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In Computer Science

Option: Network and Intelligent Systems

Title

Realization of an electronic devices remote control system by voice and brain signals

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Abstract

The realization of electronic devices remote control system by voice and brain signals is a project that can be used for controlling home appliances or wheelchair remotely. This system is designed to be used by all categories of people but must particularly be used to assist and provide support in order to fulfill the needs of elderly and disabled people. The main control system implements wireless technology through a Bluetooth module, an Infrared LED, and a radio frequency signals. This system was designed to be of low cost (compared to another project) and scalable allowing a variety of devices to be controlled with minimum changes to its core. The design is based on a standalone Arduino board and the home appliances are connected to the input-output ports of this board via relays.

The project has two parts. The first which is 'voice control' that means using human voice to control any devices or motor (in case of wheelchair). The voice recognition is done in real time using HMM model. This work provides three applications concerning the voice control, one is run on window platform and two on android platform (Home/Wheelchair Voice Control is an application run on computer while Control Wheelchair and Control Home Appliances are two other separate applications for cellphones). The second part is 'thinking control' that uses brain signals to control the wheelchair under the window platform. These signals are captured using a headset called Epoc+ from Emotiv. Those signals will be converted to actions.

Résumé

La réalisation des dispositifs de commande à distance des appareils électroniques en utilisant la reconnaissance vocale et les signaux cérébraux est un projet qui peut être utilisé pour contrôler à distance les appareils ménagers ou un fauteuil roulant électrique. Ce système peut utile pour tous les catégories des gens mais il est conçu surtout pour aider les personnes âgées et handicapées et répondre à leurs besoins. Le système de commande met en œuvre la technologie sans fil à travers le module Bluetooth, LED infrarouge, et des signaux de radio fréquence. Ce système conçu pour être à faible coût (comparé à d'autres projets) et évolutif permettant de contrôler des différents appareils sans changement dans leur infrastructure. La conception est

basée sur une carte Arduino ou les appareils ménagers sont connectés aux ports d'entrée / sortie de cette carte via les relais.

Le projet comporte deux parties, la première c'est la commande vocale qui signifie l'utilisation de la voix humaine pour contrôler tous les dispositifs d'une maison ou d'un moteur (en cas d'un fauteuil roulant). La reconnaissance vocale faite en temps réel en utilisant le modèle HMM. Concernant la commande vocale, nous développons trois applications, une conçu à exécuter sur une Platform Windows et les deux autres conçu à exécuter sur une Platform Android.

La deuxième partie est la commande avec pensé en utilisant des signaux de cerveaux pour commander un fauteuil roulant à l'aide d'un ordinateur. Ces signaux sont capturés à l'aide d'un casque appelé Emotiv Epoc+. Ces signaux seront utilisés et convertis en des actions.

الملخص

التحكم في الأجهزة الالكترونية عن بعد باستخدام الصوت أو التفكير هو مشروع يمكن استخدامه في التحكم بالأجهزة المنزلية والكراسي المتحركة لذوي الاحتياجات الخاصة. فكرة المشروع تقوم على مساعدة كافة الناس وخاصة كبار السن وذوي الاحتياجات الخاصة في ممارسة مختلف النشاطات اليومية بشكل مستقل بعيدا عن الشعور بالحرج او الحاجة الى الغير باستمرار.

يعتمد النظام على الاتصال اللاسلكي باستعمال تقنية البلوتوث، الإشارات تحت حمراء وترددات الراديو. صمم المشروع حتى يكون أقل تكلفة على غرار المشاريع المماثلة، وبحيث يكون ملائم لبنية كل المنازل أو الأجهزة المراد التحكم فيها. تستند بنية المشروع على لوحة أردوينو حيث توصل الأجهزة معها من خلال منافذ الادخال والإخراج التابعين للأردوينو.

يتكون المشروع من قسمين، الأول هو التحكم باستعمال الصوت، وهو ما يعني استخدام الصوت البشري في التحكم بكافة أجهزة المنزل أو المحركات (في حالة وجود كرسي متحرك). يتم التعرف على الصوت بشكل آني باستخدام نموذج ماركوف الخفي. في هذا السياق قمنا بتطوير ثلاثة برامج، أحدها مخصص للعمل على جهاز الحاسوب والاثنين الاخرين على الهواتف النقالة.

القسم الثاني، متعلق بالتحكم عن طريق التفكير، اعتمادا على الإشارات الدماغية المتسربة من الأعصاب الناقلة للسيالة العصبية. يمكن من خلال التفكير التحكم في أي جهاز الكتروني أو أي كرسي متحرك. يتم التقاط هذه الإشارات باستعمال جهاز يسمى Epoc من شركة Emotiv. يتم استغلال هذه الإشارات ومعالجتها برمجيا ثم تحويلها الى أوامر تطبيقية.

Dedicates

We dedicate this thesis to the sake Allah our Creator and our great teacher the messenger Mohamed "May Allah bless and grant him".

We offer this work to our dear families who give us all help and never forget us in their prayers.

A big gratitude to our parents may Allah bless them.

A special dedicate to our beloved sisters and brothers.

We send a big greeting for all our close friends and neighbors, all who never forget us and all the ones in our life who touched our hearts.

Greetings and appreciations to all those who are asking for science and never get tired of seeking knowledge.

We dedicate this research to the University Ahmed Draia, to the MI department, our professors, our classmates and the working agents.

Ayoub & Djemaa.

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In the Name of Allah, the Most Merciful, the Most compassionate all praise be to Allah, the Lord of the worlds; and Prayers and peace be upon Mohamed His servant and messenger.

First and foremost, We must acknowledge our limitless thanks to Allah, the Ever-Magnificent; the Ever-Thankful, for His help and bless. We are totally sure that this work would have never become completed, without His guidance.

We owe profound gratitude to our supervisor Mr. Djilali CHOGUEUR for his patience.

We would like to express our big gratitude to him for the useful comments, remarks and engagement through the learning process of this master thesis. Thank you for Mr. KADDI, MEDIANI Mohammed and Mr. SID AMR Allal for their help and their precious time. We would like to express our respect and gratitude to Mr. the president and all members of jury.

We also would like to express our grateful thanks to our families for their generous support they provided us throughout our entire life and particularly through all these years of study. Because of their unconditional love and prayers, we have the chance to complete this thesis.

We would say thanks for all who supported us, and help us. Special thanks and respect to all our professors and our close friends during the fifth years ago.

Thank you.

Table of Contents

List of Figures

List of Tables

General Introduction

In recent years and with the rapid development of science and technology, the need for an easy life became very important. Throughout this evolution, the human-machine or machine-to-machine communication emerged as a new type of dialogue. Therefore, it will be great to develop, for example, home devices that communicate between them or be controlled by the home's owner. That is what we call a smart home or home automation. A typical home automation system allows one to control household appliances from a centralized control unit. These appliances include lights, fans, air conditioners, television sets, etc.

Nowadays, everybody dreams of getting a smart home without having to change the infrastructure of his/her home. Every one dreams of being more at ease and of being able to control his/her environment by giving some instructions while lying down on the bed. Let us be far from laziness and think in positive way. How helpful will it be if we use those technologies to help elderly and handicapped people?

A significant number of disabled people cannot use a wheelchair or it is hard for them to drive it. They cannot even do daily tasks easily; they cannot move to turn ON room lights or a TV, for example.

The project "Realization of an electronic devices remote control system by voice and brain signals" comes to allow these people to move autonomously. The project purposes to control home devices or a wheelchair remotely using voice or thinking (mind control) without really changing the home infrastructure.

Talking about voice control means discussing the recognition process in real time. We develop two mini-projects in different platforms to control home appliances or a wheelchair using some voice instructions. First, we have applications controlled by computer and developed using C# programming language and sphinx toolkit to perform the recognition using HMM model. The second one is controlled by a cellphone (smartphone) and developed using Android Studio with setting some configuration for pocket sphinx (toolkit version android).

What about brain signals? Well, it is our challenge in this project. It is the second part of this implementation. Several programs are written to control different interfaces using Electroencephalography (EEG) data. The brain activity monitoring is a main part of the

programs to perform different tasks such as controlling a wheelchair robot or home devices. EEG data is being recorded while users are concentrating on given tasks through a headset called Epoc+ from Emotiv. Activity on different regions of the brain is measured. Using these measurements, EEG data is classified for different cognitive actions. As a beginning, we develop an application controlled by computer just for the wheelchair movement using a processing software.

The project is not based just on computer science but also needs a collaboration with the domain of electronics, which was not easy for us. To get our objective, we used an Arduino micro controller (on which are some programs to respond to our needs), which converts signals received from the developed software into actions. We used relays as switches and Bluetooth modules because our platform is based on wireless communication or precisely Bluetooth communication.

Our work is partitioned in four chapters. The first chapter describes in details the project and its aims while the second one talks about the hardware units and also the software (tools and programming languages) that has been used. To better understand the project and adapt it to a scientific standard, a conceptual study based on object approach is presented in the third chapter. The implementation and achievement are discussed in the last chapter. As a conclusion, an evaluation of our work is presented taking into account the difficulties encountered, followed by future work that may improve and develop more the present project.

Chapter 1

- **General Presentation**

- **What is "Realisation of Remote Control of Electronic Devices"?**
- **Home Automation**
- **Problematic**
- **Timing Diagram**

Introduction

The purpose of this introductory chapter is to put our work in its general context. First, we start with a brief presentation of the subject detailing its setting and features. Then we present the most known domains of its application. Finally, we define the problematic of the subject and the proposed solution in addition to the main objectives.

1. What is "Realization of an electronic devices remote control system by voice and brain signals"?

Wireless communication is often required in fields such as tele-health, household security, industrial safety, home automation, etc. Bluetooth was selected as our way of communicating computer/mobile with a central system.

In this project, the home appliances and the wheelchair will be controlled by a remote system based on Bluetooth; and two operating systems, mobile and computer. The appliances in question are appliances such as lights, TV, air-conditioner, digital satellite receiver, etc.

The system can be used to remotely switch on or off any household appliance using a prototype of Arduino Uno to achieve hardware simplicity and a Bluetooth module for feedback from a computer/android device to toggle the switch state.

2. Home Automation

Home automation is the use and control of home appliances remotely or automatically. Hardware devices can include sensors (like cameras and thermometers), controllers, actuators (to do things), and communication systems. Remote control can range from a simple remote control to a smartphone with Bluetooth, to a computer on the other side of the world connected by internet. Home automation systems which consist of a suite of products designed to work together are available today.[1]

It is a system that is supposed to be implemented in existing home environments, without any changes in its infrastructure. Home Automation allows the user to control the home from his or her computer/mobile and to assign actions that should happen depending on time or other

[1] Home Automation - Relevant to Indian Consumer & Current Market Maturity. [Online] Retrieved April 2016, from: http://ifihomes.com/blog/home-automation-relevant-to-indian-consumer-current-market-maturity

sensor readings such as light, temperature or sound from any device in the Home Automation network.

This system can be operated by electricity or a computer chip using a range of different types of switches. A simple device, such as light, can be activated by a signal from a motion detector, or can be part of a computerized home automation system. As a very basic definition, we tend to refer to home automation as anything that gives you remote or automatic control of things around the home.

Home automation systems or smart home technologies are systems and devices that can control elements of your home environment as lighting, appliances, telephones, home security and mechanical entry and safety systems.

Figure 1: Home automation system

It also called domotics which may designate an emerging practice of increased automation of household appliances and features in residential dwellings, particularly through electronic means that allow the control of things that were impracticable, overly expensive or simply not possible in recent past decades. The term may be used in contrast to the more mainstream "building automation" which refers to industrial settings and the automatic or semi-automatic control of lighting, climate doors and windows, and security and surveillance systems. The techniques employed in home automation include those in building automation as well as the control of home entertainment systems, etc.[2]

[2] *Automation*. [Online] Retrieved April 2016, from : https://en.wikipedia.org/wiki/Automation

Any automation system is composed of primary elements, which are:

- The operating system (for example, a computer or a mobile).
- The device being operated (for example, a light)
- The interface, or link, between the user and the device.

The control of devices inside this system can be done by a remote or an automatic control:

a- Remote control

Remote control gives you the convenience of controlling lighting, appliances, etc from wherever you happen to be at the time. There are several "different" methods of controlling devices remotely;

b- Automatic control

Automatic control adds even more convenience by making things happen automatically, without any effort being necessary.

3. Problematic

Imagine how helpful it will be to be able to switch on your air conditioning system, lighting system, your TV without any effort and in an easy way! How about having an easy life? This is our main purpose.

Actually, everybody wants to do all his/her tasks in short time and using less effort. That is what we call modern life where everything works automatically.

Nevertheless, did anyone think about people with special needs (disabled people in society or elderly persons)? Did the new technologies help them? Why do only normal people benefit from the advantages of development?

Asking these questions makes us in a real problem. It makes us think in a way to get good answers. Now the answers must be practical not just theoretical.

People with special needs always need someone next to them, someone to help them, and someone to take care of them and understand their needs. This is so hard for their families or neighbors and takes a lot of their time and efforts. This situation makes people with special needs feel embarrassed.

Sometimes, we cannot even understand their needs, like the 100% disabled people who cannot talk or move their hands to tell us what they need; food, drink, go out, etc.

Helping those people needs collaboration between two different domains, the first one which is the computer science domain and the second which is the electronics domain. The first one develops programs and the second uses technologies (material) and is able to assemble electronic components to get new material controlled by our application.

This project realizes a remote control of electronic devices using voice and thinking (mind control). This control includes home electrical devices and the wheelchair.

3.1. Voice part: the user will be able to control his/her home devices with his/her voice. He just has to say the order, for example, 'turn lamp on or off', etc.

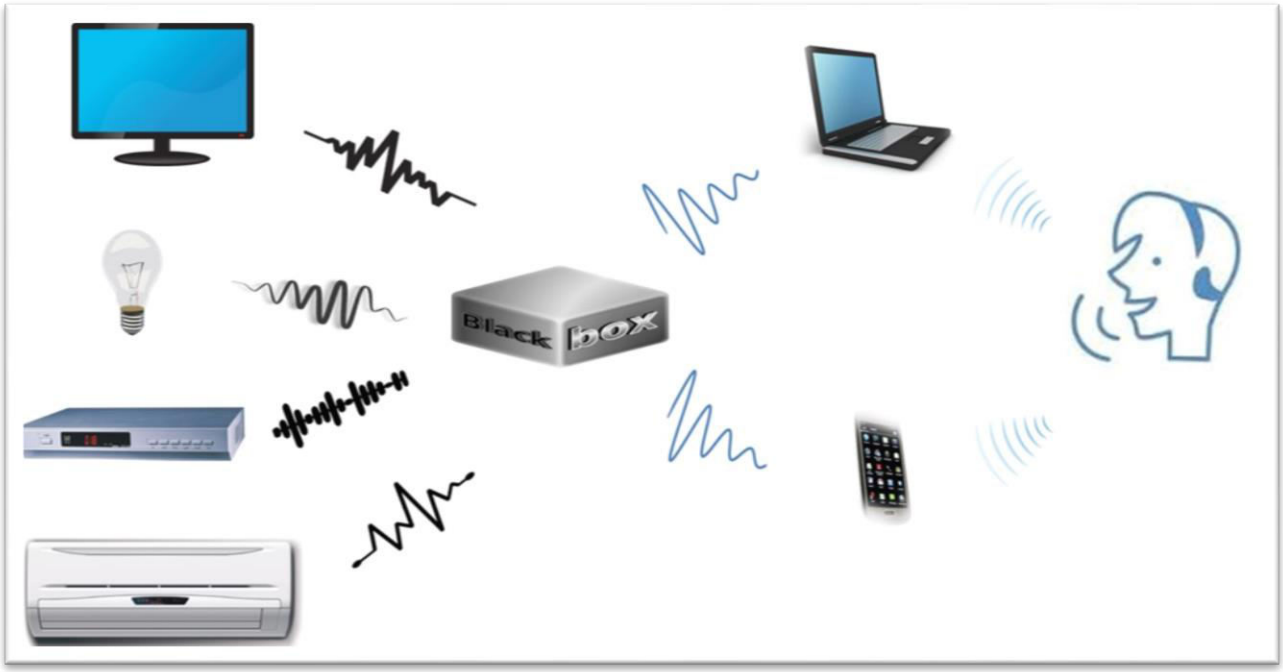


Figure 2: Voice control architecture

Two applications are developed to enable a user to control the home appliances or wheelchair, one for computer and the other for smartphone.

3.2. Thinking part: it is the challenging step. Now the user can just think to turn the lamp or any other device on and it will be on. Here we use a headset called "EPOC headset" which is based on electroencephalography (EEG) to capture some head signals. However, the problem is that the headset does not give us the possibility to save those signals, which puts us in front of a difficult situation.

The solution was making a secondary program which reads those signals and sends them to principal program in order to process them.

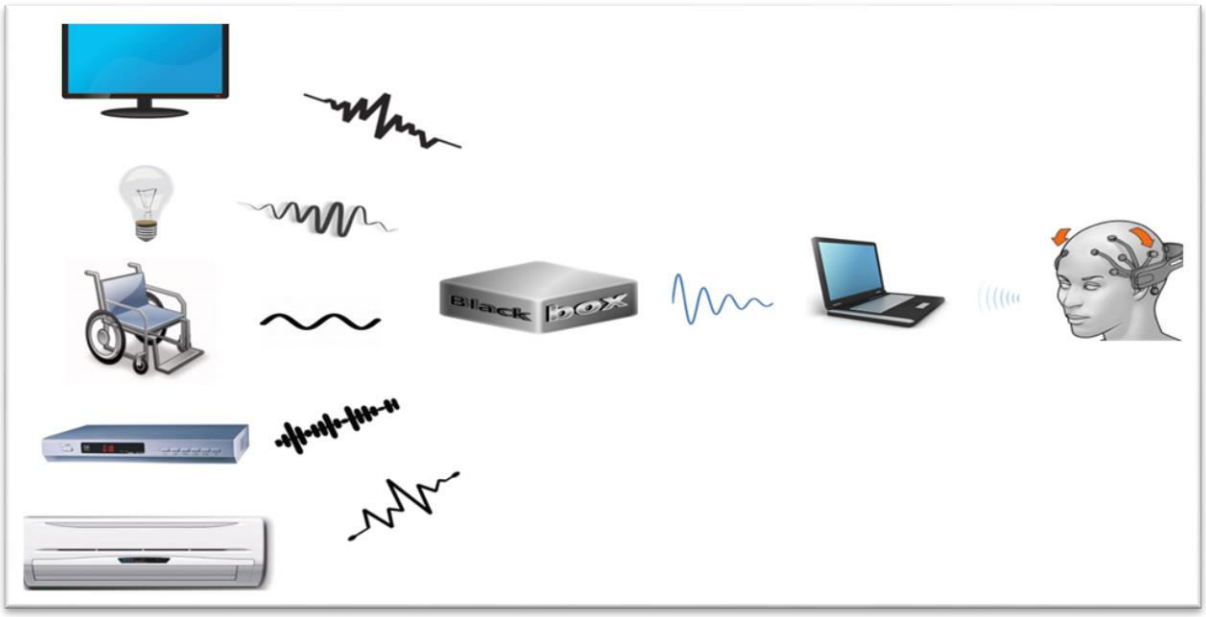


Figure 3: Mind Control Architecture

Another problem is dealing with different (distinct) programming languages in order to realize the project. Four programming languages are used to achieve this objective.

Now, the person with special needs can be able to control his/her appliances like a wheelchair and others can understand his/her needs. If a person with special needs want water, for example, a message will be shown that contains the need of water.

We can resume the objective of this work in the following points:

- Adapting new recognition system which is thinking recognition in addition to voice recognition;
- Using new technologies to facilitate life;
- No more embarrassing situations for people with special needs and elderly persons. He can control his/her appliances and wheelchair alone;
- Ability to understand more the people with special needs;
- Giving a greater control of home environment;
- Saving time and effort.

4. Timing Diagram

For the realization of our graduation project, it was necessary to follow a well-defined approach. The diagram below gives an idea about the progress of the project.

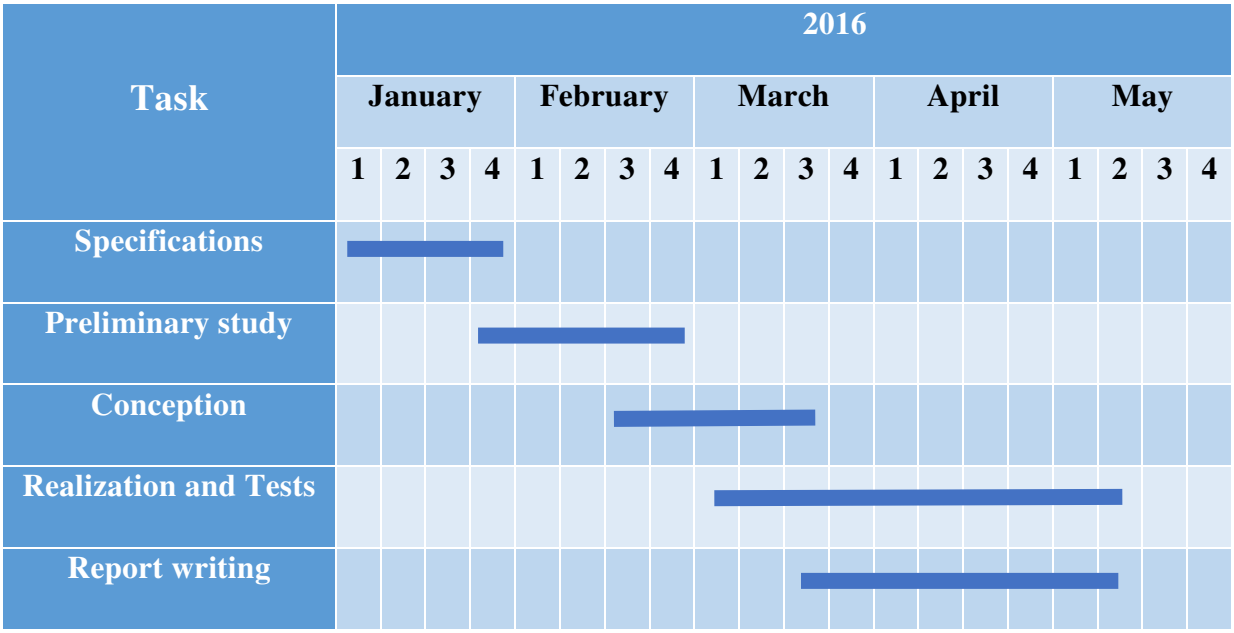


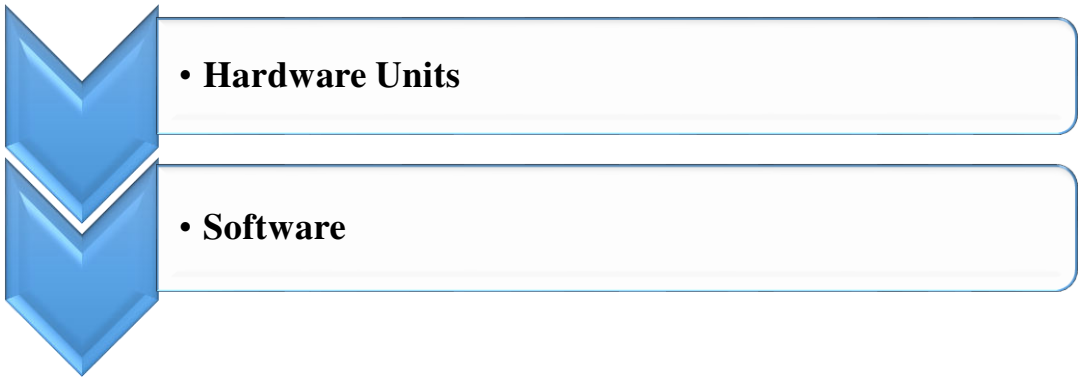
Table 1: Timing diagram

Conclusion

After the brief presentation of the project environment and understanding the problem, the difficulties, the proposed solutions and the main objectives, we will pass in the next chapter to define the units used in the achievement either in hardware or in software.

Chapter 2

- **Hardware Units and Programming Language**



Introduction

This project needs a collaboration between two distinct domains. Therefore, this chapter will present two different concepts. The first, which is the hardware part, will describe the main components that has been used while the second will present the software tools used to develop the applications.

1. Hardware Units

1.1. Arduino

a. General Presentation

Arduino is an open-source platform used for building electronic projects. Arduino has both a physical programmable circuit board (predominantly referred to a microcontroller) and a piece of software or IDE (Integrated Development Environment) that is used to write and upload computer code to the physical board.[3]

The Arduino platform has become widely popular with people just starting out with electronics because the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board. You can simply use a USB cable and upload your program onto the Arduino. Additionally, the Arduino IDE uses a simplified version of C++, which is a program that is easy to learn.

Arduino was born at the Ivrea Interaction Design Institute (in Northern Italy) as an easy tool for fast prototyping. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

b. Arduino Types

There are many types of Arduino; every one selects the best-fit (right) board for his needs depending on the project requirements and/or the level of expertise.

We will display some figures that represent some types of Arduino boards. So, here there are eight famous or more used boards:

[3] *Introduction : what is Arduino?*. [Online]. Retrieved April 2016, from: https://www.arduino.cc/en/Guide/Introduction.

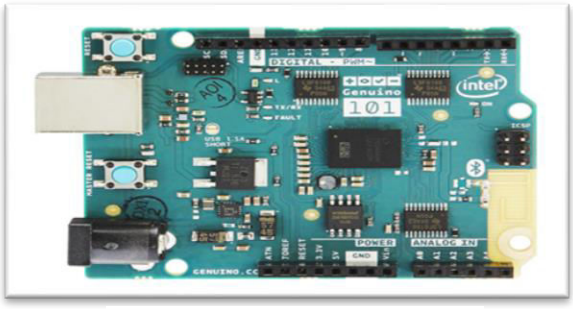


Figure 4 : Arduino 101

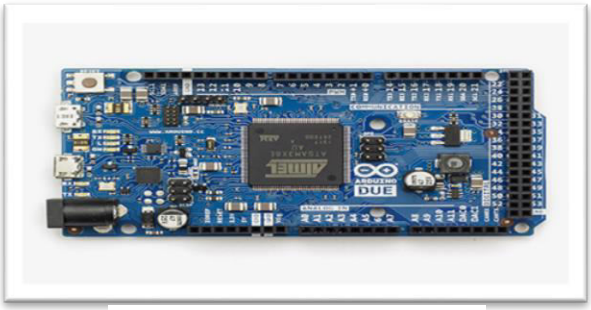


Figure 5 : Arduino Due

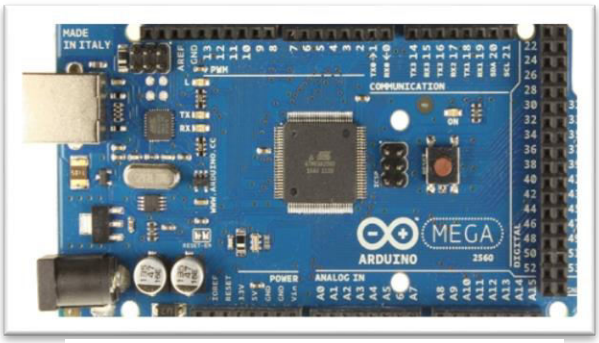


Figure 6: Arduino Mega (2560)

Figure 7 : Arduino Yun

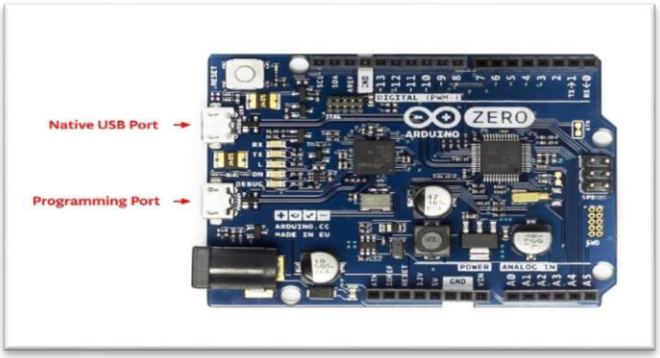


Figure 8 : Arduino Zero

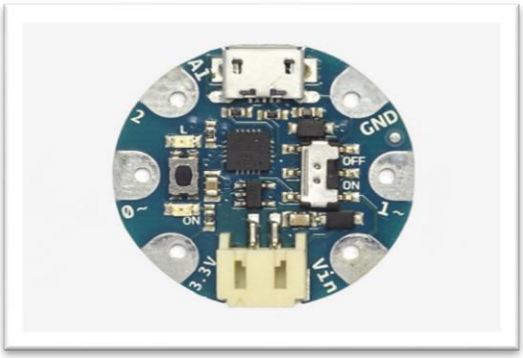


Figure 9 : Arduino Gemma

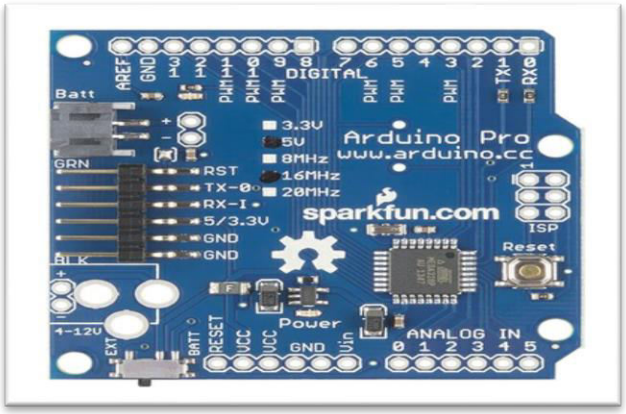


Figure 10 : Arduino Pro

Figure 11 : Arduino UNO

c. Arduino UNO

In the project, we chose Arduino UNO because the UNO is the best board to get started with electronics and coding and it is our first experience tinkering with the platform; so the UNO is the most robust board that we can start with. The UNO is the most used and documented board of the whole Arduino & Genuine family.

The Arduino UNO is a microcontroller board based on the ATmega328[4]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller, simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The UNO differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "UNO" means one in Italian and it is named to mark the upcoming release of Arduino 1.0. The UNO and version 1.0 will be the reference versions of Arduino, moving forward. The UNO is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.[5]

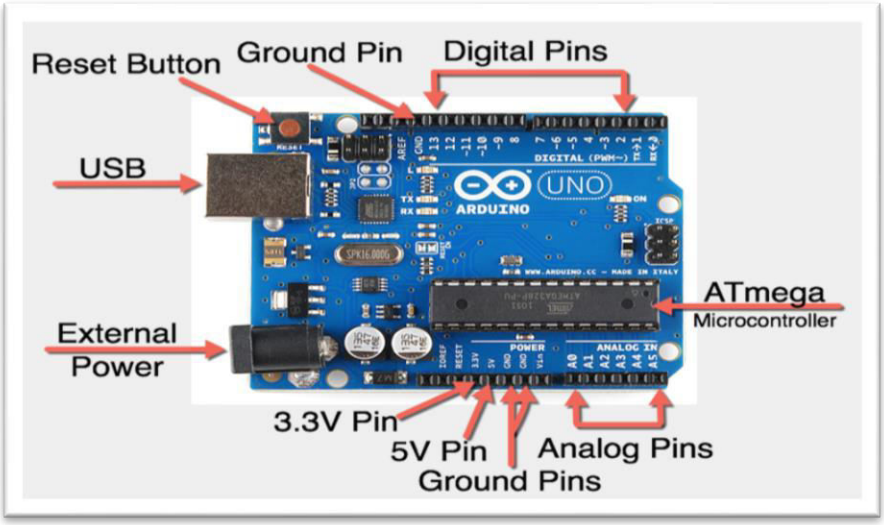


Figure 12: Arduino Uno parts

[4] The ATmega328 on the Uno comes preprogrammed with a boot loader that allows you to upload new code to it without the use of an external hardware programmer.

[5] *Arduino UNO & Genuino UNO*. [Online]. Retrieved April 2016, from: https://www.arduino.cc/en/main/arduinoBoardUno

Arduino can sense the environment by receiving inputs from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer. The Uno can be programmed with the Arduino Software (IDE).

1.2. Motor Shield and Sensor Shield v5

The Motor Shield is a driver module for motors that allows you to use Arduino to control the working speed and direction of the motor. Based on the Dual Full-Bridge Drive Chip L298, it is able to drive two DC motors or a step motor. The Motor Shield can either be powered directly by Arduino or by an external 6V~15V power supply via the terminal input. This module is used for the development of micro robots and intelligent vehicles, etc.[6]

The Arduino Motor Shield must be powered only by an external power supply, to reduce the risk of possible damage to a USB port because the motors attached to the motor shield need an ample power supply. By using the USB connection, the current will often be limited to 500 mA or 1 amp. Many motors will draw more current than the amount the USB source can supply.

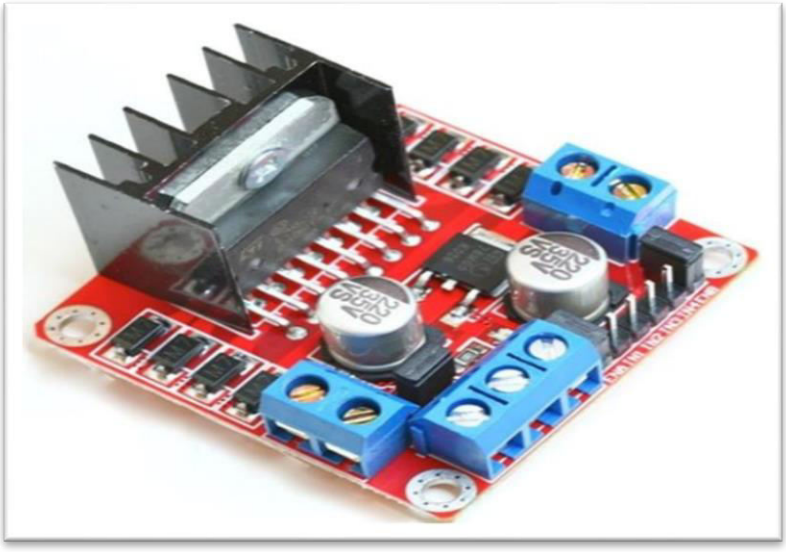


Figure 13: Motor Shield

[6] *Motor Shield V2.0.* [Online] Retrivied April 2016, from:http://www.seeedstudio.com/wiki/Motor_Shield_V2.0.

In addition, we used a shield called "Arduino sensor shield v5". The Sensor Shield's purpose is to make it easier to connect cables and devices to the correct Arduino pins. It is not an active device. It simply connects the Arduino pins to many connectors that are ready to be used to connect various devices like Servos and Sensors with simple cables.

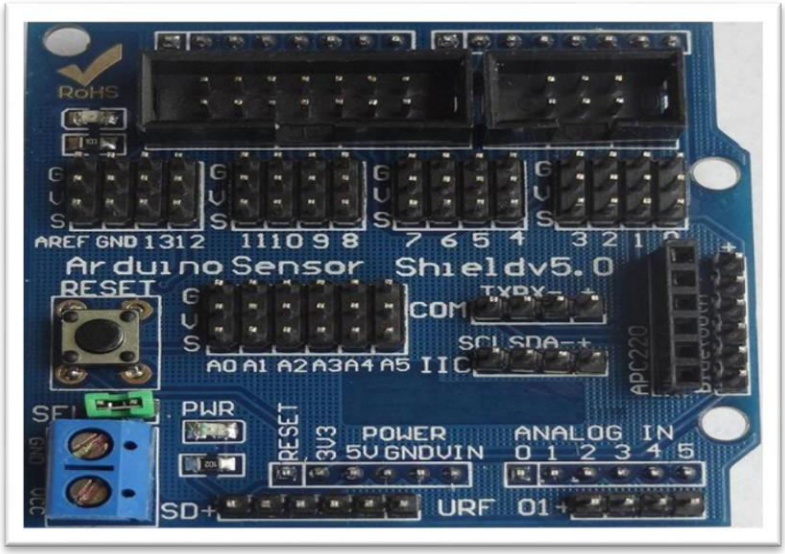


Figure 14: Arduino sensor shield v5

1.3. Bluetooth Module

a. General Presentation

Bluetooth is a type of wireless communication used to transmit voice and data at a high speed using radio waves. It is used for short-range radio communications between many different types of devices, including mobile phones, computers and other electronics. Bluetooth module has a range of around 10 meters and data transfer rate of 3 Mbps.

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module designed for transparent wireless serial connection setup. Serial port Bluetooth module is a fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04 -External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature).[7]

[7] *Serial Port Bluetooth Module (Master/Slave): HC-05*. [Online] Retrieved April 2016, from: http://wiki.iteadstudio.com/Serial_Port_Bluetooth_Module_%28Master/Slave%29_:_HC-05

HC-05 embedded Bluetooth serial communication module has two work modes: order-response work mode and automatic connection work mode. Moreover, there are three work roles (Master, Slave and Loopback) at the automatic connection work mode. When the module is at the automatic connection work mode, it will follow the default way set lastly to transmit the data automatically. When the module is at the order-response work mode, user can send the AT command to the module to set the control parameters and sent control order.

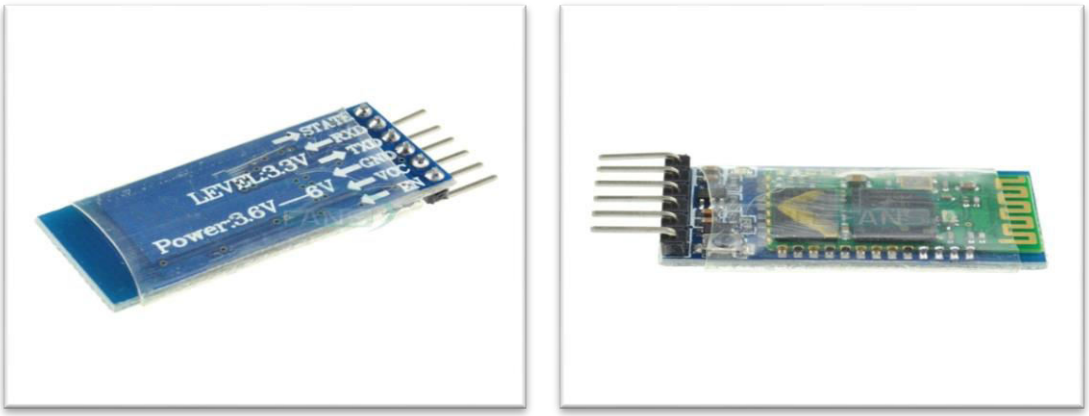


Figure 15: HC 05 Bluetooth Module

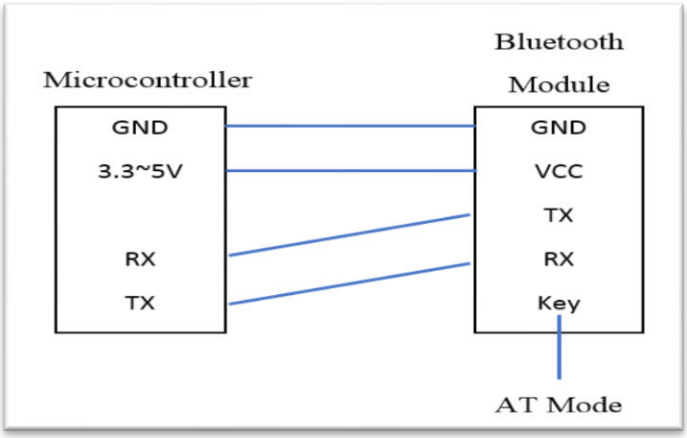


Figure 16: Typical Application Circuit

b. Characteristics:

1. Use the integrated Bluetooth chip CSR Bluetooth, v2.0 protocol standards;
2. Module Operating Voltage 3.3 V;
3. Potter default rate of 9600, the user can be established;

4. The Core Module Size: 28mm x 15mm x 2.35mm;
5. Operating Current: corresponding to 30 mA, corresponding to the communication to eight mA;
6. Used for GPS navigation system, water and electricity gas meters reading system;
7. Commercial Series: Bluetooth Serial Module Card with LED light indicator, use 150mA and 3.3V smart regulation;
8. With VCC. GND. TXD. RXD foot for Bluetooth;
9. With Bluetooth master module. "Module slave" or master-slave (whole) module;
10. Voltage Input: 3.3 ~ 6V;
11. Height: 1.55 cm x 3.98 cm;

c. Notes:

- Power Input 3.3~6 v, prohibit more than 7V; We advise to install "Bluetooth Module Master";
- No "automatically stop function power", so please properly connect the Power Supply.

1.4. Emotiv Epoc

a. Normal EEG Waveforms

Electroencephalography (EEG) can be captured at every nerve of the body. When a person attempts to move, nerve signals are sent from the brain to the muscles via moto neurons. At this moment, very weak EEG signals can be detected on the surface of the skin. The frequency of EEG rhythmic is in the range of 1–100 Hz. Each range of EEG frequency such as delta, theta and alpha signals can give information about the state of the brain. There are five bands of normal EEG rhythmic: Delta, Theta, Alpha, Beta and Gamma.[8]

[8] *GUIDELINE TO DEVELOP BRAIN COMPUTER INTERFACE.* [Online] Retrieved April 2016, from: http://sralife.com/?page=1_workblog_eeg-2014

Wave Type	Delta waves	Theta waves	Alpha waves	Beta waves	Gamma waves
Location	Frontal cortex	Locations not related to task being preformed	Posterior regions, either side of the brain	Either sides of the brain but mostly in frontal region	Somatosensory cortex
Frequency (Hz)	0-4 Hz	4-7 Hz	7-14 Hz	15-30 Hz	30-100 Hz
States of Mind (Functions)	Delta waves are present while one is fully asleep /dreaming	Theta waves occur right before going into a deep sleep (drowsiness)	Alpha waves, which are the focus of this lesson, happen in a reflective and relaxed state	Beta waves takes place when one is active and busy, stressed	Gamma waves are associated with problem solving and deep concentration

Table 2: Brainwaves, frequencies and characteristics

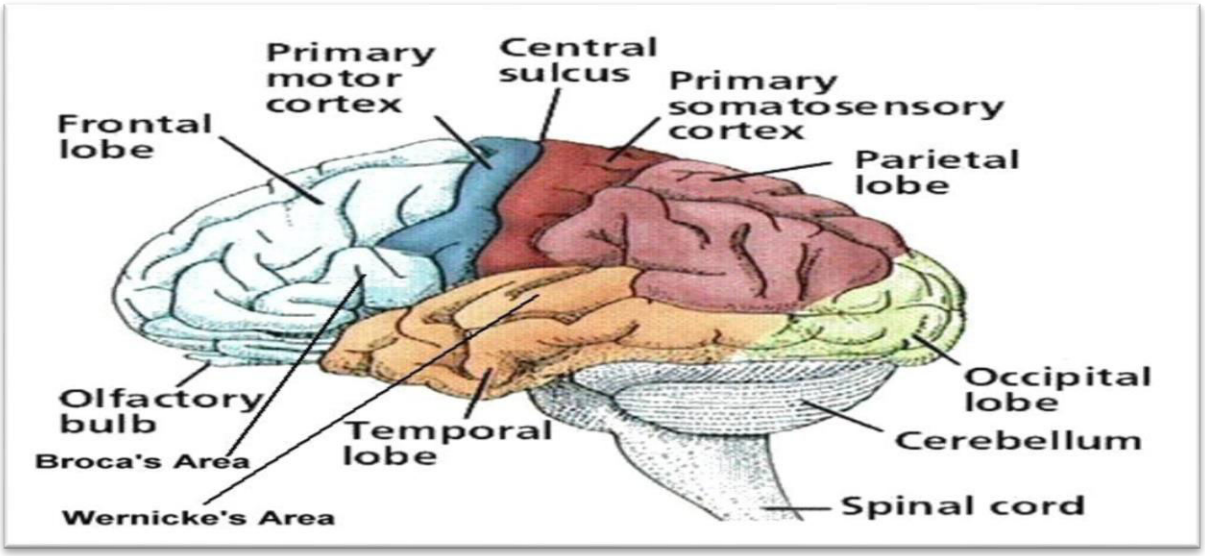


Figure 17: Brain lobe locations

b. Brain Computer Interface (BCI) System

There are three major physical components in BCI system:

1) Signal Acquisition: Converts electrode signals into digital numeric values that can be manipulated by a computer.

2) Signal Processing: Analyses and classifies EEG data:

- *Data Pre-processing:* Prepares raw data for further processing.
- *Feature Extraction:* Selects useful data for training and classification.
- *Data Classification:* Translates data into useful information such as computer command.

3) Device Receiver: Responds to the command from the Signal Processing.

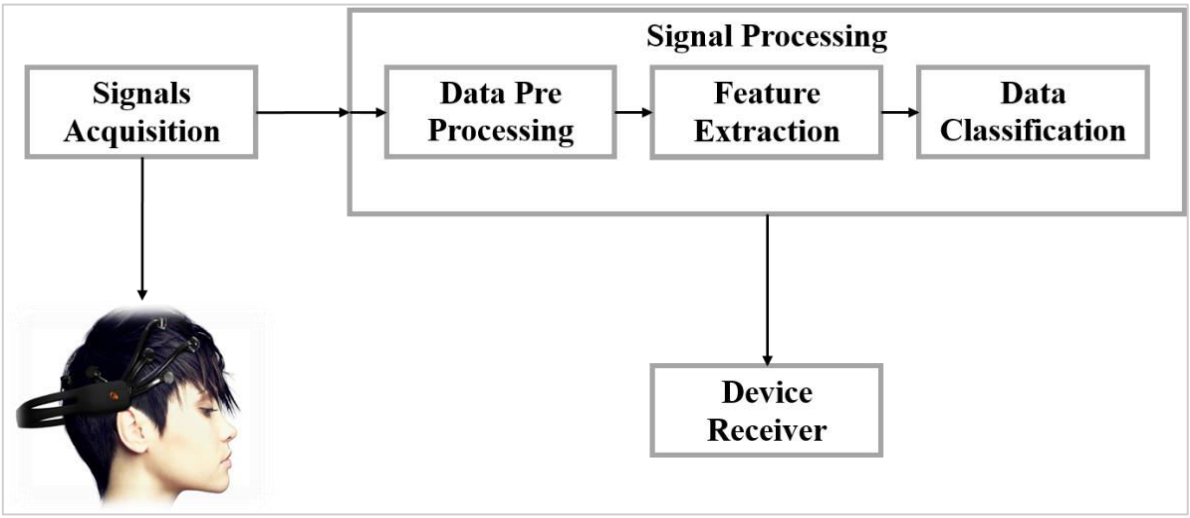


Figure 18: BCI Diagram

c. EEG headset/head caps comparison

For the Signal Acquisition, there are two types of EEG headsets and head caps. First, Single electrode headsets, such as the Neurosky Mindwave, are very simple and inexpensive but the data from single electrode is not enough to classify complex commands. Second, multiple-electrode headsets such as the Emotiv EPOC and standard EEG head cap are good in classification.

Component	Image	Channel Electrode	Wireless connection	Developer SDK
Emotiv EEG Neuroheadset		14	YES	PC/MAC
Standard EEG head cap		14-74	No	--
Neurosky Mindwave		1	YES	PC/MAC/iOS/ Android

Table 3: Headset/head caps comparison

Emotiv EEG neuroheadset was chosen as the signals acquisition devise. There are two versions of Emotiv EEG neuroheadset Epoc and Epoc+. There is no real difference between them. It is only that Epoc+ contains more monitor sensors. Asittionally, Epoc+ Supports the android 4+ platform whereas Epoc supports just PC platforms.

d. Epoc / Epoc+

Emotiv EPOC / EPOC+ has the features of 14 EEG channels plus 2 references offering optimal positioning for accurate spatial resolution. Channel names based on the international 10-20 electrode location system are AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4, with CMS/DRL references in the P3/P4 locations.[9]

Emotiv EPOC / EPOC+ operates at a resolution of 14 bits or 16* bit per channel with a frequency response between 0.16 - 43 Hz.

Emotiv EPOC / EPOC+ connects to PCs, tablets and smartphones via proprietary 2.4GHz wireless. Dongle is USB compatible and requires no custom drivers. EPOC / EPOC+ are

[9] *Emotiv Epoc/Epoc+*. [Online] Retrieved April 2016, from: http://emotiv.com/epoc-plus

powered by lithium battery, which provides 12 hours of continuous use. The Emotiv EPOC / EPOC+ neuroheadset connects wirelessly to PCs running Windows, Linux, and MAC OSX, Android or iOS.

e. Function of brain in each Emotiv EEG sensor

The 14 channels AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 shows real time brain wave activity divided into common brain wave frequencies Alpha, Beta, Theta and Delta. Quantitative Electroencephalography (QEEG) (Dr. Horst H, 2013) is a brain imaging technique that allows us to understand an individual's electrical brain activity and brain function. This research gives us useful information to understand the meaning of each Emotiv EEG sensor.[10]

Sensor	Function	Sensor	Function
AF3	Attention	FC6	Left Body controller
AF4	Judgment	T7	Verbal memory
F3	Motor planning	T8	Emotional memory
F4	Motor planning for left upper	P7	Verbal understanding
F7	Verbal Expression	P8	Emotional: Understanding, Motivation
F8	Emotional Expression: Anger, Happy	O1	Visual processing
FC5	Right Body controller	O2	Visual processing

Table 4: Channels and their Functions

[10] *Special study on guidelines to develop brain computer interface.* pp 7.[Online] Retrieved April 2016, from: http://sralife.com/workblog/eeg_2014/assets/docs/sra_special_study_eeg.pdf

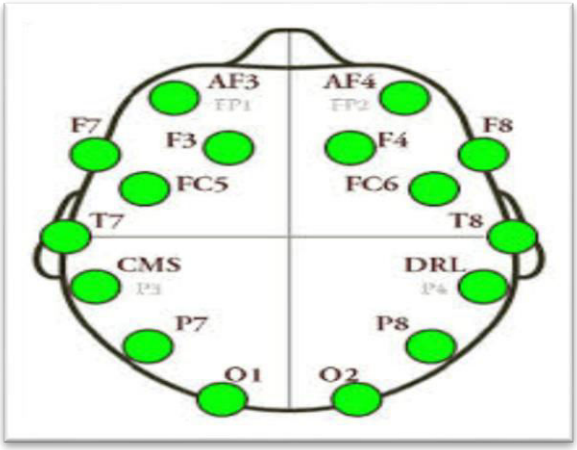


Figure 19: Emotiv EEG neuroheadset sensor location

1.5. Relay

A Relay is an electrically operated switch that allows us to turn on or off a circuit. Relays are switches that open and close circuits electromechanically or electronically.

Figure 20: A relay of 250V

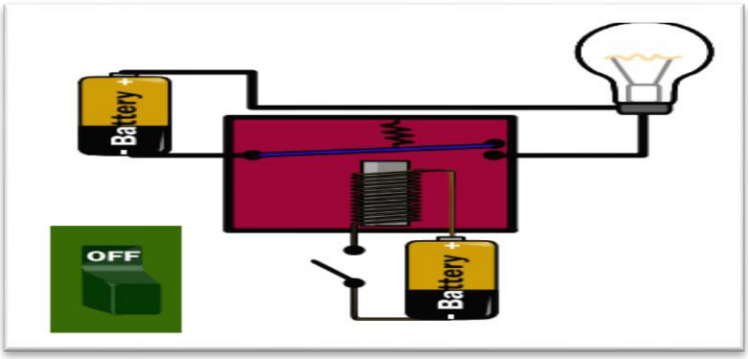


Figure 21: Relay Architecture (Simple circuit to switch a lamp)

A relay is defined as an electrically operated switch. Its main use is to control circuits by a low-power signal or when several circuits must be controlled by one signal. The first relay was used in long distance telegraph circuits such as amplifiers. They repeated the signal they received from one circuit, and transmitted it into a different one; and they were used also in early computers to perform logical operations.[11]

The Arduino relay module is designed for a wide range for microcontrollers such as the Arduino board, AVR, PIC, ARM, with digital outputs. This module incorporates two relays. The relay system is composed of the following:

a- Input: Vcc, connected to the 5V current on the Arduino Board, GND, connected to the ground and two digital inputs (In1 & In2).

b- Output: The 2-channel relay module could be considered as a series of switches: two normally Open (NO)[12], two normally closed (NC)[13] and 2 common Pins (COM).

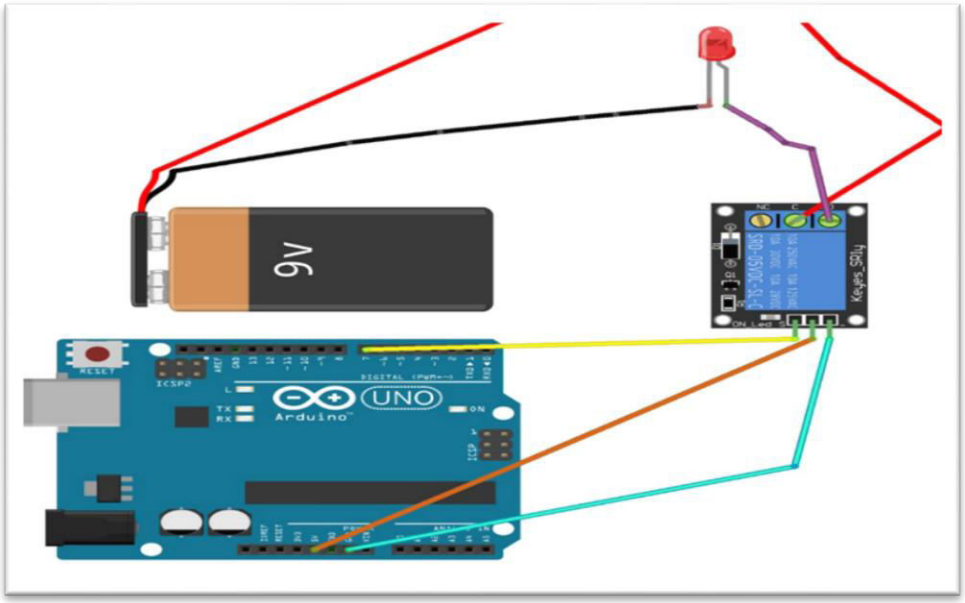


Figure 22: Simple circuit Relay-Arduino to switch a led

[11] *Relay Switch Circuit*. [Online] Retrieved April 2016, from: http://www.electronics-tutorials.ws/blog/relay-switch-circuit.html

[12] NO: Normally Open, in which case NO is disconnected with COM when INT1 is set low and connected when INT 1 is high.

[13] NC: Normally Closed, in which case NC is connected with COM when INT1 is set low and disconnected when INT 1 is high.

Since the typical applications of relays include computer interfaces, telecommunication systems, traffic control, automotive electrical systems, home appliances, lighting control systems, electric motor controllers, tools and machines, air-conditioning and heating systems, and so on, we used them in the project.

Relays used in this project are relays of 250V. 250 voltage is able to power any house appliances.

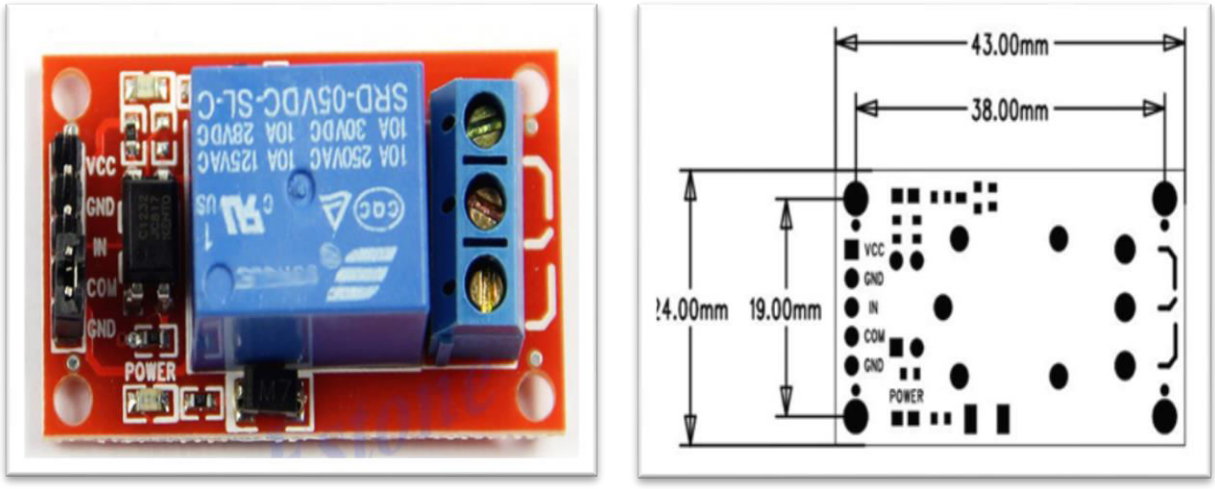


Figure 23: The Relay of 250V used in the project

2. Software

2.1. Visual Studio C#

a. Microsoft Visual Studio

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It can be used to develop console and graphical user interface applications along with Windows Forms applications, web sites, web applications, and web services in both native code together with managed code for all platforms supported by Microsoft Windows, Windows Phone, Windows CE, .NET Framework, .NET Compact Framework and Microsoft Silverlight.[14]

[14] HANS-PETTER HALVORSEN. (12 March 2014). *Introduction to Visual Studio and C#*. Kjølnes Ring 56 N°3914 Porsgrunn, Norway

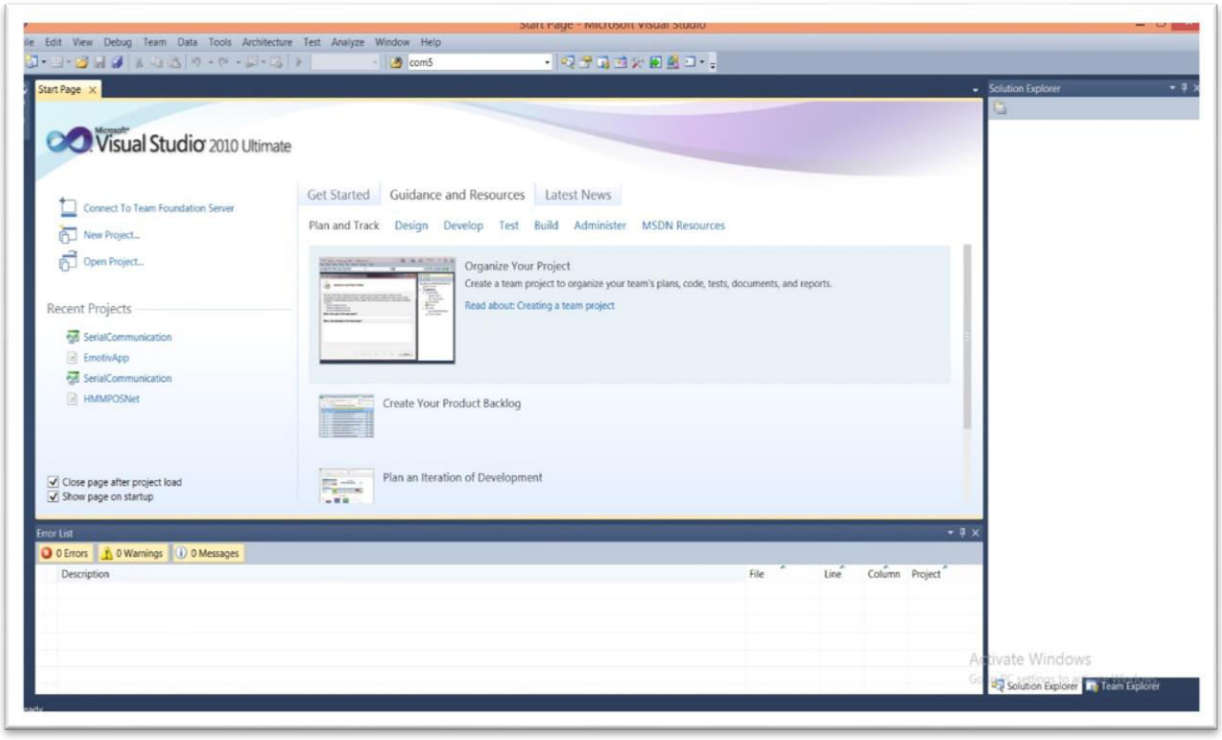


Figure 24: Microsoft Visual Studio Interface

Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language provided that a language-specific service exists. Built-in languages include C, C++ and C++/CLI (via Visual C++), VB.NET (via Visual Basic .NET), C# (via Visual C#), and F# (as of Visual Studio 2010). Support for other languages such as Python, Ruby, Node.js, and M among others is available via language services installed separately. It also supports XML/XSLT, HTML/XHTML, JavaScript and CSS.

Visual Studio includes a code editor supporting IntelliSense (the code completion component) as well as code refactoring. The integrated debugger works as both a source-level debugger and a machine-level debugger. Other built-in tools include a forms designer for building GUI applications, web designer, class designer, and database schema designer. It accepts plug-ins that enhance the functionality at almost every level—including adding support for source-control systems (like Subversion) and adding new toolsets like editors and visual

designers for domain-specific languages or toolsets for other aspects of the software development lifecycle (like the Team Foundation Server client: Team Explorer).[15]

b. C# Programming Language

C# is pronounced "See sharp". C# is an object-oriented programming language and part of the .NET family from Microsoft. C# is very similar to C++ and Java. C# is developed by Microsoft and works only on the Windows platform.

C# is a simple, modern, general-purpose programming language developed by Anders Hejlsberg and approved by European Computer Manufacturers Association (ECMA) and International Standards Organization (ISO). C# is designed for Common Language Infrastructure (CLI), which consists of the executable code and runtime environment that allows the use of various high-level languages on different computer platforms and architectures.

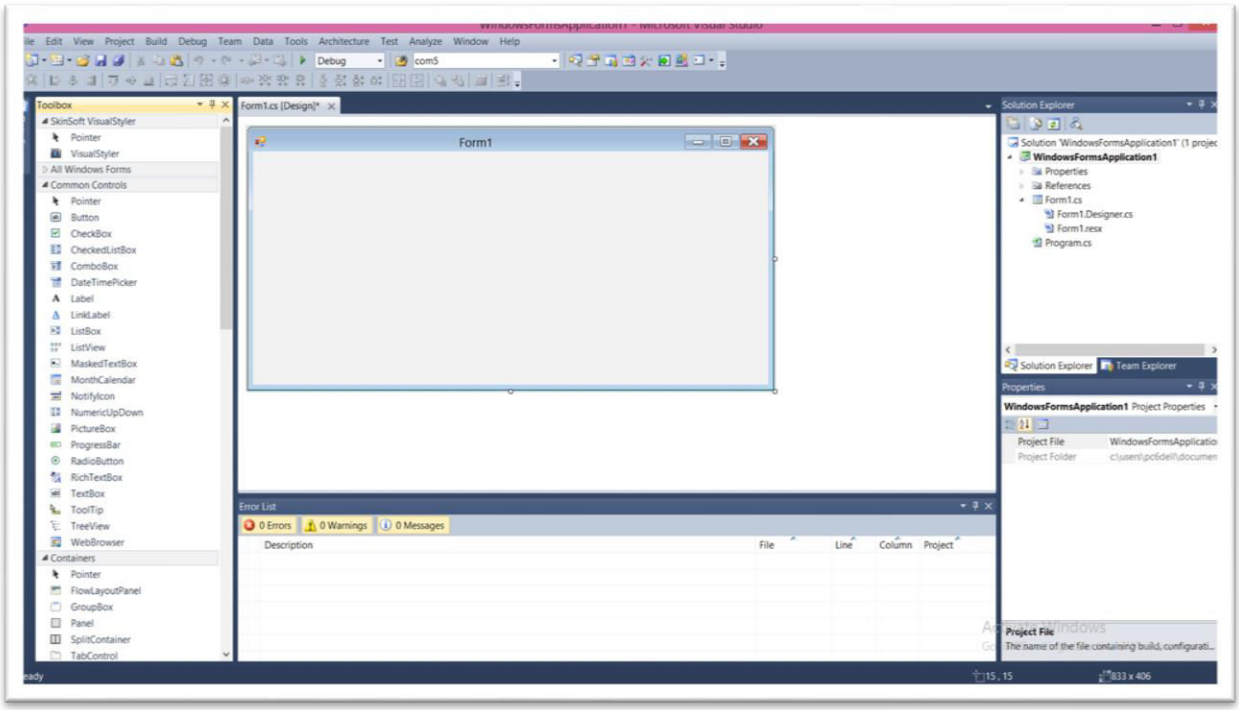


Figure 25: Microsoft Visual Studio C# Interface

The name "C sharp" was inspired by musical notation where a sharp indicates that the written note should make a semitone higher in pitch. This is similar to the language name of

[15] *Microsoft Visual Studio.* [Online] Retrieved April 2016, from: the free encyclopedia: https://en.wikipedia.org/wiki/Microsoft_Visual_Studio

C++, where "++" indicates that a variable should be incremented by 1. The sharp symbol also resembles a ligature of four "+" symbols (in a two-by-two grid), further implying that the language is an increment of C++.

The C# programming language was chosen to develop the computer application.

2.2. Android Studio

Android Studio is the official IDE for Android app development, based on IntelliJ IDEA. It was announced on May 16, 2013 at the Google I/O conference.

Android Studio was in early access preview stage starting from version 0.1 in May 2013, then entered beta stage starting from version 0.8, which was released in June 2014. The first stable build was released in December 2014, starting from version 1.0.

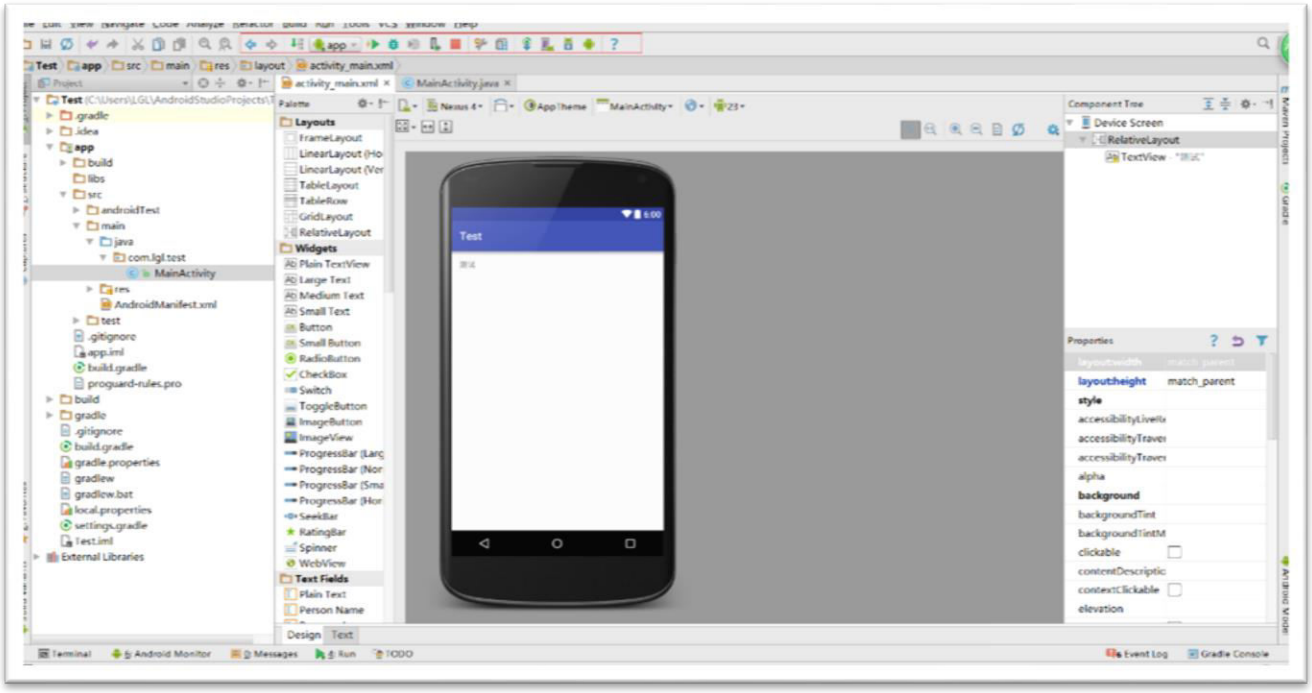


Figure 26: Android Studio Interface

Android Studio is designed specifically for Android development. It is available for download on Windows, Mac OS X and Linux, and replaced Eclipse Android Development Tools (ADT) as Google's primary IDE for native Android application development.

Android Studio offers even more features that enhance the productivity when building Android apps, such as:

- A flexible Gradle-based build system
- Build variants and multiple APK file generation
- Code templates to help you build common app features
- A rich layout editor with support for drag and drop theme editing
- Lint tools to catch performance, usability, version compatibility, and other problems
- Code shrinking with ProGuard and resource shrinking with Gradle
- Built-in support for Google Cloud Platform, making it easy to integrate Google Cloud Messaging and App Engine

Android Studio is used to develop the android application for the cellphone control.

2.3. EPOC Control Panel

a. Presentation of Epoc Panel

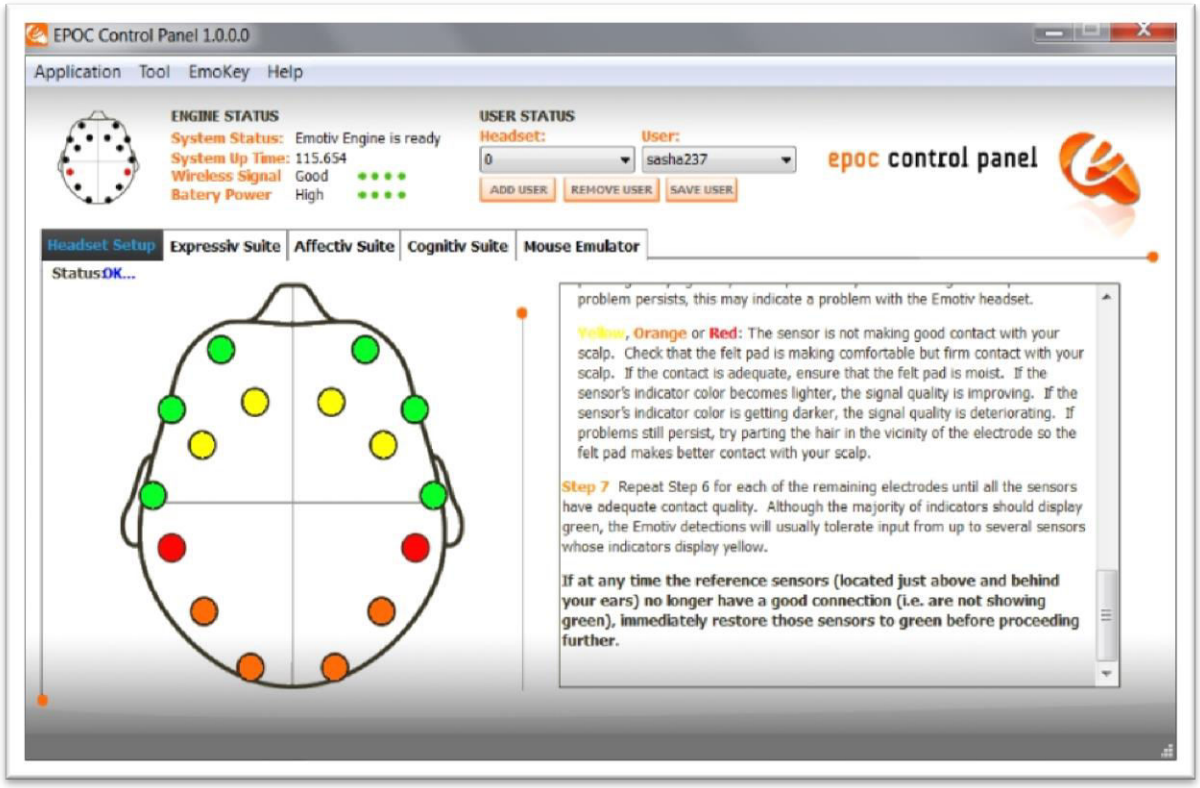


Figure 27: EPOC Control Panel Interface after login

EPOC Control Panel is a handy application for the Emotiv EPOC headset users. The program is designed to help setting up the headset and to connect it to the computer. It supports multiple users.

The user can enable other features of the EPOC device by using the Control Panel applications. Thus, user can use the included gyro as a mouse emulator and map EmoKey to keystrokes on his keyboard.

The HEADSET SETUP panel is displayed by default when starting Emotiv Control Panel. The main function of this panel is to display contact quality feedback for the neuroheadset's EEG sensors and provide guidance to the user in fitting the neuroheadset correctly. It is extremely important for the user to achieve the best possible contact quality before proceeding to the other Emotiv Control Panel tabs. Poor contact quality will result in poor Emotiv detection results.

The image on the left is a representation of the sensor locations when looking down from above onto the user's head. Each circle represents one sensor and its approximate location when wearing the SDK headset. The color of the sensor circle is a representation of the contact quality. To achieve the best possible contact quality, all of the sensors should show as green. Other sensor colors indicate:

1) Black: No signal
2) Red: Very poor signal
3) Orange: Poor signal
4) Yellow: Fair signal
5) Green: Good signal

Only after the neuro-headset sensor contact quality has been verified, we should move on to other Emotiv Control Panel tabs.

b. Control Panel tabs

1. Expressive Suite

The figure below shows the Expressive suit of the Emotiv Control Panel. An Expressive suite permits a user to perform facial expressions and these expressions can be seen on the face of the robot on the software screen. The expressions such as blink, wink, smile, clench etc. can be performed. The user can also enable a head tracker, which will track the position of the user's head. These actions can further be used to perform actions in the computer such as write or move the mouse cursor.

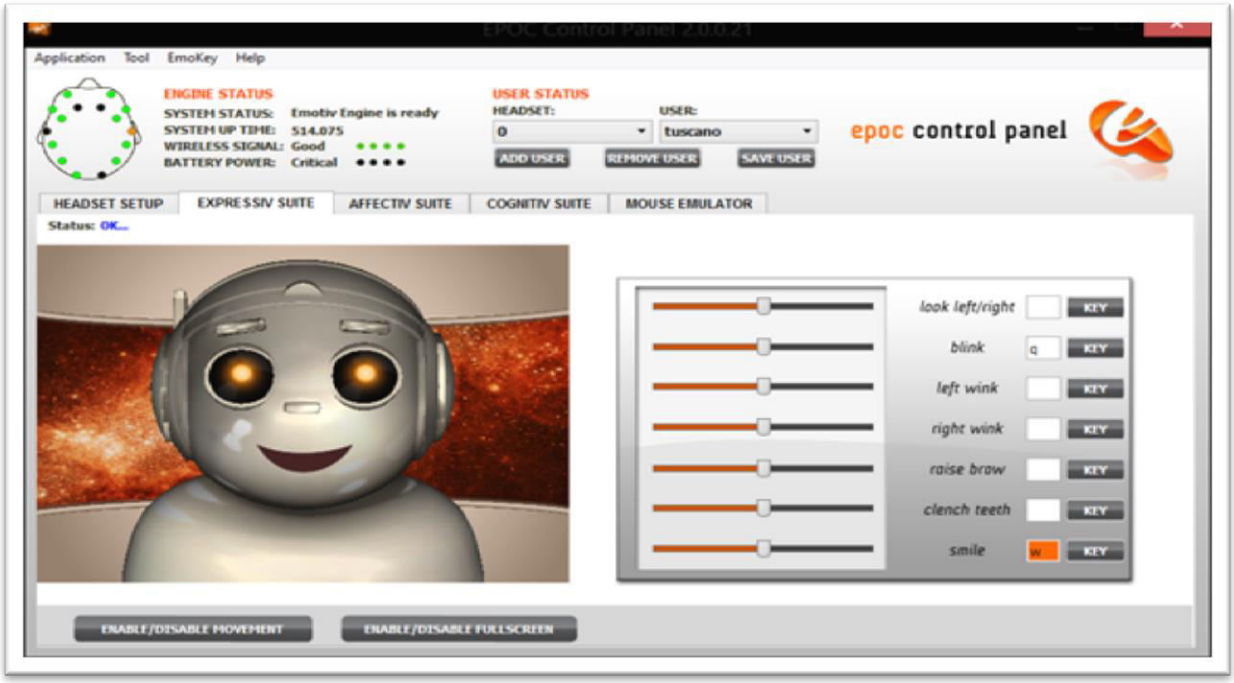


Figure 28: Expressive Suite Sensitivity Adjustment Panel

2. Affective Suite

The affective suite shows a graphical representation of the emotional state of the user in real time. The Emotional states such as Excitement/Calm, Engagement/Disengagement, and Meditation can be seen in this suite. These states can also be used to control functions on your computer or to find out the mental state of a user.

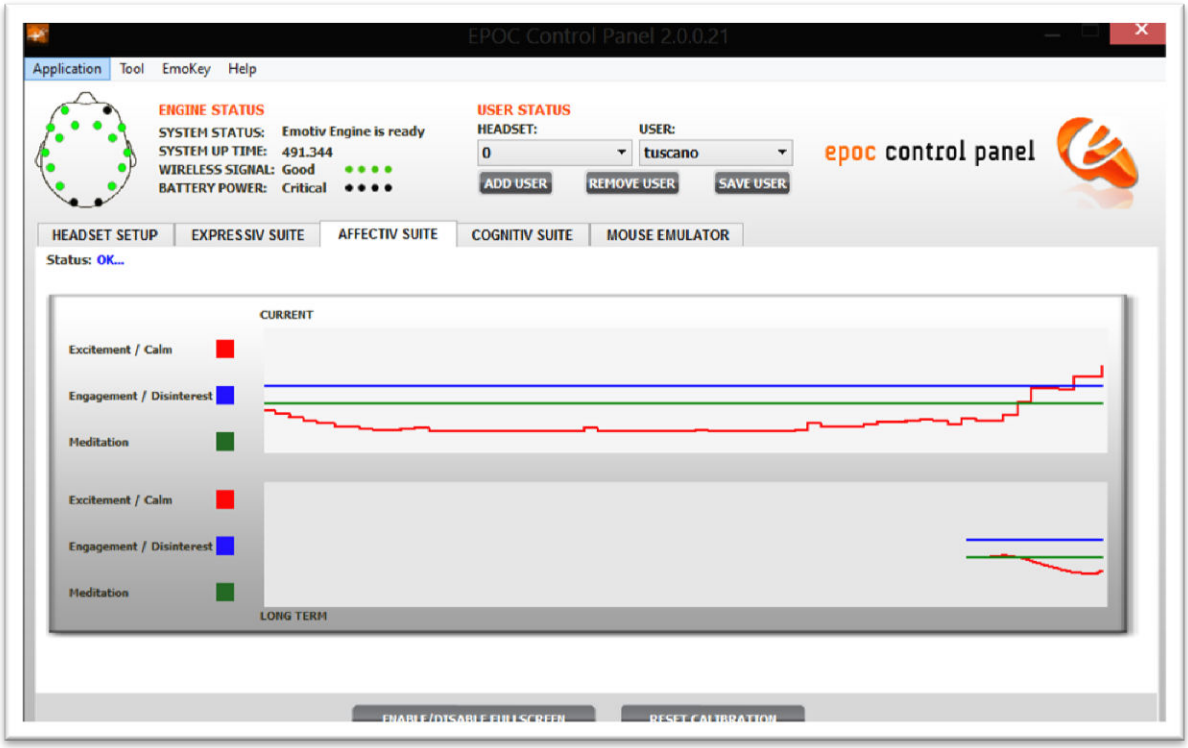


Figure 29: Affective Suite tab

3. Cognitive Suite

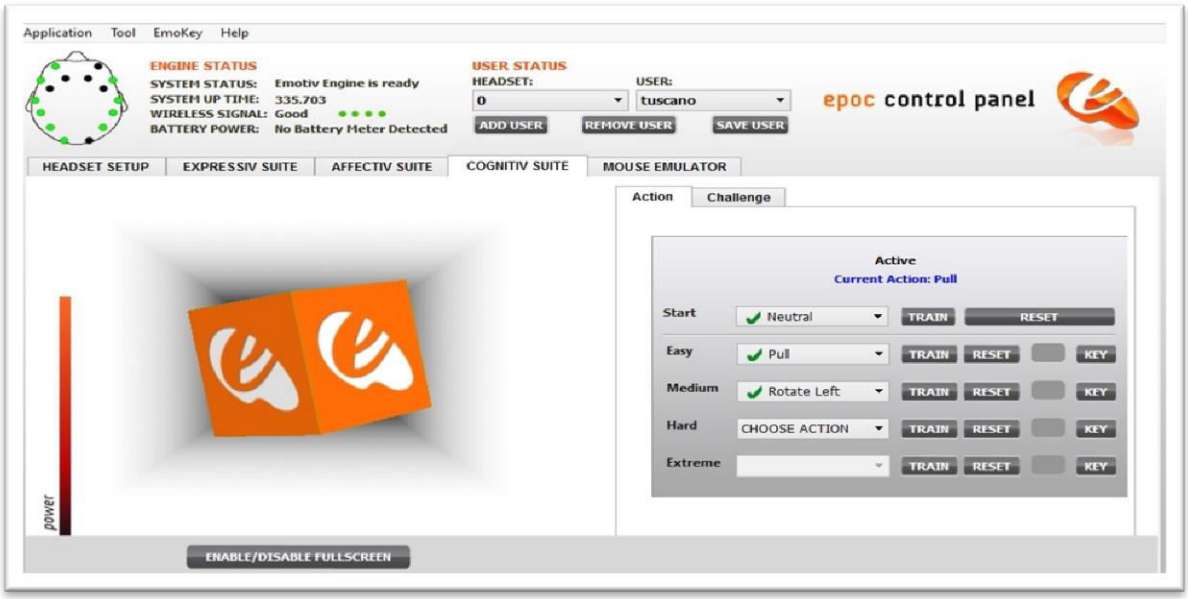


Figure 30: Cognitive Suite tab

The cognitive suite is a more advanced interactive suite which allows the user to concentrate on his/her thoughts to control a box in a 3-D space. A user can train his mind to perform different actions on the box which is floating in the air. The user can lift, pull, push and rotate the box to train his mind and for fun as well. Different keys can be assigned to these actions for a more interactive experience.

2.4. Arduino Software

The open-source Arduino Software (IDE) makes it easy to write a code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software. This software can be used with any Arduino board.[16]

Arduino Software (IDE) contains a text editor for writing a code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

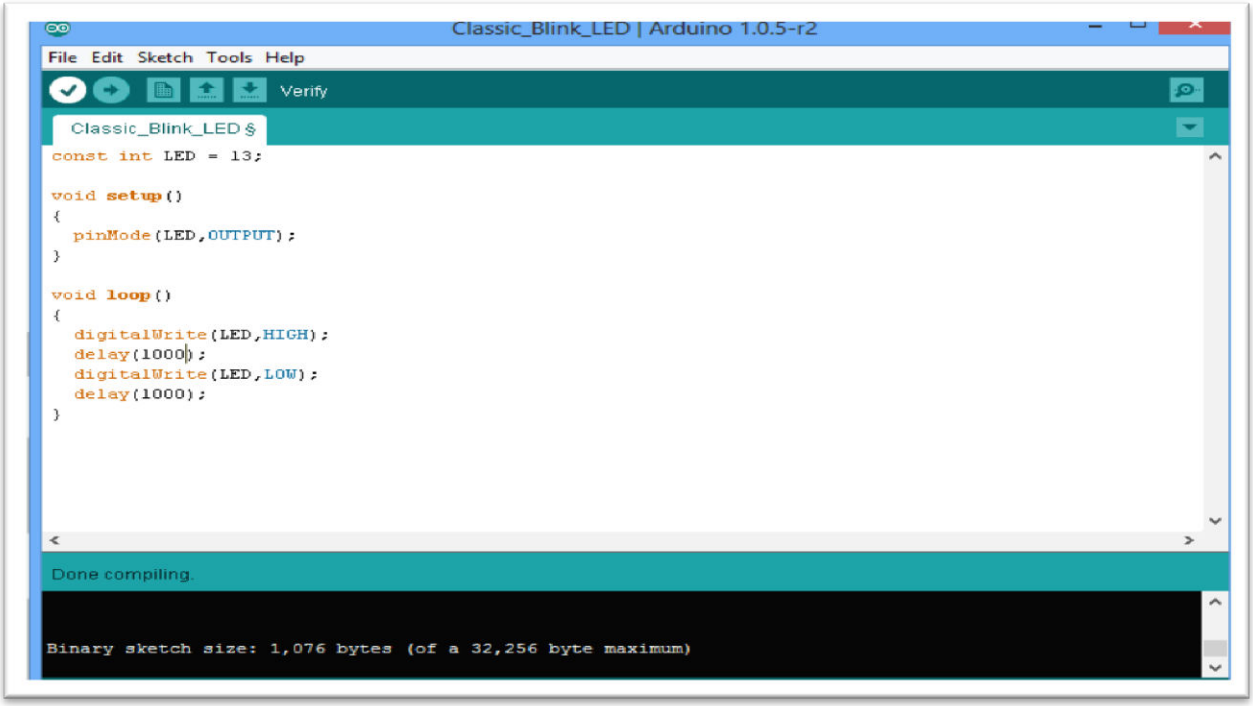


Figure 31: Arduino programming interface

[16] *The Arduino Software*. [Online] Retrieved April 2016, from: https://www.arduino.cc/en/Main/Software

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing a text. The message area gives feedback while saving and exporting, and displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information.

Note:

Versions of the Arduino Software (IDE) prior to 1.0 saved sketches with the extension .pde. It is possible to open these files with version 1.0, you will be prompted to save the sketch with the .ino extension on save. Before uploading your sketch, you need to select the correct items from the **Tools > Board** and **Tools > Port** menus.

2.5. Processing programming language

Processing is an open source programming language and integrated development environment (IDE) built for electronic arts, new media art, and visual design communities with the purpose of teaching the fundamentals of computer programming in a visual context and to serve as the foundation for electronic sketchbooks. The project was initiated in 2001 by Casey Reas and Benjamin Fry, both of them formerly of the Aesthetics and Computation Group at the MIT Media Lab. One of the stated aims of Processing is to act as a tool to get non-programmers started with programming through the instant gratification of visual feedback. The language builds on the Java language, but uses a simplified syntax and graphics programming model. In 2012, they started the Processing Foundation along with Daniel Shiffman, who formally joined as a third project lead.

Processing 3 is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. There are tens of thousands of students, artists, designers, researchers, and hobbyists, who use Processing for learning and prototyping.

Figure 32: Processing programming language icon

2.6. CMU Sphinx Toolkit

CMU Sphinx, also called Sphinx in short, is the general term to describe a group of speech recognition systems developed at Carnegie Mellon University. These include a series of speech recognizers (Sphinx 2 - 4) and an acoustic model trainer (Sphinx Train).

In 2000, the Sphinx group at Carnegie Mellon committed to open source several speech recognizer components, including Sphinx 2 and later Sphinx 3 (in 2001). The speech decoders come with acoustic models and sample applications. The available resources include in addition software for acoustic model training, Language model compilation and a public domain pronunciation dictionary, cmudict[17].

The used version of sphinx is 4. Sphinx-4 is a state-of-the-art speech recognition system written entirely in the Java™ programming language. It was created via a joint collaboration between the Sphinx group at Carnegie Mellon University, Sun Microsystems Laboratories, Mitsubishi Electric Research Labs (MERL), and Hewlett Packard (HP), with contributions from the University of California at Santa Cruz (UCSC) and the Massachusetts Institute of Technology (MIT).

[17] The CMU Pronouncing Dictionary (also known as CMUdict) is an open source-pronouncing dictionary originally created by the Speech Group at Carnegie Mellon University for use in speech recognition research. Cmudict can be used as a training corpus for building statistical grapheme-to-phoneme (g2p) models that will generate pronunciations for words not yet included in the dictionary.

Sphinx-4 started out as a port of Sphinx-3 to the Java programming language, but evolved into a recognizer designed to be much more flexible than Sphinx-3, thus becoming an excellent platform for speech research.

2.7. Used Signals

a. IR Infrared

Infrared (IR) is invisible radiant energy, electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers (frequency 430 THz) to 1 mm (300 GHz).[18]

Infrared technology is what most TV remotes use. The distance an infrared signal can travel varies based on the strength of the remote, but is usually less than 50 feet for household electronics. In order for an infrared signal to be detected, there must be a direct line of sight between the transmitter (remote) and the receiver (TV). If there is a wall or large object between them, the signal will not pass through it.

b. IR Radio Frequency (RF)

Radio frequency (RF) is any of the electromagnetic wave frequencies that lie in the range extending from around 3 kHz to 300 GHz, which include those frequencies used for communications or radar signals. RF usually refers to electrical rather than mechanical oscillations. However, mechanical RF systems do exist.[19]

Although radio frequency is a rate of oscillation, the term "radio frequency" or its abbreviation "RF" are used as a synonym for radio – i.e., to describe the use of wireless communication, as opposed to communication via electric wires.

Conclusion

Now, as the main concepts were described. So, it will be easy to understand the next chapter which will be about the implementation of the project.

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[18] *Infrared*. [Online] Retrieved April 2016, from: https://en.wikipedia.org/wiki/Infrared

[19] *Radio Frequency*. [Online] Retrieved April 2016, from: https://en.wikipedia.org/wiki/Radio_frequency

Chapter 3

- **Conceptual Study**

- **Why choose object approach?**
- **UML (Unified Modeling Language)**
- **The different UML diagrams**
- **Conception of our Study**

Introduction

Each project begins with a conceptual Study, which includes analysis and identifying the needs, analysis of the diverse factors that will influence the project; choosing the method of conception and realization, etc. Therefore, in order to develop our project we have to pass through this phase, which is the conceptual study.

The approach used in the conception of our work is the object approach. In addition, we chose for our application modeling based on UML (Unified modeling language). In this context, we will use diagrams of use cases, sequence and activity.

1. Why choosing the object approach?

In this project, we chose the object approach for the conception of our application because the object approach has several advantages:

- The developed system is easier to maintain because the objects are independent. Objects can be modified without affecting the other objects of the system.
- The objects are reusable components because of their independence. Therefore, we can develop new conception using objects created in other conceptions.
- For some kinds of system, there is a clear correspondence between real-world entities (such as hardware) and objects of the system that control which, improved the understanding of the conception.

2. UML (Unified Modeling Language)

The Unified Modeling Language (UML) is a general-purpose visual modeling language that is used to specify, visualize, construct, and document the artifacts of a software system. It captures decisions and understanding about systems that must be constructed. It is used to understand, design, browse, configure, maintain, and control information about such systems. It is intended for use with all development methods, lifecycle stages, application domains, and media.[20]

[20] James Rumbaugh, Ivar Jacobson and Grady Booch," UML Overview", *the Unified Modeling Language Reference Manual*. Second Ed.

UML is a formal language that has many characteristics like:

- It is not a closed rating; it is extensible, generic and configurable by the user;
- An unambiguous language;
- A universal language which may provide support for any object-oriented language;
- A way to define the structure of a program;
- A visual representation allowing communication between actors of the same project;
- A simple graphical notation, understandable even by computer science non-specialists.

3. The different UML diagrams

There are three broad categories of diagrams and they are also divided into sub-categories, the next figure shows a summary for most known diagrams and their categories:

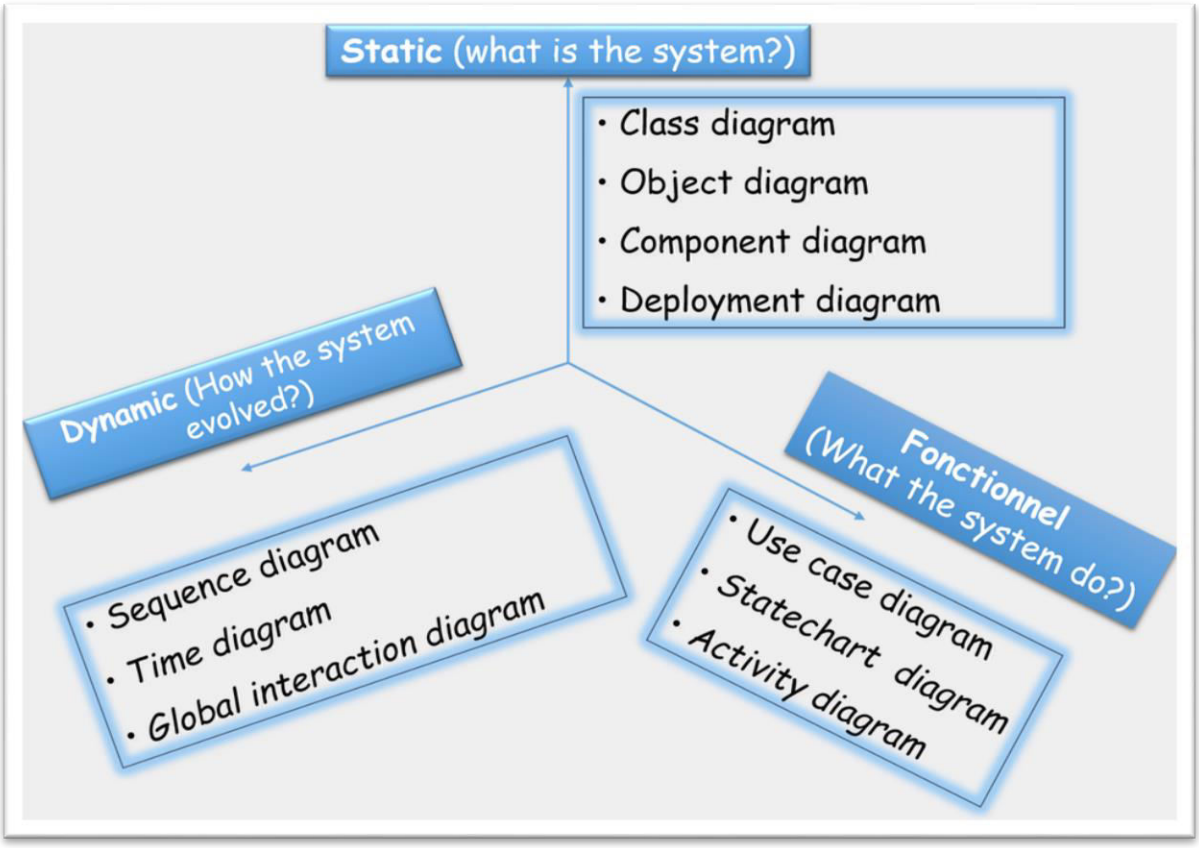


Figure 33: Types of UML diagrams

4. Conception of our project

4.1. Identify Actors

The functional specification describes the main functions of the application; which must satisfy the needs identified in the study. Two functions are important:

a. Authentication:

System users must authenticate through a login, to access the computer / mobile interface of the services offered by the home automation system.

b. Administration:

An administration system must be taken into consideration because the system needs a good configuration of both hardware and software. For that reason, we have two actors, the user and the administrator.

4.2. Use case diagrams

Use case diagrams are a set of use cases, actors and their relationships. They represent the use case view of a system. A use case represents a particular functionality of a system. Therefore, 'use case diagram' is used to describe the relationships among the functionalities and their internal/external controllers. These controllers are known as actors.

As the next figure shows, the home automation system has two actors, the admin and the user; the admin also can be a user.

The admin has the configuration task. He configures both the hardware and the software. Then the user can access the system in order to control the configured devices.

Initially, there are four devices to be controlled; lamps, TV, satellite receiver and power sketch. Each use case or function is associated to a special devise.

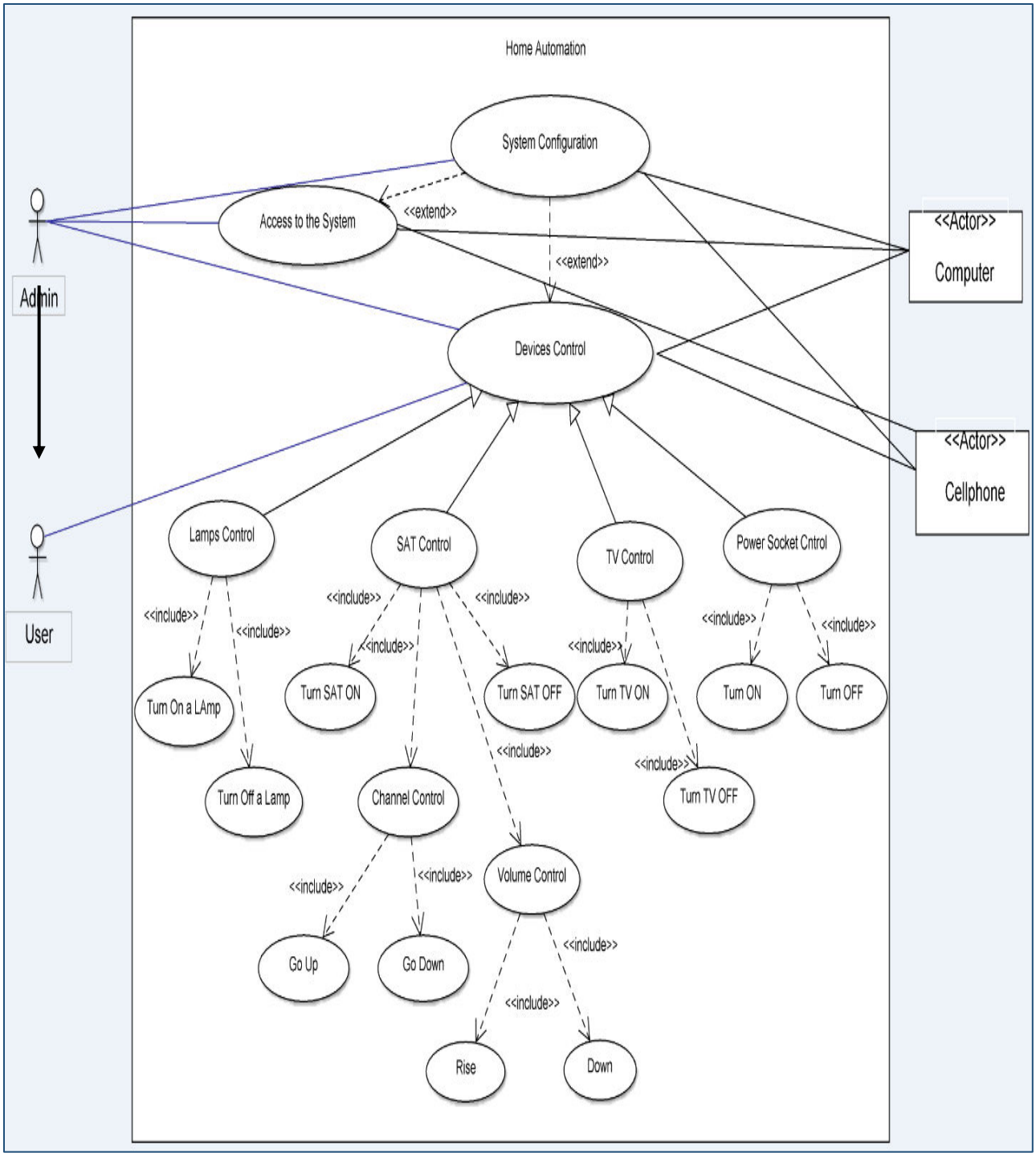


Figure 34: Use case diagram (Home Automation system)

a. Lamps control: the user can turn the lamp either ON or OFF;

b. SAT control: this use case includes four sub-functions which are turn the SAT (digital satellite) device ON, turn it OFF, change the channel (up and down) and adjust the volume;

c. TV control: the user is able to turn the TV both ON or OFF;

d. Power socket control: the user can use this automatic socket to turn ON or OFF any other home appliance such as an air-conditioner, etc.

All those use cases are controlled either by a computer or by a cellphone (smartphone) through the associated applications.

The following use case diagram represents the system of the wheelchair where the user must login first in order to get access to the system. The login here is important for the user's security. After entering to the system, the user can control the movement of the wheelchair by his personal computer. The control of the wheelchair is a mind (thinking) control.

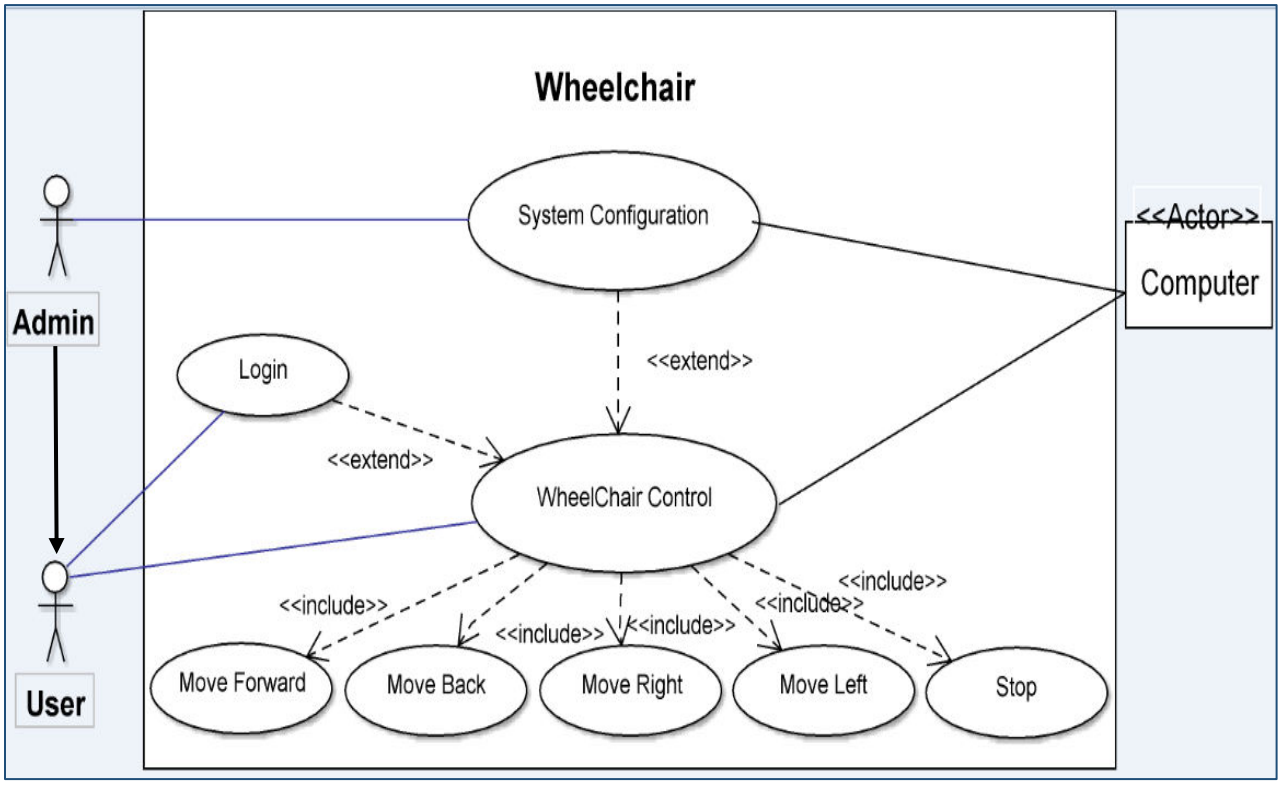


Figure 35: Use case diagram (Wheelchair System)

4.3. Sequence diagram

A sequence diagram is an interaction diagram. It is clear that the diagram deals with some sequences which are the sequence of messages flowing from one object to another.

Interaction among the components of a system is very important from the implementation and execution perspectives. So Sequence diagram is used to visualize the sequence of calls in a system to perform a specific functionality.

When a user wants to access his automation system, he must first access the interface of this system using a computer or a cellphone. After that, a Bluetooth connection must be established.

The access to the voice interface is so simple and needs just to call the interface and establish the connection as the following figure shows:

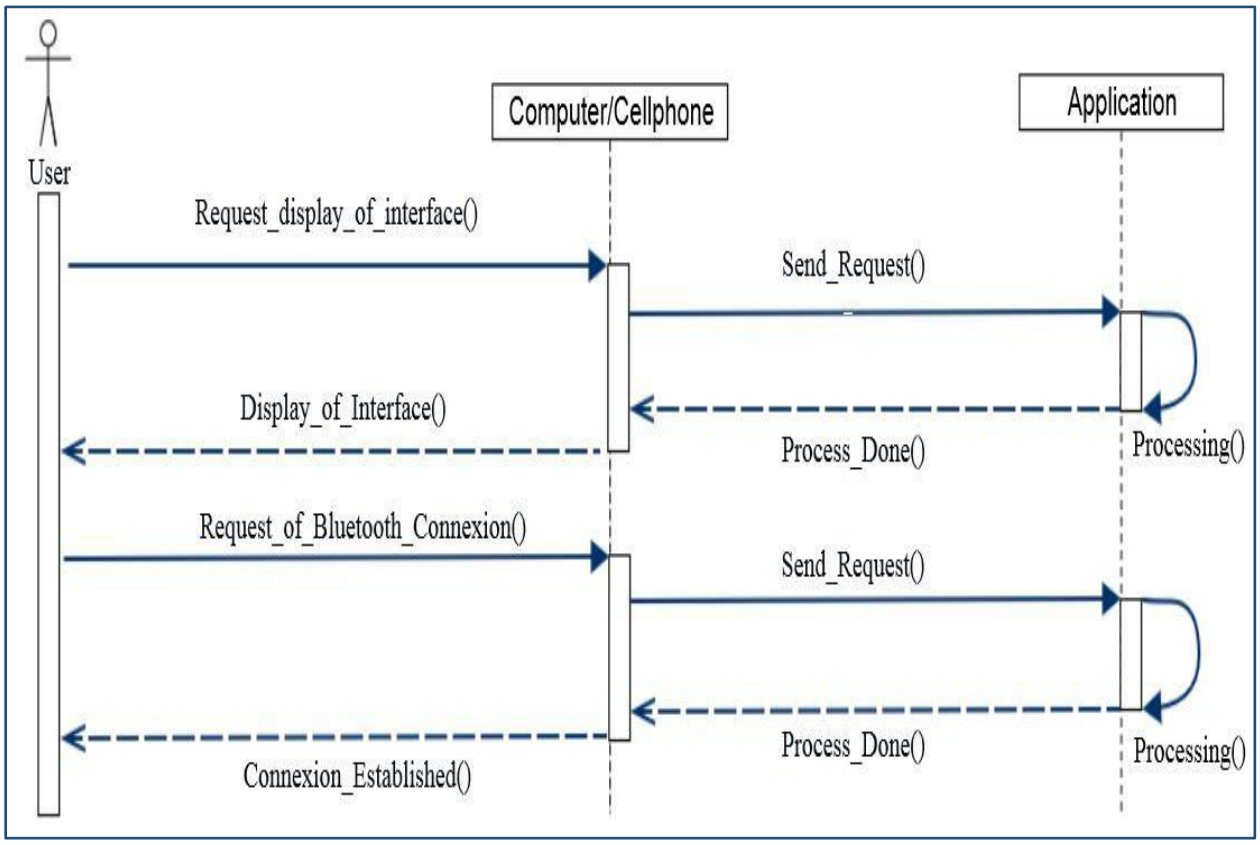


Figure 36: Sequence Diagram (The access to the automation home system with Voice)

The access to mind or thinking interface is similar to the voice one, just here the user must identify in order to use the system.

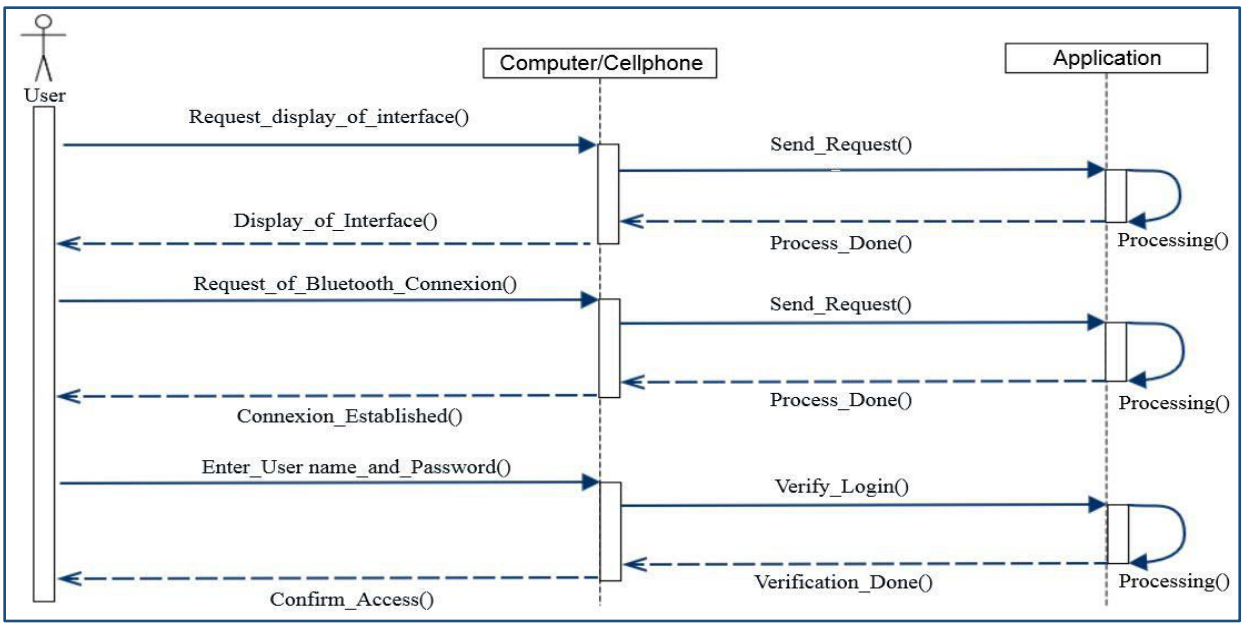


Figure 37: Sequence Diagram (The access to the automation home system with Thinking)

To activate an equipment, the user must first choose his desired interface (voice or mind) then call the system to display the list of appliances. The user will choose from the list an appliance to activate and call the system to display the list of the associated actions for this appliance. Here, he will choose the activation function and confirm it.

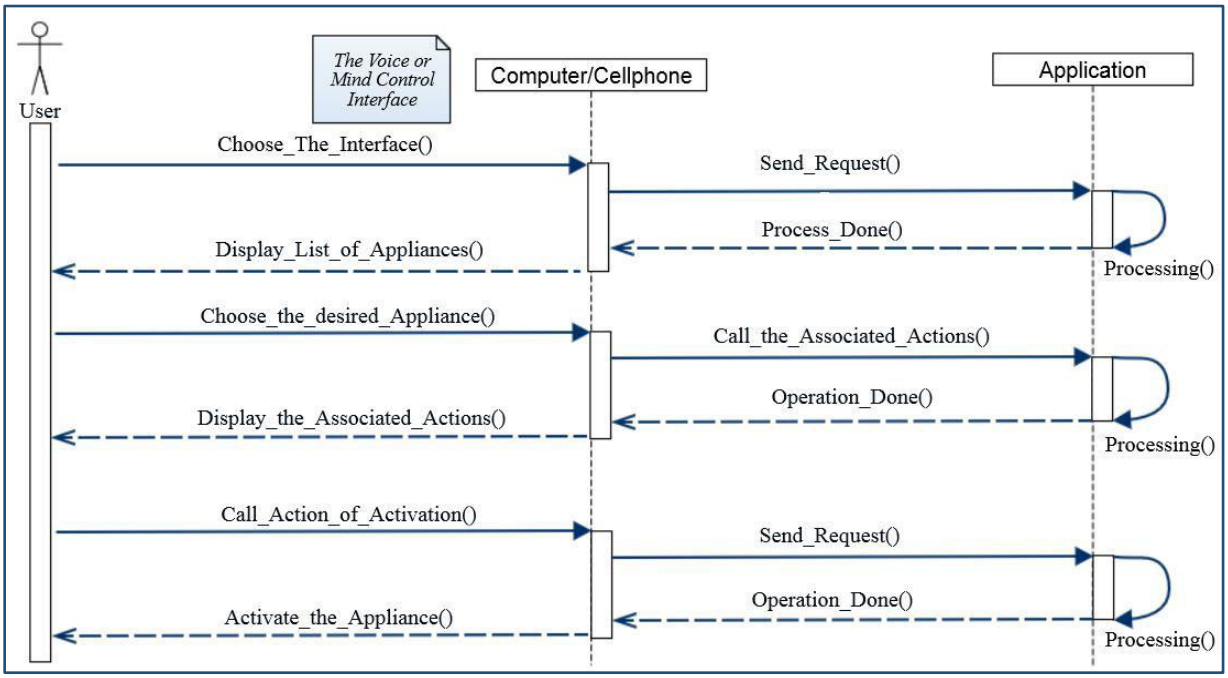


Figure 38: Sequence Diagram (Activate an Equipment)

The same procedure will be repeated for each appliance. It will be repeated also for each action such as deactivate an appliance.

4.4. Activity diagram

Activity diagram describes the flow of control in a system. Therefore, it consists of activities and links. The flow can be sequential, concurrent or branched. Numbers of activity diagrams are prepared to capture the entire flow in a system.

Activity diagrams are used to visualize the flow of controls in a system. This is preparatory to have an idea of how the system will work when executed.

The purpose of the activity diagram is to model the procedural flow of actions that are part of a larger activity. In projects in which use cases are present, activity diagrams can model a specific use case at a more detailed level[21].

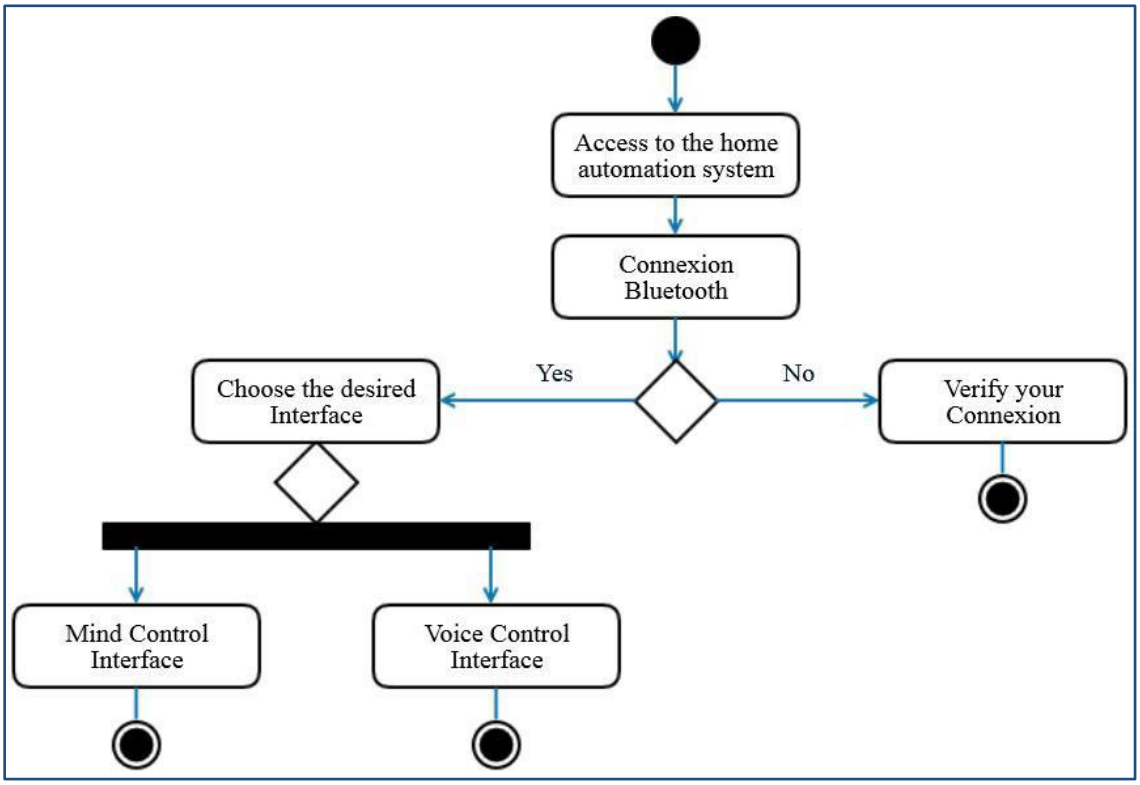


Figure 39: Activity Diagram (Access to the System)

[21] (2003). *UML basics Part II: The activity diagram*. Retrieved from: https://www.ibm.com/developerworks/rational/library/content/RationalEdge/sep03/f_umlbasics_db.pdf

The access to home automation system must be completed by establishing a Bluetooth connection. If the connection is established, the user can enter and choose his desired interface; otherwise, he must verify his connection.

After accessing and choosing the voice interface, a list of activities will be displayed as the activity diagram (Choose an activity-Voice Interface) shows; the user is able now to control any device he wants. Each device has some actions like essentially turning ON or OFF the appliance.

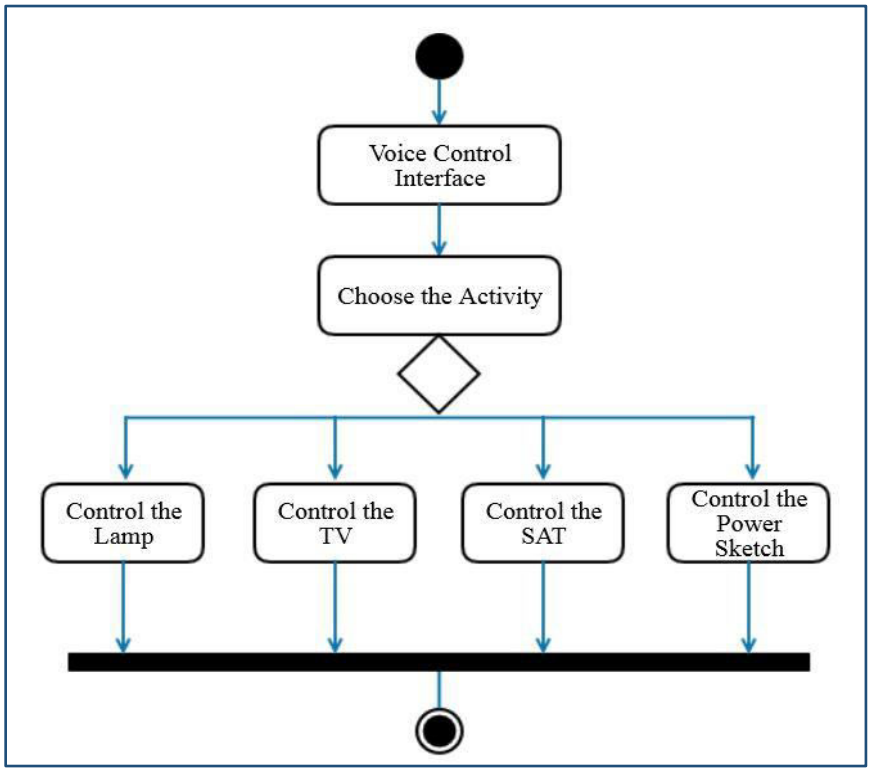


Figure 40: Activity Diagram (Choose an activity-Voice Interface)

If a mind control interface is chosen, a login panel will appear. The authentication is necessary.

The user must enter his username and password, and then the system will verify the validity of that information.

If they are not valid, the system will notify that there is an error, and go back to the login panel. Otherwise, if the entered information are correct, the user will be able to use the system and control his devices.

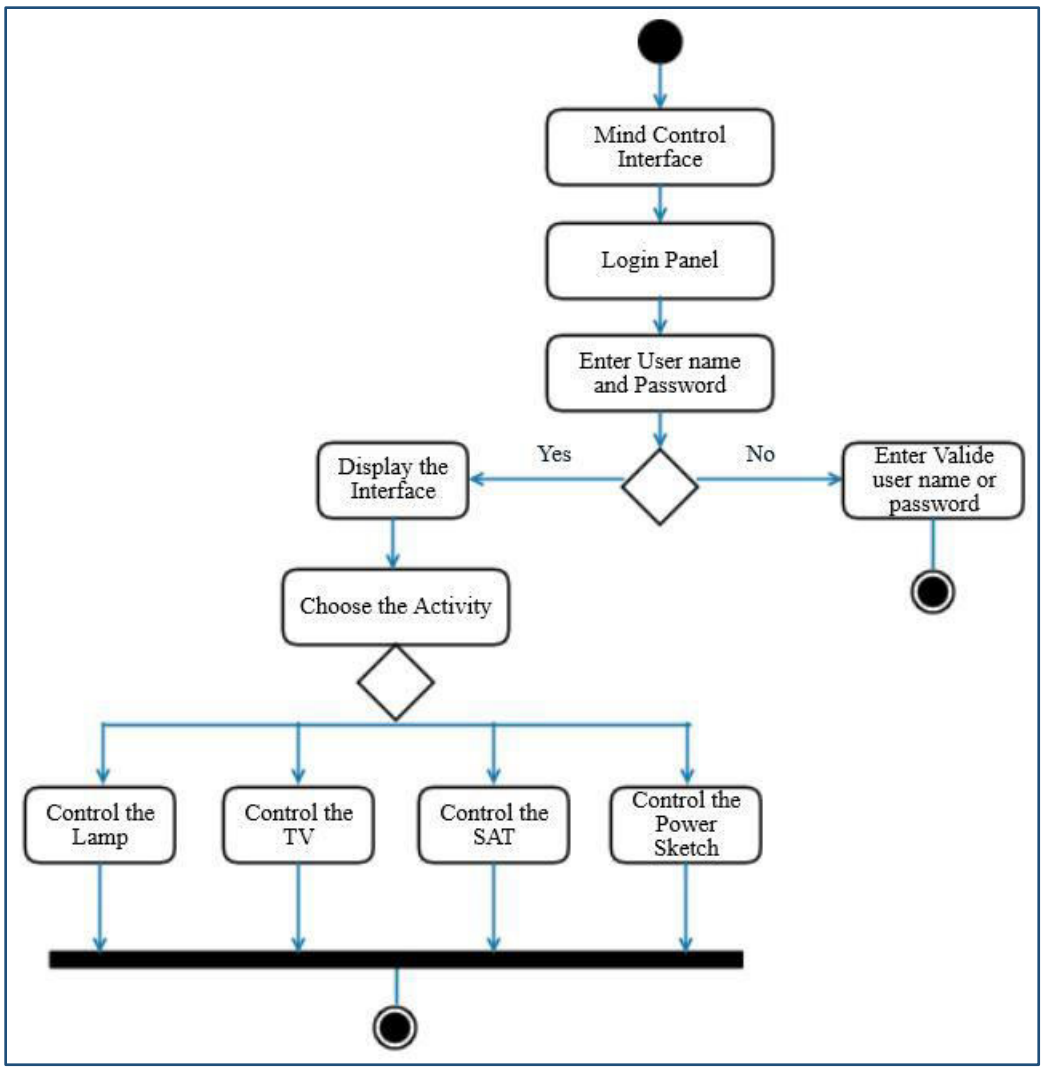


Figure 41: Activity Diagram (Choose an activity-Mind Interface)

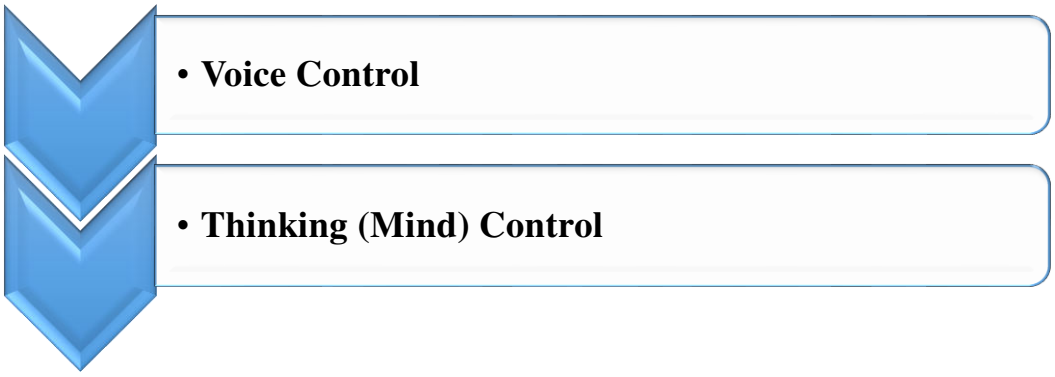
The same procedure will happen concerning the wheelchair control process. Therefore, its activity diagram is similar to "Choose an activity-Mind Interface" diagram.

Conclusion

Throughout this chapter, we described better the project functionalities and objectives using a unified model, which is UML. Its diagrams help to understand better the system and its principal cases and even its sub-functions.

Chapter 4

- **Implementation**



Introduction

1. Voice Control

Voice Control can be great as soon as it starts controlling your devices while you are on your bed or couch. Imagine the possibility of monitoring and controlling all various devices in your home by using the sound of your voice!

We have all seen shows and movies where the characters give voice commands to computers, then doors open, screens lower, or lights turn on. Those ideas and concepts are far-fetched or see so. Not anymore! Especially that technology is now becoming available to everyone. We can now control many features in our homes using simple voice commands.

Actually, the voice control is largely used in our daily life. Therefore, thinking about this technology in order to help some categories of people in society will be great.

Three applications are developed to run in two different controllers, the first controller is the computer and the second is the cellphone.

1.1. Computer Application

Voice Control is an application that lets you command your device with your voice using your computer. Its functions include activating home appliances, deactivating them, moving the wheelchair in the four directions, and so on.

a. Recognition Principle

When we talk about voice, we directly think of recognition. There are many methods and systems for voice recognition. In this project, we used a toolkit called Sphinx.

Modern general-purpose speech recognition systems are based on Hidden Markov Models. These are statistical models that output a sequence of symbols or quantities. HMMs are used in speech recognition because a speech signal can be viewed as a piecewise stationary signal or a short-time stationary signal. In a short time-scale (e.g. 10 milliseconds), speech can be approximated as a stationary process. Speech can be thought of as a Markov model for many stochastic purposes.

HMMs are popular because they can be trained automatically and are simple and computationally easy to use. In speech recognition, the hidden Markov model would output a

sequence of n-dimensional real-valued vectors (with n being a small integer, such as 10), outputting one of these every 10 milliseconds. The vectors would consist of cepstral coefficients, which are obtained by taking a Fourier transform of a short time window of speech and decorrelating the spectrum using a cosine transform, then taking the first (most significant) coefficients. The hidden Markov model will tend to have in each state a statistical distribution that is a mixture of diagonal covariance Gaussians, which will give a likelihood for each observed vector. Each word, or (for more general speech recognition systems), each phoneme, will have a different output distribution; a hidden Markov model for a sequence of words or phonemes is made by concatenating the individual trained hidden Markov models for the separate words and phonemes. That is why we use sphinx-4, which is based on HMM to create acoustics models.

b. Circuit

The first device used as a controller is the computer. Then, there is the Arduino UNO, which receives the orders from the computer by Bluetooth module (HC-06). These orders are infrared signals. The Arduino can sense the environment by receiving input signals and affect its surrounding by controlling peripherals like lights, home appliances or motors.

As the figure 42 shows, we have an Arduino UNO matched with a Bluetooth module. The circuit also contains a lamp, a relay and two resistors; one of 100 Ohm and the second of 200 Ohm. That means the Arduino here controls the lamp and the relay.

To build this circuit, connect one end of the resistor (100 Ohm) to the Arduino pin 3. Connect the anode of the lamp (the positive leg) to the other end of the resistor. Connect the cathode leg of the lamp (the negative leg) to the Arduino GND, as shown in the schematic figure 42 below.

The same thing is done with the relay. We just have to connect one end of the resistor (200 Ohm) to the Arduino pin 13, Connect the input of the relay to the other end of the resistor, then connect the GND of the relay to the Arduino GND.

The relay here is like a switch. It can control any device at home (because we used a relay of 250 V).

The Arduino can be powered using a USB cable or any other AC-AD power adapter.

This circuit is just an example; we can in this way develop any other circuit or add other devices to it.

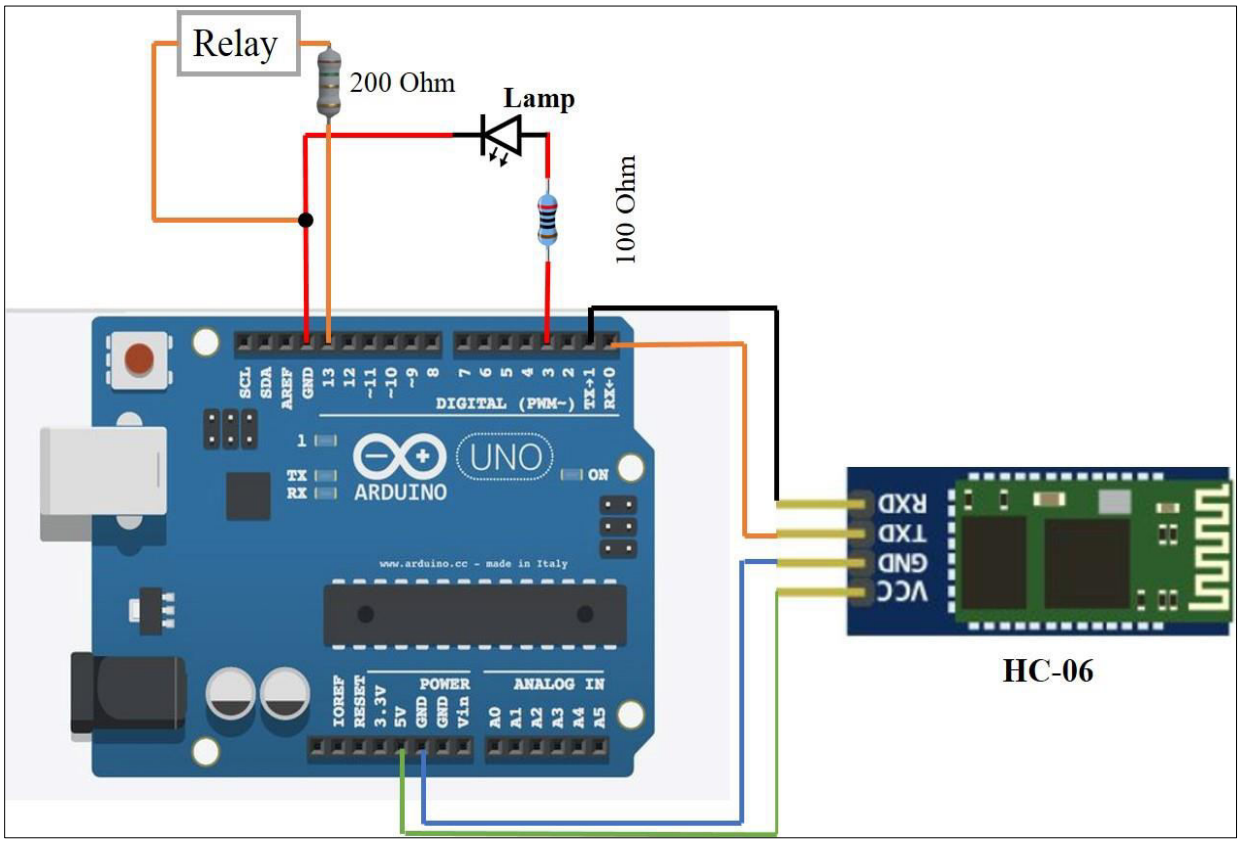


Figure 42: Simple Arduino circuit to control a lamp and a relay

c. Application

Voice Control of home appliances is an application developed on Microsoft visual studio C#. It is set to run automatically when the computer is started. It contains three tabs. The first interface or tab is designed to give a clear idea about the content of the application. It is called configuration tab. When we run the application for the first time, we have to configure the Bluetooth connection. There is in the configuration tab a small rectangle that shows all available devices, we have just to push the search button then choose the concerned Bluetooth module from the search list and push the button 'connect'. The application saves this configuration even if the computer or the application is shut down. When we push 'connect', the two other tabs will be enabled.

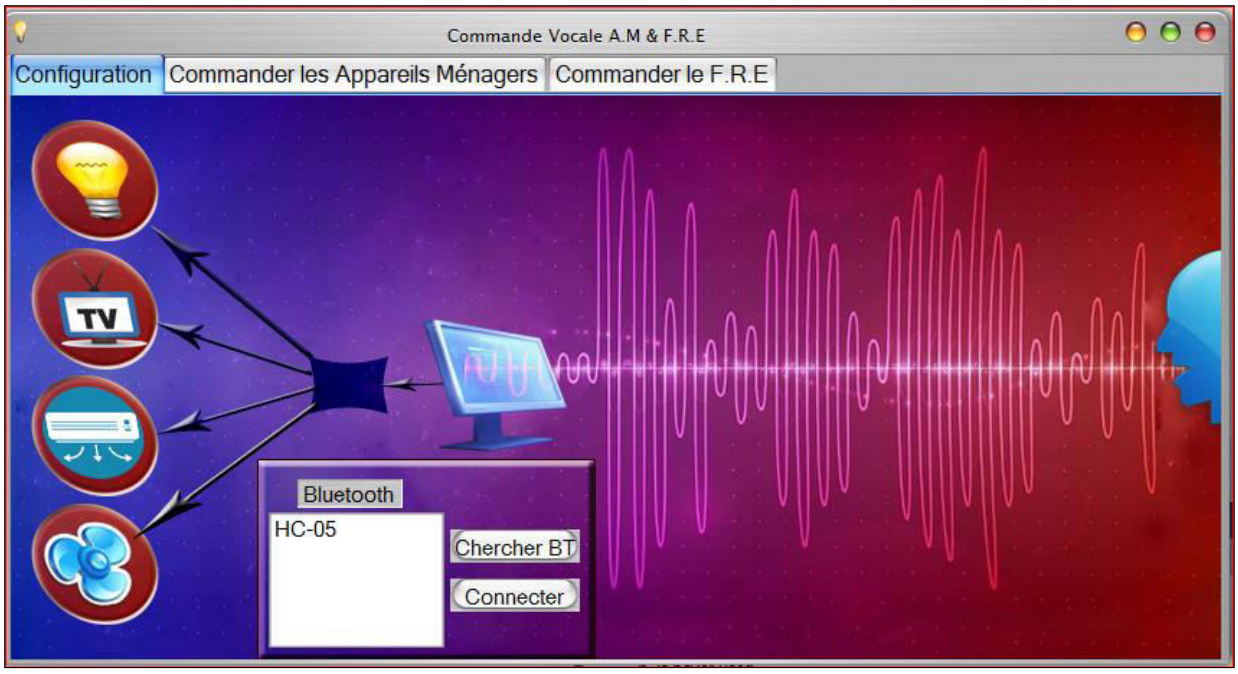


Figure 43: Configuration Tab Interface

The second tab is a Control Home Devices Interface where we find a set of devices and how to control them. The devices that can be controlled are a lamp, TV, Digital SAT and Power Socket.

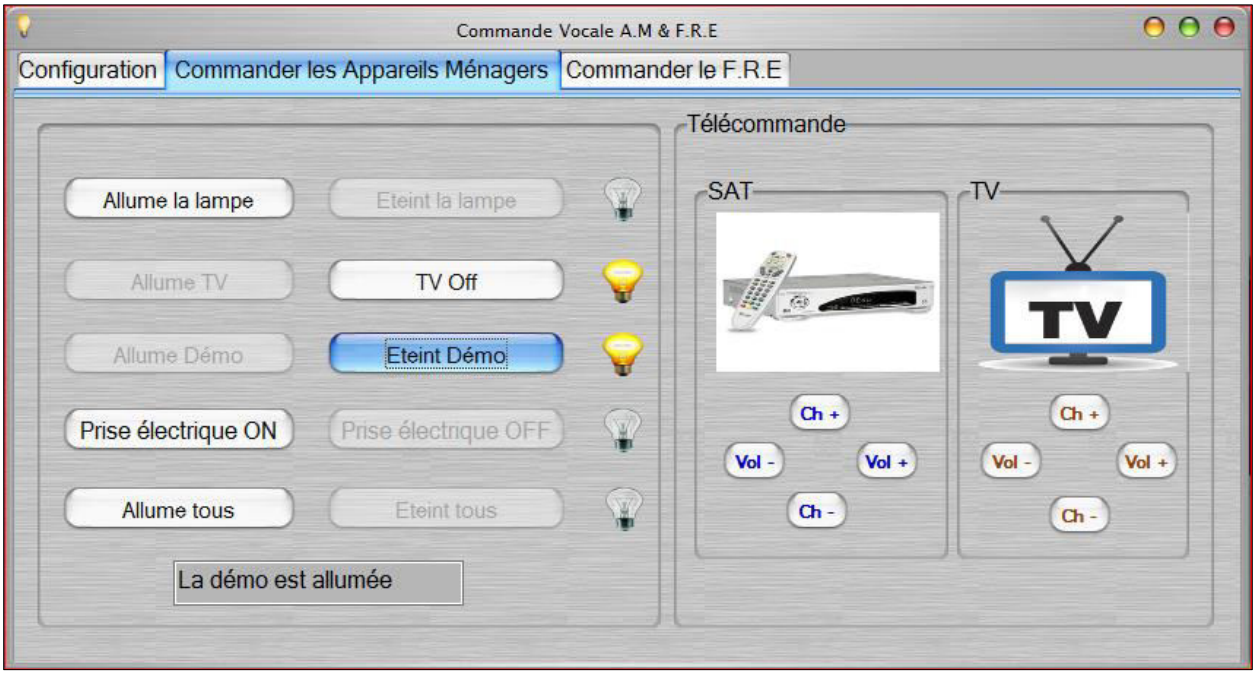


Figure 44: Control Home Devices Interface

Using the sound of your voice makes you able to control any devices you want; you just have to say the specific order. If you want, for example, to activate a lamp use “lamp on”, to deactivate it use “lamp off”; the same thing for all other devices.

The table below show all the orders and their specification:

Order	Specification
Ecouter	It is a word key to make the program start recognition; the user has to say it before any other order
Allume la lampe	Turn the lamp ON
Eteint la lampe	Turn the lamp OFF
Allume télé	Turn the television ON
Eteint télé	Turn the television OFF
Allume démo	Turn the digital SAT ON
Eteint démo	Turn the digital SAT OFF
Volume plus	Rise the volume of your SAT by 3 units
Volume moins	Make down the volume of your SAT by 3 units
Programme suivant	Change the actual channel to the next one (Example: from 1 to 2)
Programme avant	Change the actual channel to the previous one (Example: from 5 to 4)
Prise ON	Turn the power socket ON; any devices attached to the socket will be ON
Prise OFF	Turn the power socket OFF; any devices attached to the socket will be OFF

Table 5: Appliances Control Orders and their meaning

The third tab is Control Wheelchair. The user can move the wheelchair in the four directions and can stop it.

Figure 45: Control Wheelchair Interface

The table below shows the orders of the wheelchair and their meaning:

Orders	Specification
Stop	To stop the wheelchair
À gauche	Go left
À droite	Go right
Avant	Go ahead
Arrière	Go back

Table 6: Wheelchair Control Orders and their Meaning

1.2. Cellphone Application

For the cellphone, there are two separate applications; One for the home appliances and the second for the wheelchair.

Home Control Devices is an application that responds to your voice commands. The supported functions are the same as the second tab in the computer application.

The Wheelchair Control is an application that responds to the same orders like the third tab in the computer application.

a. Recognition Principle

The principle of recognition is based always on HMM and uses the sphinx tool; but this time around, we use the compatible version of android that is called Pocket Sphinx Android.

We use studio Android to develop the cellphone application and adapt the Pocket Sphinx in order to make an offline recognition.

b. Circuit

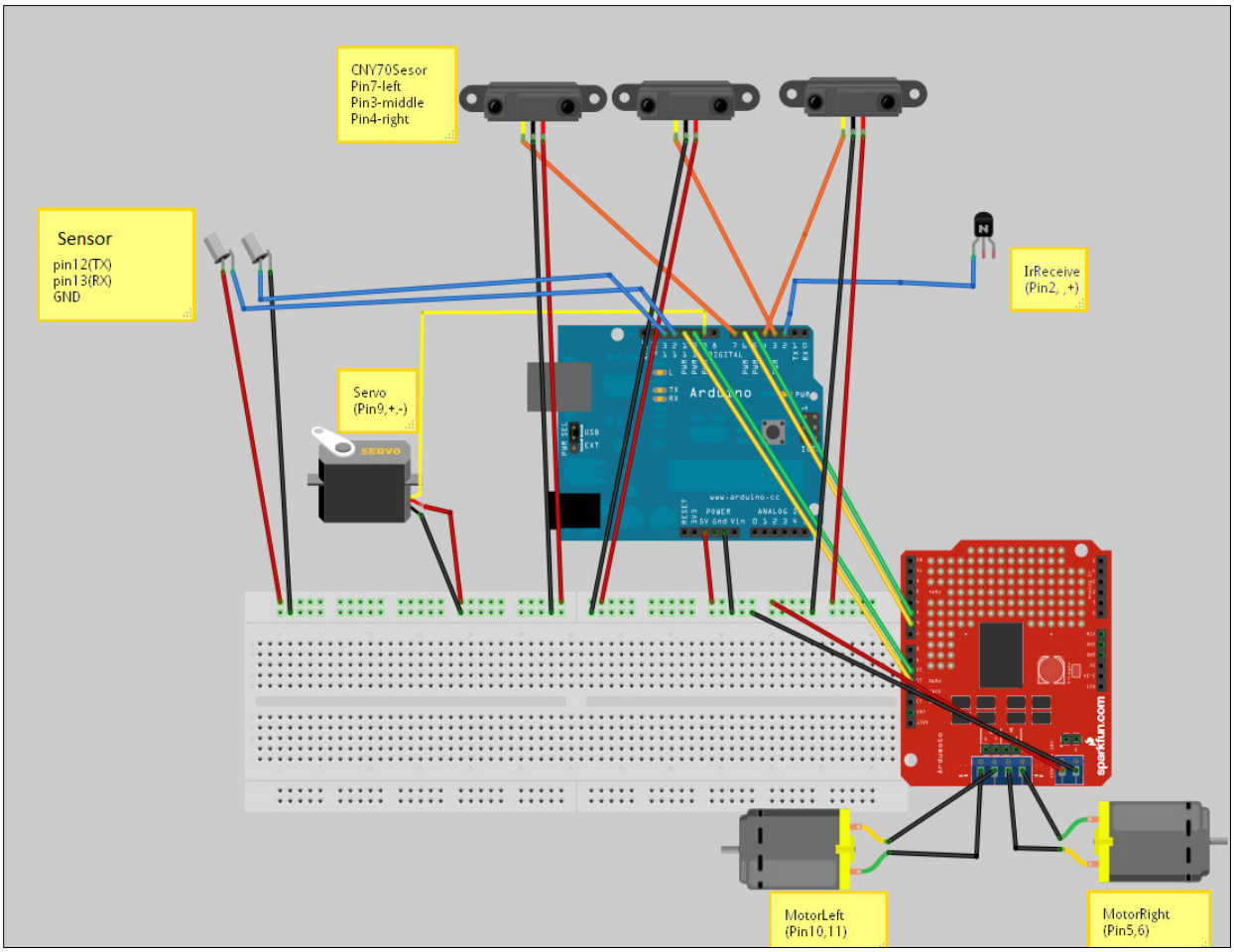


Figure 46: Simple circuit to control two motors

Because we talked before about the circuit of home control, we will have to consider now the wheelchair.

The controller is the cellphone. Since we gave an example before about the home control devices circuit, now we will give a simple example about the wheelchair circuit. The circuit contains an Arduino UNO, a motor shield, two motors, a power adapter, and a Bluetooth module.

c. Application

Because the android does not allow us to develop one application to connect with two different Bluetooth modules, we were obliged to develop two applications, one for the home appliances and the other for the wheelchair.

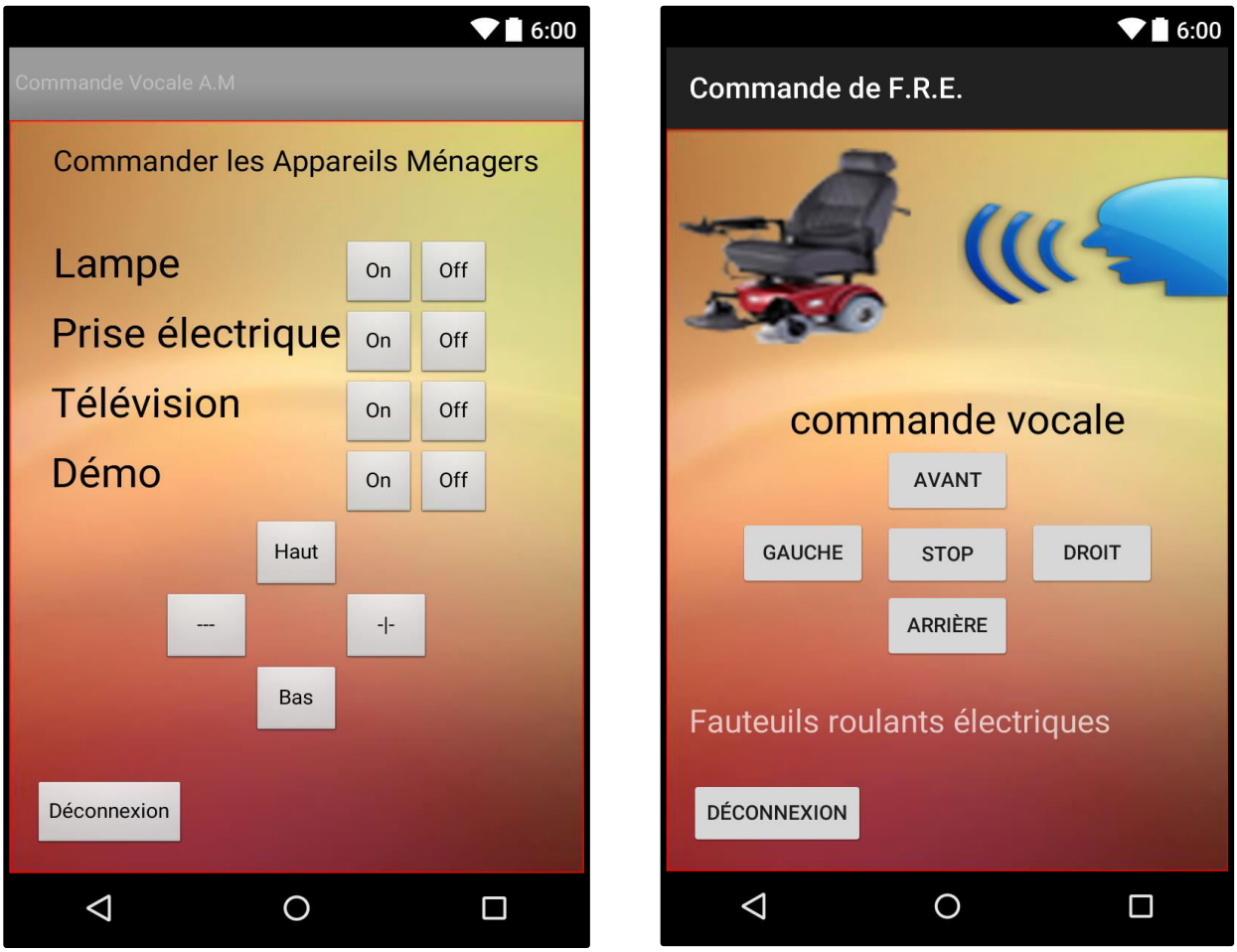


Figure 47: Cellphone Applications, “Commande Vocale A.M” for home control and “Commande de F.R.E” for wheelchair control

As to the functionalities, they are the same as the computer application. We just have now an android version.

In order to have access to the application, the user have to connect with the according Bluetooth; then after connecting, he can have access to the main interface where there is the control menu.

2. Thinking (Mind) Control

In this study, we have developed a system that allows a person to communicate with the computer through the brain wave sensor (Emotive Epoc+ in this case) and control different objects like a wheelchair, a remote control, a car or home devices.

To realize this project, several steps are followed. The diagram below will resume them:

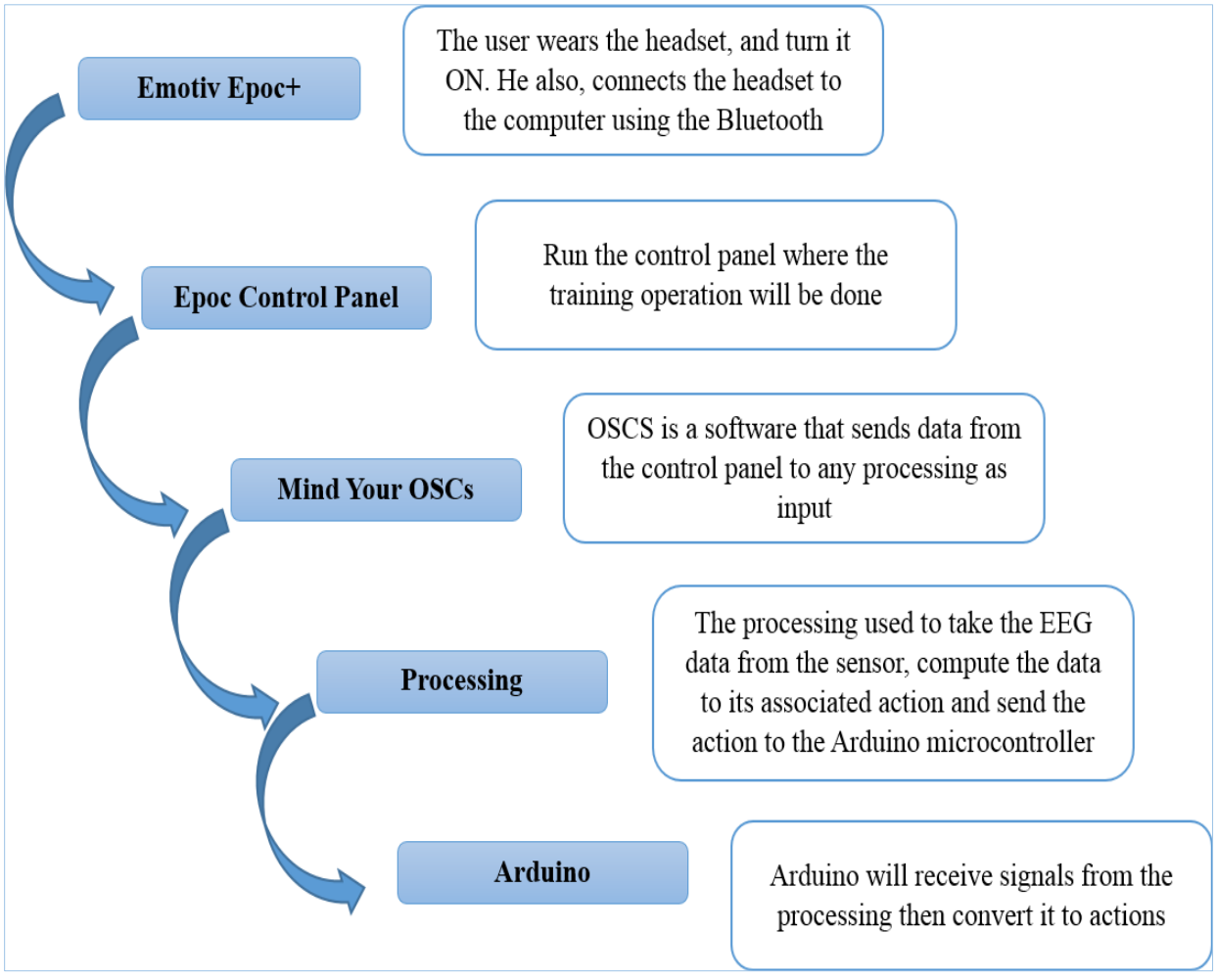


Figure 48: Realization Diagram

2.1. Diagram Explication

a. Control Panel

The Last suite that is included in this control panel is a cognitive suite which allows the user to concentrate on his/her thoughts to control a box in a 3-D space. A user can train his mind to perform different actions on the box which is floating in the air. The user can lift, pull, push, move left or right and rotate the box to train his mind. Different keys can be assigned to these actions for more interactive experience.

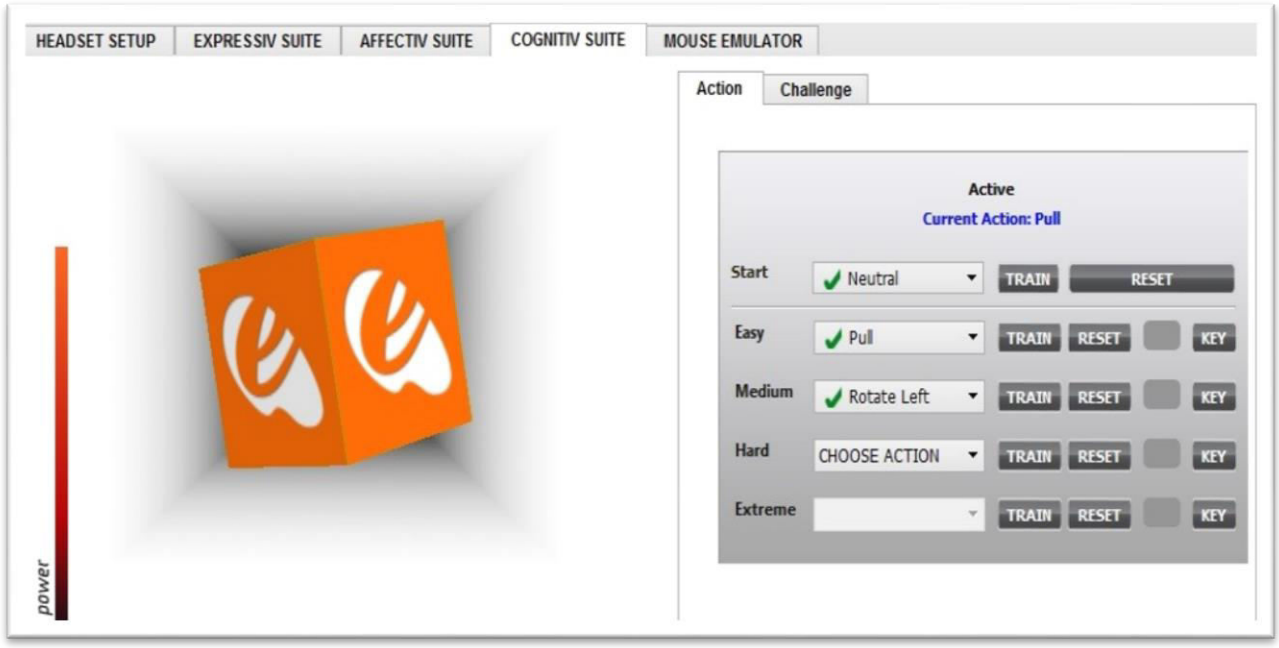


Figure 49: Cognitive suite training

b. Mind Your OSCs

'Mind your OSCS' is a software that sends data from the Emotiv Epoc to any software. In our case the other software is processing, Mind your OSCS sends the EEG data from the Emotiv Epoc to the processing software as an input. The connection between the Emotiv software, Mind Your OSCs and Processing is simple: just select the port number and press 'connect' and the connection will be established. The Mind your OSCS screen is shown in the figure below.

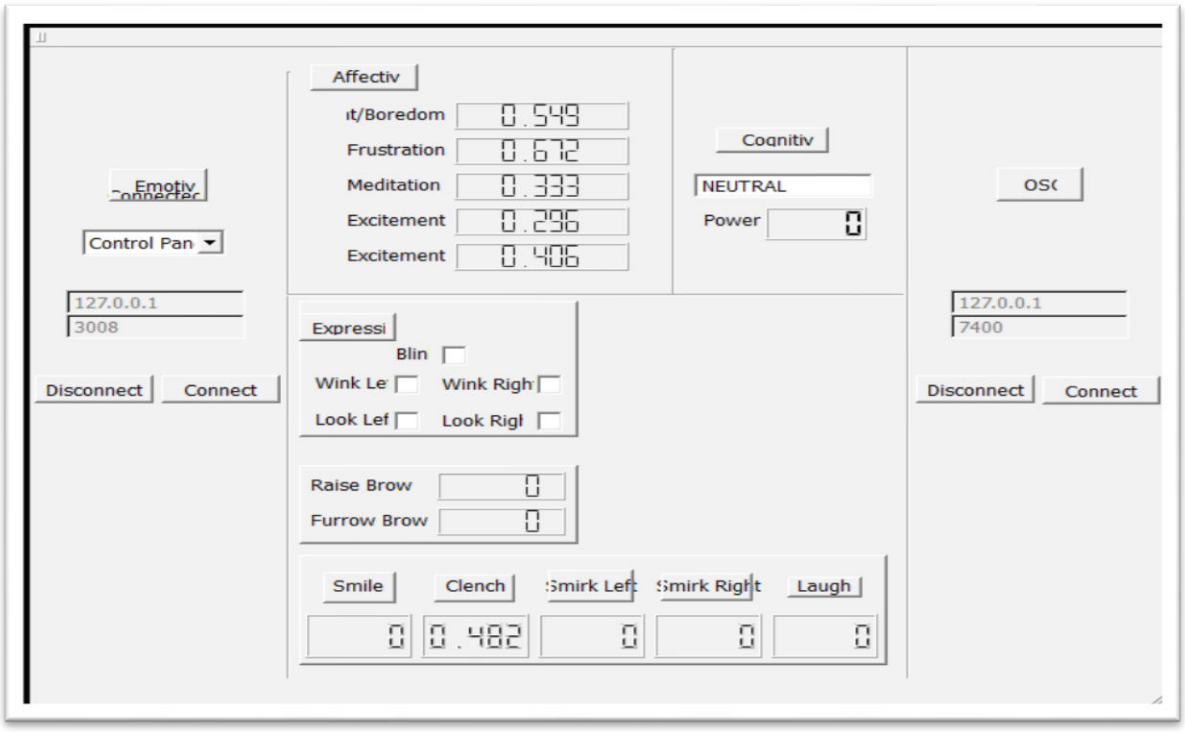


Figure 50: Mind your OSCs Interface

c. Processing Software

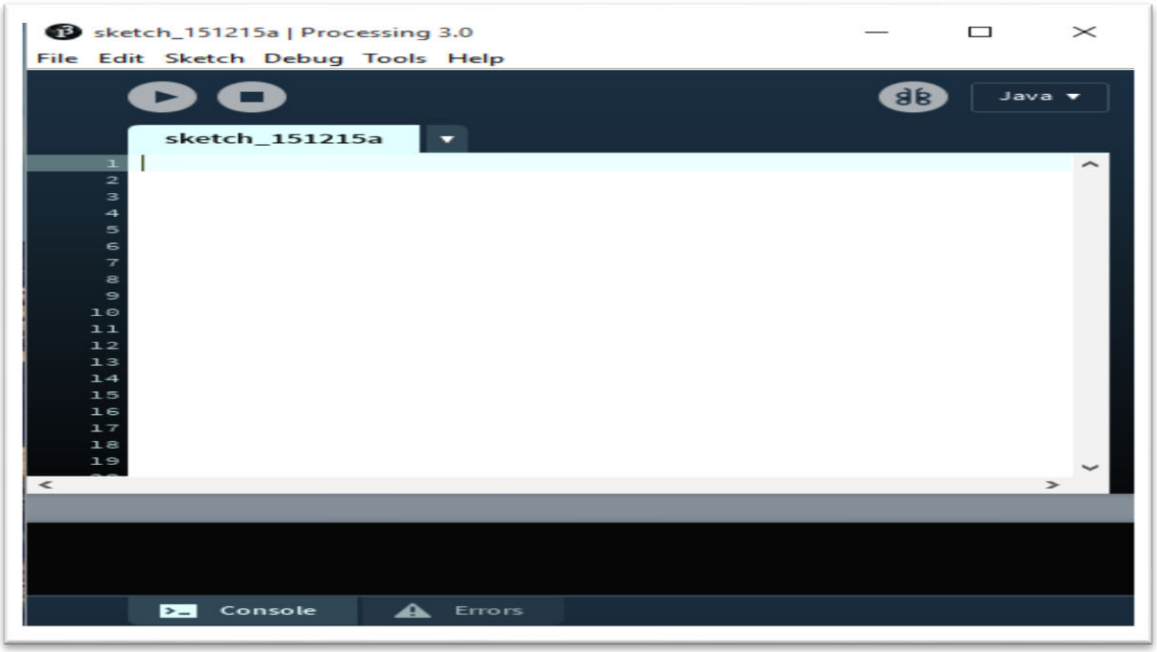


Figure 51: Processing 3 Interface

The processing software is used to take the EEG data from the EEG sensor, compute the data to its associated action and send the action to the Arduino microcontroller, which will then send the relative voltage to the digital potentiometer to control the wheelchair. For the connection between Processing and Arduino, we need few libraries called processing serial. For the communication between Epoc and Processing through mind OSCS we need a library called OSCp5.

d. Arduino Software

The Arduino software makes it easy to write and upload the code onto the Arduino micro-controller. The communication between the Arduino and processing is done serially. To control the digital potentiometer, the SPI library is included in Arduino. We choose serial port connection because we need to load a special code on the Arduino board.

e. Implementation and Working

Prepare Emotive Epoc Headset by first moisturizing 14 sensors by salinized water. Then install all the sensors on the headset. Now connect the wireless dongle to establish the connection successfully between Emotive Epoc+ headset and Emotive Epoc+ control panel. Connect Emotive Epoc+ control Panel with Mind Your OSCs. In the Left-hand side of the Mind Your OSCs window, you can see the IP address and port number for data coming in of Mind Your OSCs from Epoc control panel as shown in the figure below:

Figure 52: Connecting OSCs with Emotiv control panel

Connect Mind your OSCS with Processing 3.In the right-hand side of the Mind Your OSCs window, you can see the IP address and port number for data going out of Mind Your OSCs as shown in the figure below. Connecting this will make successful the connection with Processing 3.

Figure 53: Connecting OSCs with Processing 3

Load and run the processing and Arduino codes. When you run the processing code, you will see a screen shown in the figure below. Note that, the wheelchair can only be controlled when the power is ON.

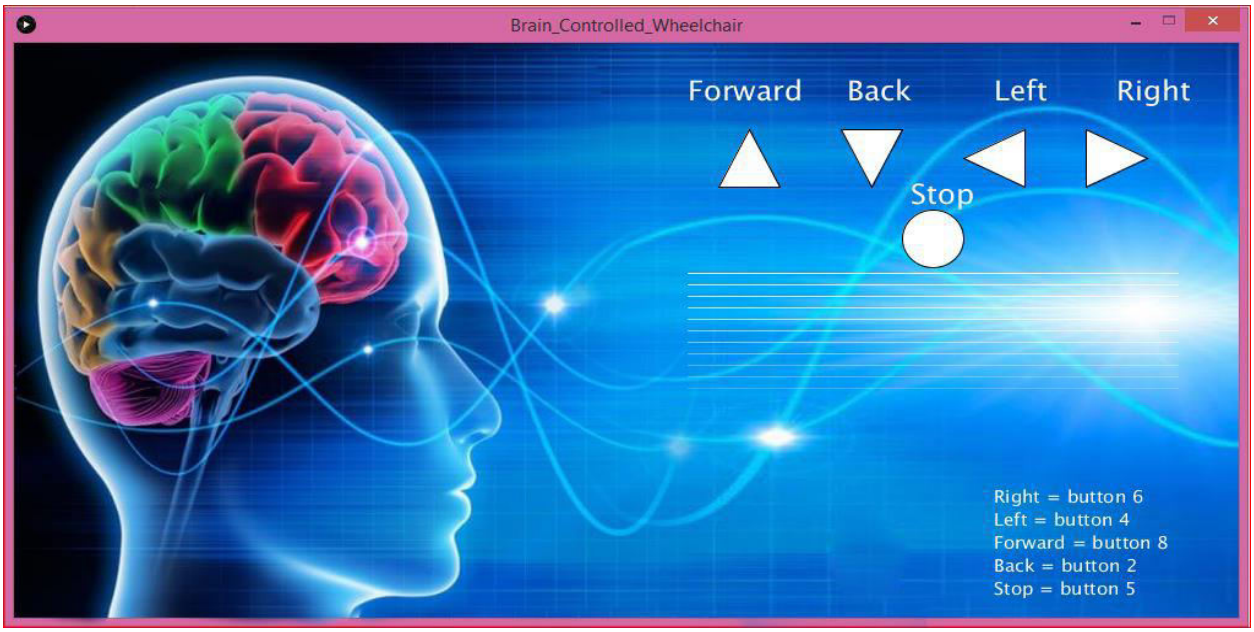


Figure 54: Control Wheelchair Interface

2.2. Hardware attachment

We can resume the whole process of mind control on the figure 55, from wearing the headset and access to the system, into controlling the wheelchair.

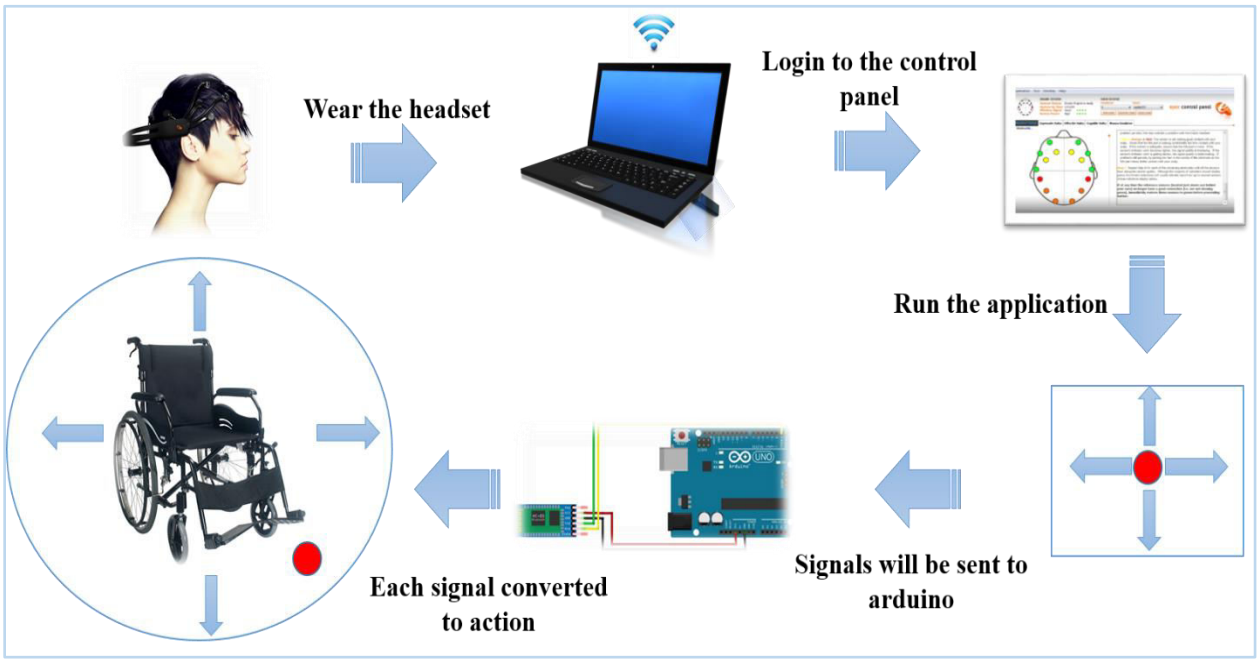


Figure 55: Hardware attachment of the wheelchair

Conclusion

About the mind control application, the user must authenticate (login) because each person have different brain signals and for security too.

The use of applications can be with voice, think and with pressing the buttons (traditional way).

May the description of implementation is too brief, but it touch the most important points in project

General Conclusion

This thesis has shown the development of new systems in the technology world. Realization of an electronic devices remote control system by voice and brain signals give us a lot of experience in short time. We can say that this project is a big gain for us. It was not easy to deal with all those new concepts, platforms, programming languages, new technologies, and especially new domain we mean the electronic domain. At first time, it appear as if it is impossible to realize all the requirements of the system, but the spirit of competition has encouraged us in all the periods of work. All we can say, now is that it was really hard work but it deserves it. Regarding the obtained results, for us they were very good and we are satisfied because we achieved all the goals with good level (the voice recognition is very accurate and for each instruction the system take 1 second to recognize it. In addition, the use of brain signals be a reality).

There was a big insufficiency on the hardware side, and this has stopped the work many times. That was so horrible because there was no time to waste.

We can say that the voice control can be commercialized, since we are not obliged to authenticate each time we want to control any device. Everyone can use this universal application just it is necessary to know the right orders to give.

The mind control using the EEG sensors and Epoc+ headset was demonstrated in the implementation phase. It is important to authenticate for security (to save who drive the wheelchair) and because each person has a special brain signals that are different from another one. Now, nothing is becoming impossible, we have to be ready to enjoy a new world with thought recognition.

Our work will not stop here, we have many points we decide to develop and to enhance. First of all, we think to discover a way to extract the brain signals and save them in databases to use them in future works. Second, we are starting to add the Arabic language in voice control because it is our original language and that includes local languages. Third, as we said before we can configure the mind control according to the user needs, that he can use his expressive or thought to control devices. Therefore, it will better if we can develop one application that

contains all those options to avoid configuration each time. Fourth, because it was not easy to get the materials, we will not let it like this and we already think of a new project in where we will exploit those units.

Glossary

A

ADT	Android Development Tools
AFH	Adaptive Frequency Hopping Feature
APK	Android application package
AT command	Attention command

B

BCI	Brain Computer Interface

C

CLI	Common Language Infrastructure
CMOS	Complementary metal-oxide semiconductor
CSR	Corporate social responsibility
CSS	Cascading Style Sheets

E

ECMA	European Computer Manufacturers Association
EDR	Enhanced Data Rate
EEG	Electroencephalogram
EPOC	Excess Post-Exercise Oxygen Consumption

F

FTDI	Future Technology Devices International

G

GND	Ground
GUI	Graphical user interface

H

HTML	Hyper Text Markup Language

I

ICSP	In-Circuit Serial Programming
IDE	Integrated Development Environment
ISO	International Standards Organization

P

PWM	Pulse Width Modulation

Q

QEEG	Quantitative Electroencephalography

S

SPP	Serial Port Protocol

U

UML	Unified modeling language
USB	Universal Serial Bus

$\mathcal{V}$

VCC	voltages, currents, and some components

$\mathcal{X}$

XML	Extensible Markup Language
XSLT	Extensible Stylesheet Language Transformations
XHTML	Extensible Hypertext Markup Language

Annex 1: Recognition Process

Recognition process

The common way to recognize speech is the following: we take waveform, split it on utterances by silences then try to recognize what's being said in each utterance. To do that we want to take all possible combinations of words and try to match them with the audio. We choose the best matching combination. There are few important things in this match.

First, it is a concept of **features**. Since number of parameters is large, we are trying to optimize it. Numbers that are calculated from speech usually by dividing speech on frames. Then for each frame of length typically 10 milliseconds we extract 39 numbers that represent the speech. That is called **feature vector**. The way to generate numbers is a subject of active investigation, but in simple cases it is just a derivative from spectrum.

Second, it's a concept of the **model**. Model describes some mathematical objects that gather common attributes of the spoken word. In practice, for audio model of senone is gaussian mixture of its three states - to put it simple, it is a most probable feature vector. From concept of the model the following issues raised - how good does the model fits in practice, can the model be made better of its internal model problems, and how the adaptive model is reacting to the changed conditions.

The model of speech is called Hidden Markov Model or HMM, it's a generic model that describes black-box communication channel. In this model, process is described as a sequence of states, which change each other with certain probability. This model is intended to describe any sequential process like speech. It has been proven to be really practical for speech decoding.

Third, it is a matching process itself. Since it would take a huge time more than universe existed to compare all feature vectors with all models, the search is often optimized by many tricks. At any points, we maintain best matching variants and extend them as time goes producing best matching variants for the next frame.

Models

According to the speech structure, three models are used in speech recognition to do the match:

1. **Acoustic model** contains acoustic properties for each senone. There are context-independent models that contain properties (most probable feature vectors for each phone) and context-dependent ones (built from senones with context).
2. **Phonetic dictionary** contains a mapping from words to phones. This mapping is not very effective. For example, only two to three pronunciation variants are noted in it, but it's practical enough most of the time. The dictionary is not the only variant of mapper from words to phones. It could be done with some complex function learned with a machine learning algorithm.
3. L**anguage model** is used to restrict word search. It defines which word could follow previously recognized words (remember that matching is a sequential process) and helps to significantly restrict the matching process by stripping words that are not probable. Most common language models used are n-gram language models-these contain statistics of word sequences-and finite state language models-these define speech sequences by finite state automation, sometimes with weights. To reach a good accuracy rate, your language model must be very successful in search space restriction. This means it should be very good at predicting the next word. A language model usually restricts the vocabulary considered to the words it contains. That's an issue for name recognition. To deal with this, a language model can contain smaller chunks like subwords or even phones. Please note that search space restriction in this case is usually worse and corresponding recognition accuracies are lower than with a word-based language model.

Those three entities are combined together in an engine to recognize speech. If you are going to apply your engine for some other language, you need to get such structures in place. For many languages there are acoustic models, phonetic dictionaries and even large vocabulary language models available for download

Other concepts used

1. A **Lattice** is a directed graph that represents variants of the recognition. Often, getting the best match is not practical; in that case, lattices are good intermediate formats to represent the recognition result.
2. **N-best lists** of variants are like lattices, though their representations are not as dense as the lattice ones.
3. **Word confusion networks** (sausages) are lattices where the strict order of nodes is taken from lattice edges.
4. **Speech database** - a set of typical recordings from the task database. If we develop dialog system it might be dialogs recorded from users. For dictation system it might be reading recordings. Speech databases are used to train, tune and test the decoding systems.
5. **Text databases** - sample texts collected for language model training and so on. Usually, databases of texts are collected in sample text form. The issue with collection is to put present documents (PDFs, web pages, scans) into spoken text form. That is, you need to remove tags and headings, to expand numbers to their spoken form, and to expand abbreviations.

What is optimized

When speech recognition is being developed, the most complex issue is to make search precise (consider as many variants to match as possible) and to make it fast enough to not run for ages. There are also issues with making the model match the speech since models aren't perfect.

Usually the system is tested on a test database that is meant to represent the target task correctly. The following characteristics are used:

Word error rate: Let we have original text and recognition text of length of N words. From them the I words were inserted D words were deleted and S words were substituted Word error rate is:

$$WER = (I + D + S) / N$$

WER is usually measured in percent.

Accuracy: It is almost the same thing as word error rate, but it does not count insertions.

$$\text{Accuracy} = (N - D - S) / N$$

Accuracy is actually a worse measure for most tasks, since insertions are also important in final results. But for some tasks, accuracy is a reasonable measure of the decoder performance.

Speed: Suppose the audio file was 2 hours and the decoding took 6 hours. Then speed is counted as 3xRT.

ROC curves: When we talk about detection tasks, there are false alarms and hits/misses; ROC curves are used. A curve is a graphic that describes the number of false alarms vs number of hits, and tries to find optimal point where the number of false alarms is small and number of hits matches 100%.

Annex 2: CMU Sphinx

CMU Sphinx

CMU Sphinx, also called Sphinx in short, is the general term to describe a group of speech recognition systems developed at Carnegie Mellon University. These include a series of speech recognizers (Sphinx 2 - 4) and an acoustic model trainer (Sphinx Train).

In 2000, the Sphinx group at Carnegie Mellon committed to open source several speech recognizer components, including Sphinx 2 and later Sphinx 3 (in 2001). The speech decoders come with acoustic models and sample applications. The available resources include in addition software for acoustic model training, Language model compilation and a public domain pronunciation dictionary, cmudict.

The used version of sphinx is 4. Sphinx-4 is a state-of-the-art speech recognition system written entirely in the Java™ programming language. It was created via a joint collaboration between the Sphinx group at Carnegie Mellon University, Sun Microsystems Laboratories, Mitsubishi Electric Research Labs (MERL), and Hewlett Packard (HP), with contributions from the University of California at Santa Cruz (UCSC) and the Massachusetts Institute of Technology (MIT).

Sphinx-4 started out as a port of Sphinx-3 to the Java programming language, but evolved into a recognizer designed to be much more flexible than Sphinx-3, thus becoming an excellent platform for speech research.

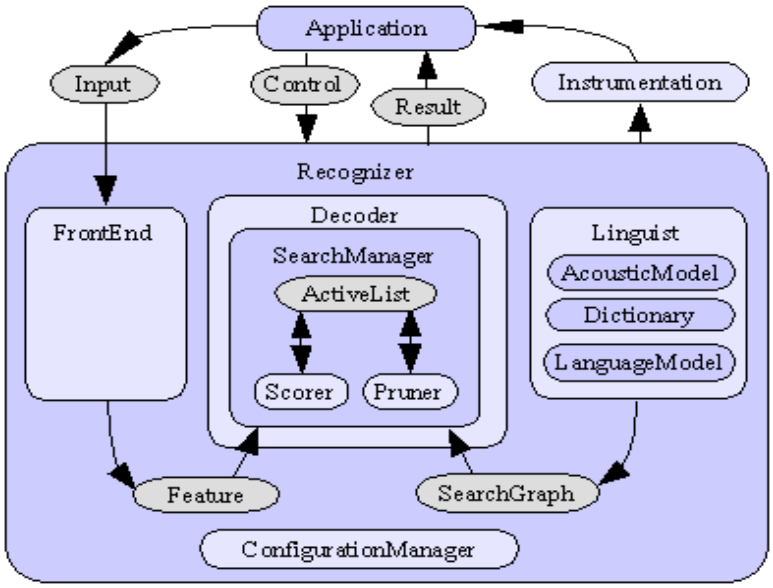


Figure: The architecture diagram of Sphinx-4

Recognizer: Contains the main components of Sphinx-4, which are the front end, the linguist, and the decoder. The application interacts with the Sphinx-4 system mainly via the Recognizer.

Front End: Performs digital signal processing (DSP) on the incoming data.

Feature: The output of the front end are features, which are used for decoding in the rest of the system.

Linguist: Embodies the linguistic knowledge of the system, which are the acoustic model, the dictionary, and the language model. The linguist produces a search graph structure on which the search manager performs search using different algorithms.

Acoustic Model: Contains a representation (often statistical) of a sound, often created by training using lots of acoustic data based on Hidden Markov Model (HMM).

Dictionary: Responsible for determining how a word is pronounced.

Language Model: Contains a representation (often statistical) of the probability of occurrence of words.

Search Graph: The graph structure produced by the linguist according to certain criteria (e.g., the grammar), using knowledge from the dictionary, the acoustic model, and the language model.

Decoder: Contains the search manager.

Search Manager: Performs search using certain algorithm used, e.g., breadth-first search, best-first search, depth-first search, etc. Also contains the feature scorer and the pruner.

Active List: A list of tokens representing all the states in the search graph that are active in the current feature frame.

Scorer: Scores the current feature frame against all the active states in the ActiveList.

Pruner: Prunes the active list according to certain strategies.

Result: The decoded result, which usually contains the N-best results.

Configuration Manager: loads the Sphinx-4 configuration data from an XML-based file, and manages the component life cycle for objects.

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