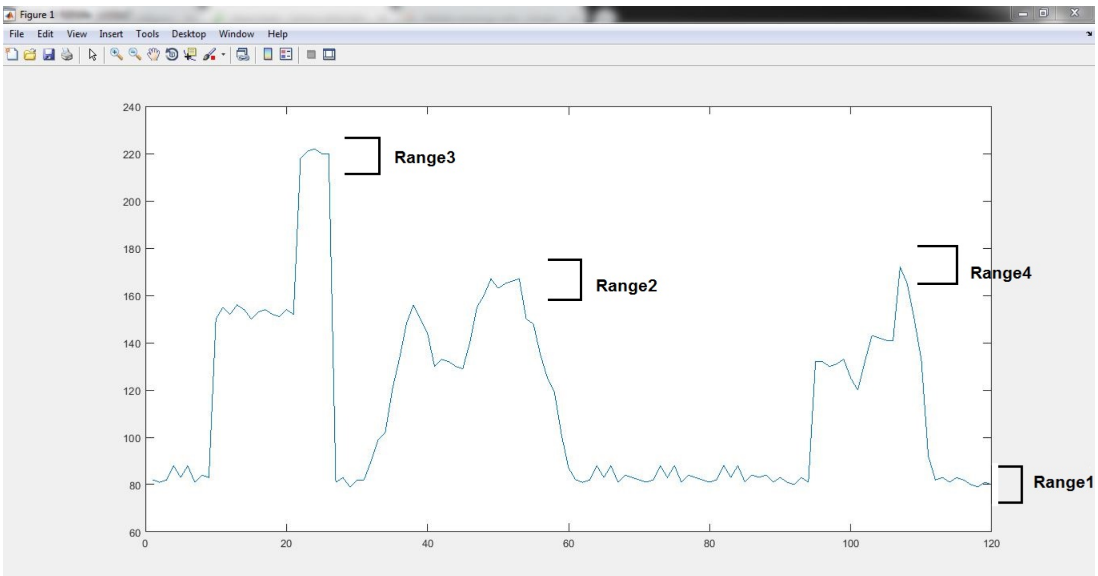

Figure 4.33: Peak Ranges.

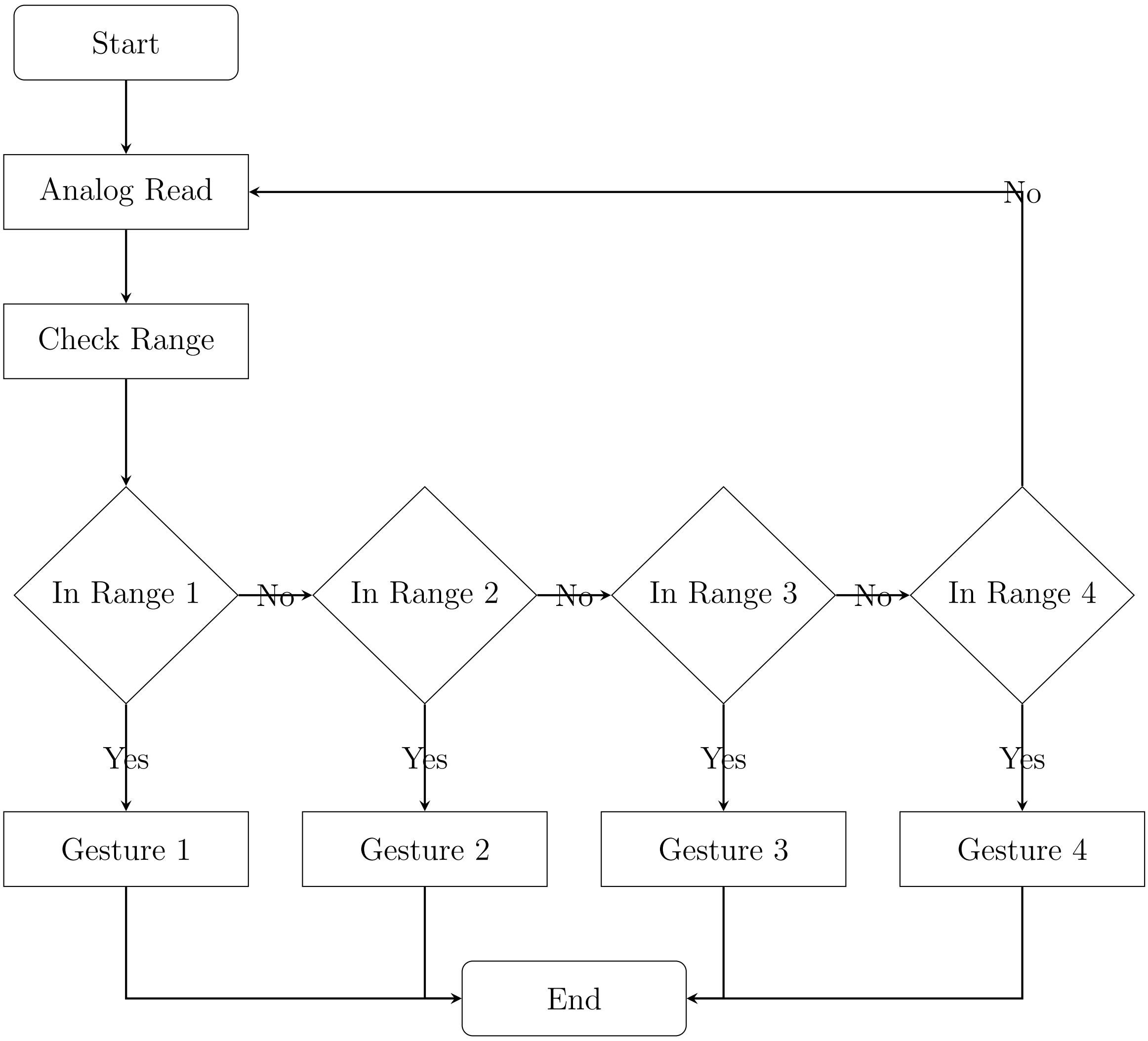

Figure 4.34: Amplitude classification Flowchart

General Shape Classification :

This approach allows for a wider range of gestures to be identified. MATLAB software provides us several methods and functions to classify gestures. Coefficient correlation one of these functions which classify gestures according to their shapes, matrix of two random variables is the matrix of correlation coefficients for each pairwise variable combination [11].

Correlation coefficient formulas are used to find how strong a relationship is between data. The formulas return a value between -1 and 1, where:

- 1 indicates a strong positive relationship.
- -1 indicates a strong negative relationship.
- A result of zero indicates no relationship at all.

The absolute value of the correlation coefficient gives us the relationship strength. The larger the number, the stronger the relationship.

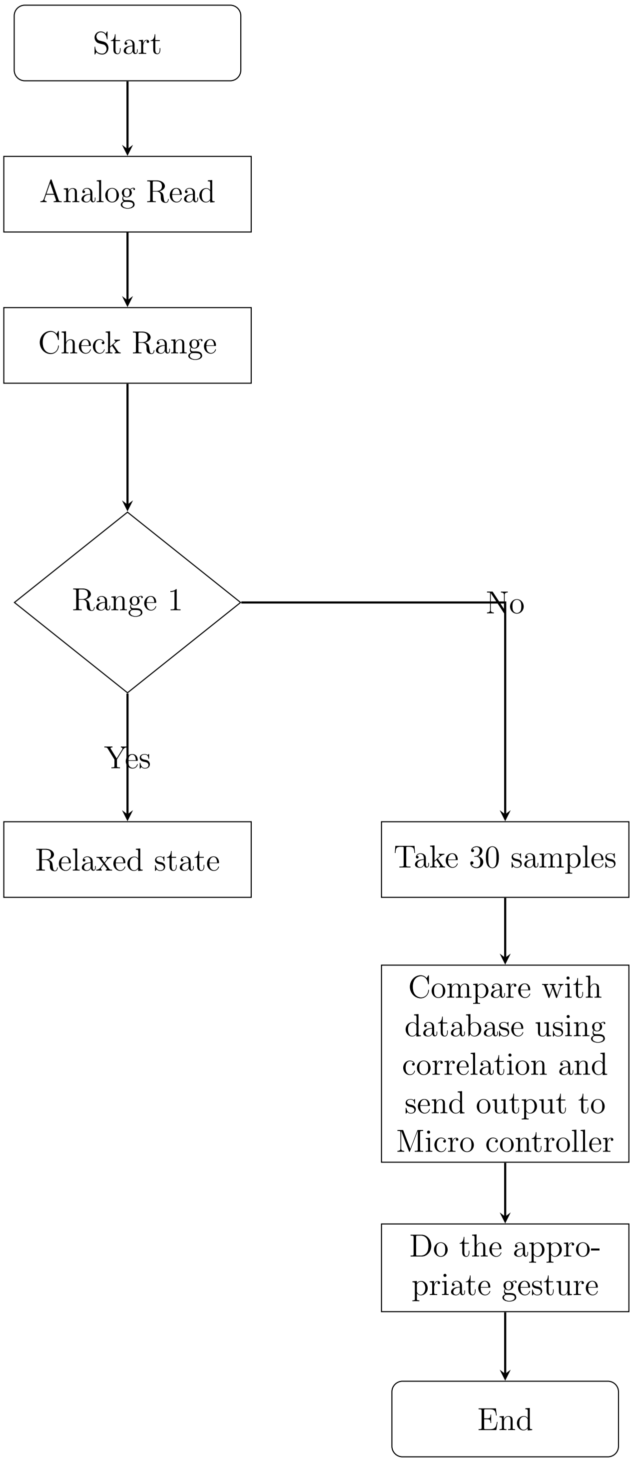

Figure 4.35: Grneral shape classification Flowchart

First, we have extracted and saved a number of gestures as CSV files (in our example six gestures), each has 30 samples with 80 millisecond delays between each two, this gives us a frequency of $F = 1/T = 1/0.080 = 12.5Hz$.

A scientific recommendation is 1000 Hz sampling frequency to avoid signal loss. But in our case the signal is already amplified and filtered in order to get a sampling frequency equal twice the highest frequency of the signals.

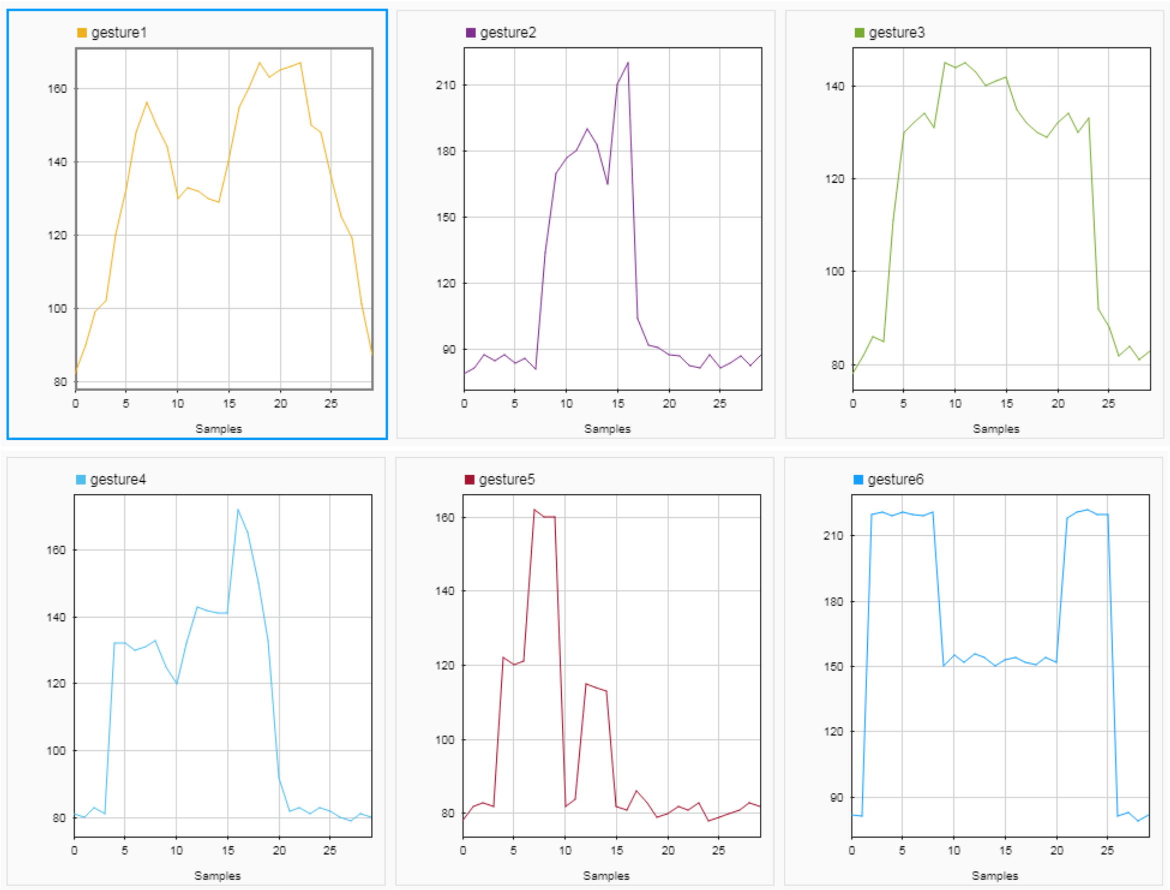

Figure 4.36: Gestures database.

Now for the testing data obtained from the sensor, the first 30 values after reaching our Open hand state value (relaxed state), will be saved and mapped to a specific gesture after correlating through our gesture database. Correlation coefficients will give us a range from -1 to +1, the highest amongst values from that range will decide our desired gesture.

We use the following Matlab code to save the first 30 samples after reaching ”rest gesture” as a test gesture :

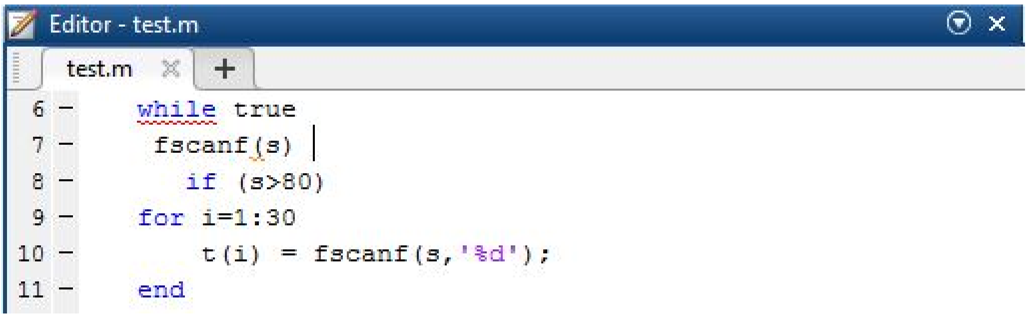

Figure 4.37: Test samples code

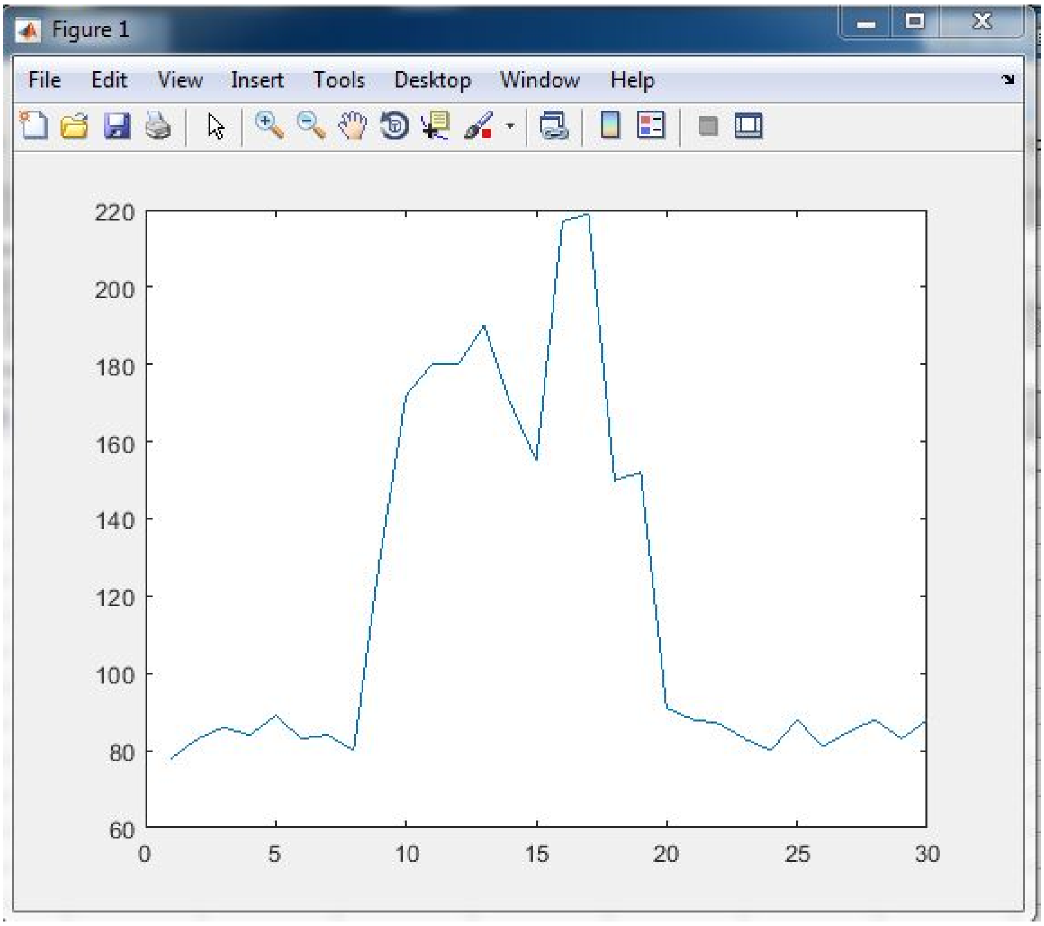

Figure 4.38: Test gesture

Now we are going to compare this test gesture with our signals database using correlation coefficients function. We found the following result :
CC1 = +0.41 (correlation result with gesture1)
CC2 = +0.83 (correlation result with gesture2)
CC3 = +0.22 (correlation result with gesture3)
CC4 = -0.57 (correlation result with gesture4)

CC5 = +0.36 (correlation result with gesture5)
CC6 = +0.13 (correlation result with gesture6)

As we have seen before the absolute value of the correlation coefficient gives us the relationship strength. The larger the number, the stronger the relationship. So in this case the larger result is CC2=+0.83, which means test gesture match gesture 2.

4.2.3 Application

Now for the application of the classified EMG signals we have assigned movements for the hand for each gesture in our database so that when correlation function give us result, Matlab will send message to the micro controller via UART in order to generate the appropriate control signals for the servo motors to make the appropriate gesture.

Figure 4.39: BRH movements.

Chapter 5

Result and Discussion

The final shape of the Bionic hand is exactly like the 3D model, it matches also a real human hand. In addition to it light weight that make it a complete product. useful for disabled people.

Generally, the two approaches used in signal analysis are working properly with some issues. Amplitude classification method cannot handle many gestures, we were able to do limited gestures. General shape classification can perform many gestures but due to time needed for Matlab analysis we had a problem of delay. We can say technically that the hand is able to mimic several gestures made by the user, but still not able to catch every move, this due to the unprofessional equipment used.

Another factor worth taking into consideration is the noise coming from the surrounding environment which affect the hand functionality and make it unstable, but this problem can be overcome. We also notice that the EMG signal can differ from a person to another in terms of amplitude and frequency, meaning that the hand cannot be used by different users with the same gestures database.
This table shows the difference between the two methods of signal analysis we used :

	Amplitude classification	General shape classification
time response	Excellent 30ms-500ms	Good 500ms-1000ms
Accuracy	Good	Excellent
Gestures number	$\langle 8$	$\langle 25$

Table 5.1: Comparison table.

One another problem is that the system is affected by environmental noise coming from the surrounding components like power supplies, computers and specially charger of laptop, also the noise coming from the rings and bracelets and all other things that can deform the signal and makes the hand less stable, human skin plays a major role in the quality of measured signal, the hair on the skin of the arm really affects the signal as many other factors do.

Chapter 6

Conclusion and Future work

Our principal objectives were met, we implemented a robotic bionic hand controlled by EMG signals. It is designed to match a real human hand. The overall system generally performs well, since the robotic hand is able to mimic the gestures made by the users. The micro controller receives it input signal from the muscle sensor, and then generates the desired output based on those inputs. So, it can be used by people with disabilities since it is easy to use. Which makes our project conform to actual technologies and robotics researches. The product sale website has been been developed successfully.The clients easily perform ordering or others functions on the platform. The administrator well receives the data.This project made us face different issues and problems especially in the hardware part. Due to it we learnt how to model using 3D design software, and printing as well as implementing a complete system, web development, write programs and algorithms that match our desired gestures.

As our researches extended to Design models, building a complex and efficient product, we learned some information outside the electrical engineering world.
Finally, in our study we discovered that our project could have a real impact on the Humanitarian aspects, because it is huge benefit to amputees that lack their hands due to accidents or due to congenital malformations since they still have EMG signals, The functionality of the hand allows its user to do simple everyday tasks such as picking up items, eating using a spoon, typing and clicking a mouse or opening doors. The hand can also be a good choice in the economic and marketing side, as it is built with a low-cost material compared to the actual ones available in the market, it is cheap so that it can be very productive as the market in our country is quite empty in the robotic prosthetic field and many people could really benefit from it

Different adaptations and improvements have been left for the future due to luck of means and time.This future work consist of bringing modifications and adding some characteristics that will extends the hand's performance. The following ideas could be added:

- We could put additional sensors in order to make the prosthesis sensible to the external world. As an example adding a temperature sensor to notify the user in case of a high temperature around the hand.

- We could use more powerful motors that will allow more weight handling while lifting.
- We could work on reducing the time response of the hand.

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