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Home Automation Using BCI "Microcontroller Based System"

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Abstract

The aim of the project is to facilitate access to home devices and control it by the fully paralyzed people. The solution is based on recording Electroencephalography brain signals using a modern headset that has 16 electrodes. The headset is meant to work as a computer input device called "Emotiv Epoc". Then use these signals to control the home devices by the microcontroller after sending it to the control panel using the USB receiver.

The process will start by training the "Emotiv Epoc" through its control panel which comes with Emotiv to record EEG brain signals caused by nerve impulse from the (Blink, Left wink, Smile, Laugh, excitement, Long term, excitement, Frustration, Engagement, Push, Pull, Lift, Drop , Left, Right etc ...). After that we will use these signals to control home devices using microcontroller.

The system succeeded to control some home devices. It turns on the lamp by smiling, and blinking for turning the lamp off. To open the door, the user needs to look right, and look left to close the door, wink right to turn the fan on and wink left to turn off the fan.

Abbreviations

BCI : Brain Computer Interface.

EEG : Electroencephalography.

PC : Personal Computer.

SDK : Software Development Kit.

DC : Direct Current.

AC : Alternating Current.

API : Application Programming Interface.

IDE : Integrated Development Environment.

USB : Universal Serial Bus.

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Chapter 1

Introduction

This chapter presents an overview of the project, including literature review, motivation, project objectives, and a brief description of the project.

1.1 Overview

The great development of information and communication technology have lead them to be used in many areas of life. There are many researches who took place on the theme of trying to read the ideas and understanding of the mechanism of the brain work.

Binding the mind to a computer was not a new idea, where it was firstly appeared in the 1970's [1]. BCI system has two ways in obtaining electrical activities, invasive where it calls for a neurosurgery intervention to implant a physically device in their brain, and non-invasive which is more spread out, because there is no need of any kind of surgery, and detect directly the electrical activity from over the scalp [2].

Our brain is made of about one hundred billion neuron, a neuron is a nerve cell, that communicates with each other by an electrochemical signals [3]. EEG emit voltage fluctuations from the neurons electrical activity on the scalp, due to their ionic current flows in a short time period [4]. EEG is the data input for most BCI systems, and it helps disabled people to control devices through their

brain activities [4].

Recently, technology has been moving toward cheap and simple solutions for patients who are paralyzed, or for people who use technology to improve their daily lives.

BCI technology helps the people with disabilities to live normal life and use devices easily only by their brain activities. Based on in neuro technology, most of the current BCI systems obtain the needed information from the brain activity through EEG. There for; applications and researches have increased due to the availability and presence of EEG headset recorders in markets. Also many of papers and researches are specialized in this field to give patients with physical disorders the ability to communicate with the outside world through their mental activity.

In our project, we will use the Emotiv Epoc headset to read the brain signals, record these signals through the control panel, send it to emokey, then use a microcontroller to control some home device (lamp, door, and fan).

1.2 Literature Review

Muscle movements is being controlled by the brain motor cortex, so researchers were interested in it [5]. The invasive techniques found to be slow after experiments on motor neuron responses in monkeys [6][7], and using a prosthetic the monkey feed himself by its thoughts [8]. Patients with tetraplegia were enabled in 2006 to use prosthetic, a mouse cursor, and a television [9].

EEG technology is for noninvasive type. It had been applied on dogs with another term "electrocerebrogram" by Vladimir.P.N in 1912. Then applied on human by Hans.B who named it EEG [10]. Then in 1950's it was developed by Herpert.J [11], afterward this is became the standard brain measurements. Since

EEG technology is the recording of brain activity, then it is affected by the alertness condition or mental disorders [12]

Selecting characters mentally for fully paralyzed was accomplished in the 2000, despite of being slow and not completely flawless [13]. And in 2008, a team were able to control a wheelchair, but still not approved on as a solution [14].

1.3 Motivation

Since the world is moving towards cheap and easy living solutions for patients; this project can be a very important step in accomplishing that. Our system aims to help fully paralyzed patients to make their live easier. It also helps other people who have disabilities such as blindness and aging. This is accomplished by targeting them to enhance their controlling abilities through this system, After recording the EEG signals using a neural headset. Finally, The commands can passed to a microcontroller 'Arduino' in order to control home devices (lamp, door, and fan).

1.4 Objectives

Build a user friendly system to help the fully-paralyzed people to control the home devices by the microcontroller based on the brain activities.

1.5 Brief Description of the Project

The main objective of the project is to make an application of BCI system. Firstly, by reading brain signals using the "Emotiv EPOC" headset, with computer through wireless receiver. It aims to detect brain signals around the scalp

using electrodes while the user is (smiling, blinking, laugh, left winking, right winking, etc ...), to use these signals after conversion by "Emokey SDK" to control the home devices using microcontroller. These control signals can help fully paralyzed people to control the home devices (lamp, door, and fan) using our brains easily.

Chapter 2

Problem Statement

2.1 Overview

This chapter discusses the problem analysis, the list of requirements, and finally the expected results are illustrated.

2.2 Problem Analysis

There is a need to solve the problem of access to home devices and controls it by the fully paralyzed people. We planned to design and build a cheap, an effective, and a user friendly system that reads people brain signals using "Emotiv Epoc" headset electrodes installed on the scalp, to control the home devices using the microcontroller.

2.3 List of Requirements

System requirements can be summarized as:

- Headset electrodes installed on the scalp to read EEG signal recorded the brain activities.
- Wireless transporter for EEG recorded signal from headset to computer.

- A software to make classification for brain activities and then convert the EEG recorded signal into keystrokes.
- A microcontroller to control the lighting lamps, door, and fan.
- Graphical interface to allow the user to connect the emotiv with the arduino.

2.4 Expected Results

- Reading the brain signals by Emotiv Epoc and send it to control panel.
- Connect the control panel with emokey software to convert the signal to understandable symbols.
- Transmit these symbols to Arduino using the API.
- Control the two motors and the light depends on the commands which sent to the arduino software.

Chapter 3

Background

3.1 Overview

This chapter introduces the theoretical background of the project; description of the parts used in the system, short description of the hardware and the software components used in the system and why they are used, also discusses the design specifications and constraints.

3.2 Theoretical Background

This project helps fully paralyzed people to control surrounded devices in their own home. It basically depends on the use of brain EEG recorded signals that controls the automated home. Its main advantage is to enhance the interaction between them and the surrounding environment using "Emotiv Epoc" and Arduino microcontroller. Helping this sector to control the automated home is a very important issue since these people have difficulties in interacting with devices. This project covers a large sector of people who have disabilities and can be developed later to cover other sectors.

3.2.1 The System Sequence Summarized As

- The system should be ready (The Epoc headset charged).
- The Epoc headset reads the brain signals and sends it to the PC wirelessly.
- The Emotiv SDK checks if the signal in the range or not, if the signals are notified to have poor connection, then we need to start troubleshooting.
(e.g. see if the electrodes placed properly on the scalp, if the user is standing in the range close to the PC, or the electrodes are all wetted with the saline solution, etc...) then start over again from the second step.
- Analyze the brain signals and translate the emotional signals to keystrokes using Emokey SDK.
- Pass the symbol to microcontroller to control devices through the API.

3.2.2 BCI Inner Emotiv

Figure 3.1 represents the block diagram of BCI inner Emotiv steps: The first step shows an EEG technique in signal acquisition stage, which is used to detect the brain activity. In the pre-processing stage, filters are used to improve and clarify the signal for feature extraction. The feature vectors are often of high dimensionality; to reduce the dimensionality the feature selection can be performed. In this step, the most useful features are chosen, while other are omitted. Finally, the classification stage classifies the features in order to make the decision [15].

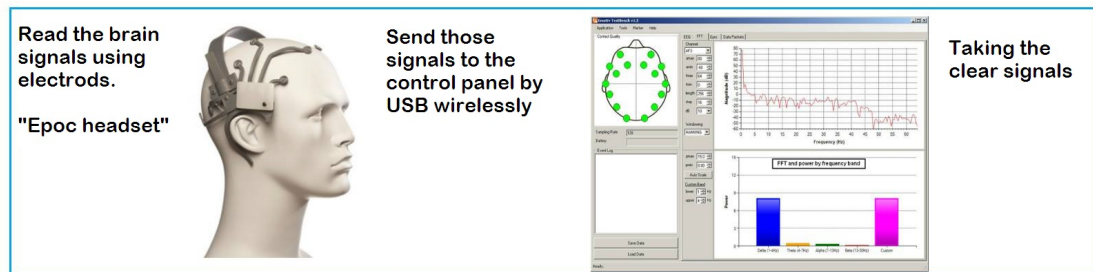


Figure 3.1: Emotiv BCI System.

3.3 System Parts

These are all parts that will be used in this system:

3.3.1 Neural headset

Headsets record the EEG signals then transmit them to computers. That is displayed later on screen. Like "Emotiv Epoc" and "Neurosky" [16].

3.3.2 Wireless Connection

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor. Wireless is a technique used to connect two or more nodes in a network without the use of electrical cables or wires, by a radio communication [17].

3.3.3 Arduino Microcontroller

Arduino is a microcontroller and an open source platform, used to control and run creative projects by uploading a program written by us. Many tasks can be done by it, such as, controlling a car, or as in this project in controlling home devices [18].

3.3.4 Home Automation

It is the residential extension of building automation. It is automation of the home, housework or household activity. Home automation may include centralized control of lighting, HVAC (heating, ventilation and air conditioning), appliances, security locks of gates and doors and other systems, to provide improved convenience, comfort, energy efficiency and security. Home automation for the elderly and disabled can provide increased quality of life for persons who might otherwise require caregivers or institutional care [19].

3.4 Hardware Components of the System

This section describes the hardware components used in the project, why they are used, how they are attached to the system, and the components images.

3.4.1 Items in the Epoc headset Kit

The Epoc headset Kit consists of: the "Emotiv Epoc" headset, "Emotiv Epoc" USB Receiver, Rubber Comfort Pads, Epoc Felt Sensors, "Emotiv Epoc" Hydrator Pack and Saline Solution.

For more details see Appendix A.

3.4.2 Arduino Microcontroller

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

We could use arduino Uno, but because arduino Mega was available from an old project we use it[20].

As shown in figure 3.2 Mega 2560 Microcontroller is chosen, since it has specifications illustrates in the design options in chapter 4.

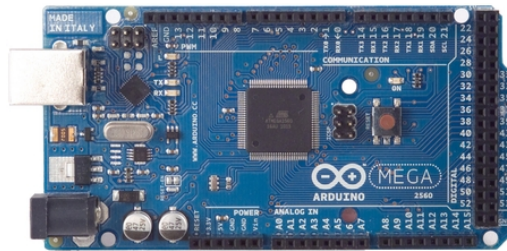


Figure 3.2: Arduino Mega 2560 Microcontroller Board

3.4.3 L298N H-bridge

As shown in figure 3.3 H-bridge module that can allow you to control the speed and direction of two DC motors, or control one bipolar stepper motor with ease.

The L298N H-bridge module can be used with motors that have a voltage of between 5 and 35V DC. With the module used in this tutorial, there is also an on-board 5V regulator, so if your supply voltage is up to 12V you can also source 5V from the board [21].

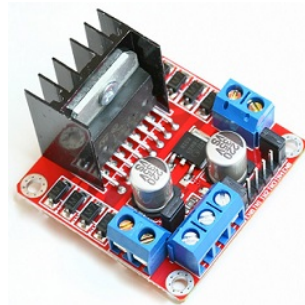


Figure 3.3: L298N H-bridge

3.4.4 Computer (laptop or desktop)

We need a computer (laptop or desktop) to be connected with the "Emotiv EPOC" headset to send the brain signals to it.

3.4.5 DC Motor

As shown in figure 3.4, they come with a wider operating range than most of motors: from 4.5 to 9V DC instead of 1.5-4.5V. This range makes them perfect for controlling with an Adafruit Motor Shield, or with an Arduino where you are more likely to have 5 or 9V available than a high current 3V setting. They'll fit in most electronics that already have 130-size motors installed and there's two breadboard-friendly wires soldered on already for fast prototyping [22].



Figure 3.4: DC Motor

3.4.6 Power Supply

A step down transformer was used to transfer AC voltage from 220 v to 9v. Then to get a 5 DC volt to feed the motors , the h bridge was used. And to feed the lamp the plug was used to get a 220 volt AC.

3.5 Software Component

3.5.1 SDK

The "Emotiv Epoc" SDK Research Edition is a single user license for companies / Educations that are creating proprietary applications and/or are also developing new applications / detections using raw EEG data from the "Emotiv Epoc", it includes a high resolution, neurosignal acquisition and processing wireless neuroheadset [23].

3.5.2 Emokey

Emokey is a great feature which translates emotional states for application inputs, and it is built-in the Epoc Control Panel (compatible with all Emotiv headset models). Emokey can identify user's emotional activities and facial expressions. It works like a switch where the user only decides when they need to active or not. Emotive app store is also providing Emokey based keyboard for the "Emotiv Epoc" users [24].

3.5.3 Control Panel

"Emotiv Epoc" control panel show cases the capabilities of the "Emotiv Epoc" Neuroheadset to decipher brain signals, facial expressions and even mouse control using the in-built motion sensors. The control panel has been divided into three categories: Expressive Suite (facial expression), Affective Suite (subjective emotional responses) and the Cognitive Suite (intentional thoughts). We will only use the: Expressive Suite in our project, although the other two are very interesting too [25].

3.5.4 Arduino Home Automation Control Program

Integrative developmental environment for writing software for the Arduino. The reason for choosing Arduino id program because it is much easier to deal with. And it has stronger abilities to deal with various electronic parts and Software.

3.6 Design Specifications and Constraints

3.6.1 Design Specifications

The system must be able to take brain signal of fully paralyzed people. By using 14 EEG channels plus 2 references from the "Emotiv Epoc" headset, then transmit these signal through "Emotiv Epoc" USB Receiver to computer. After that, it uses the Emokey to translate these signals to a keystrokes. Then uses these keystrokes to control home devices by microcontroller.

3.6.2 Design Constraints

1. The "Emotiv Epoc" SDK license is very expensive, but after hard research, we figured out an alternative method to use "Emotiv Epoc" tools without its original SDK.
2. The port we are using is probably quite close to internal components of the PC that interfere with the reception such as wireless or Bluetooth cards hard drive controllers etc or external components like routers, cordless phones, cell phones etc, this leads to a poor wireless range.

Chapter 4

System Design

4.1 Overview

This chapter consist of the block diagram of the system, flowchart, use case diagram, and discuss the design options.

4.2 Block Diagram

Figure 4.1 is the general Block Diagram of the project.

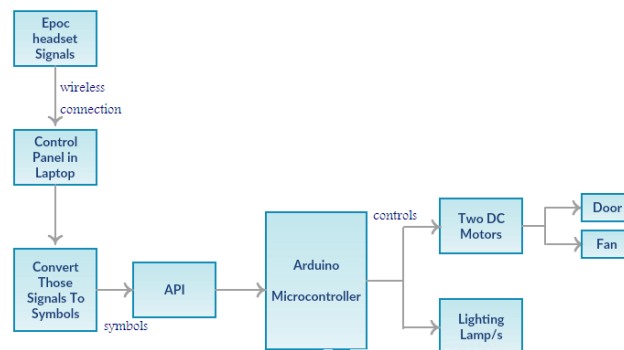


Figure 4.1: System Block Diagram.

4.3 Flowchart

Figure 4.2 represents the meanings of the symbols (Key strokes), and figure 4.3 represents the flowchart diagram of the system activity.

| Symbol | Action | Reaction |
|--------|-------------|----------------------------|
| 1 | Smile | Turn ON the lighting lamp |
| 2 | Blink | Turn OFF the lighting lamp |
| 3 | Looks right | Open the door |
| 4 | Looks left | Close the door |
| 5 | Right wink | Open the fan |
| 6 | Left wink | Close the fan |

Figure 4.2: The meanings of the symbols in the flowchart.

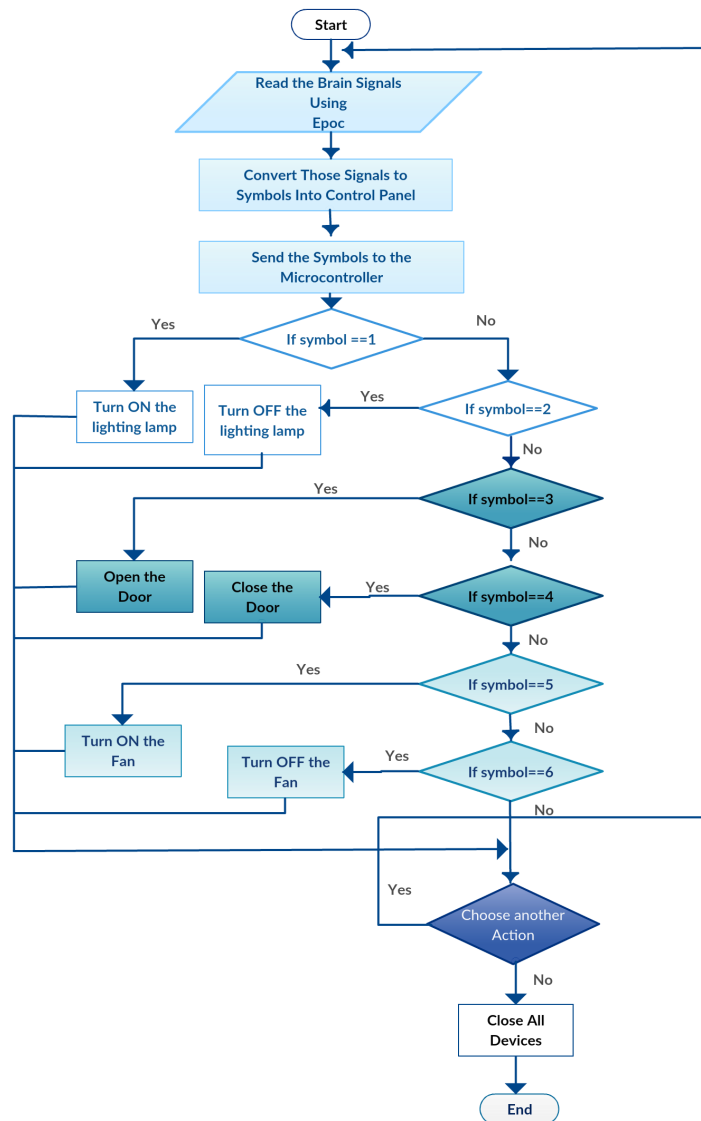


Figure 4.3: System Flowchart.

4.4 Sequence Diagram

Figure 4.4 represents the Sequence Diagram of the system.

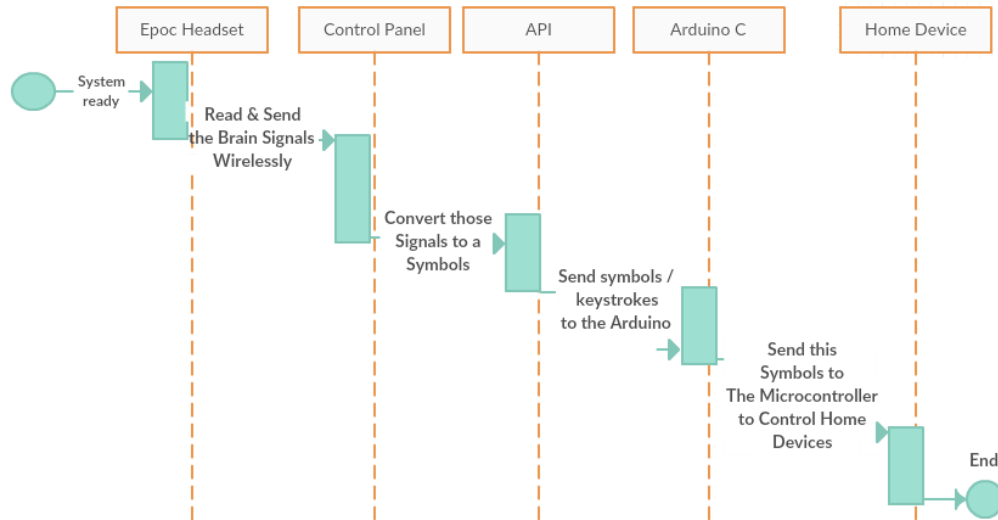


Figure 4.4: Sequence Diagram.

4.5 Design Options

4.5.1 Headset Options

First Option: Neurosky

It has a single sensor located on the user's forehead over the left frontal cortex. The problem is that it is difficult for any EEG system to see brain activity when nearby muscles are firing and so it is easy to confuse a BCI built on one forehead sensor.

Second Option: Emotiv

It has 14 sensors, located all over the head. It is much easier to classify and dis- miss different muscle signals because of how they appear to different surrounding sensors which gives more accurate detection, and also they can be used to derive facial expressions from the muscle activity, which is not possible with one sensor.

Chosen Option:

We have chosen the second approach, due to its previous advantages.

4.5.2 Motor controller Options

First Option: L298N H-bridge

Use the L298N H-bridge integrated circuit to control the motors, it provides easier software programming, giving more consistent results, and it is cheaper.

Second Option: Pi MCB/Servo Board

Use the Pi MCB/Servo board to control the motors.

Chosen Option: We have chosen the first approach, due to its previous advantages.

4.5.3 Microcontroller Options

First Option: PIC18F458

It is a moderate ease of programming , also PIC's are difficult to be connected to the EEG headsets.

Second Option: Arduino Mega 2560

The Arduino is inexpensive, easy to be programmed, cross platform, open source and has extensible software and hardware.

Chosen Option: We have chosen the second approach, due to its previous advantages.

4.6 Detailed Hardware Connection

Figure 4.5 represents the detailed hardware connection for the lamp.

Connect IN pin of the relay to pin 13 on the arduino, connect one of the ground pins of the arduino to GND pin on the relay, one of the VCC pins of the arduino to VCC pin on the relay.

Connect the NO and COM pins of the relay to a 220 V.

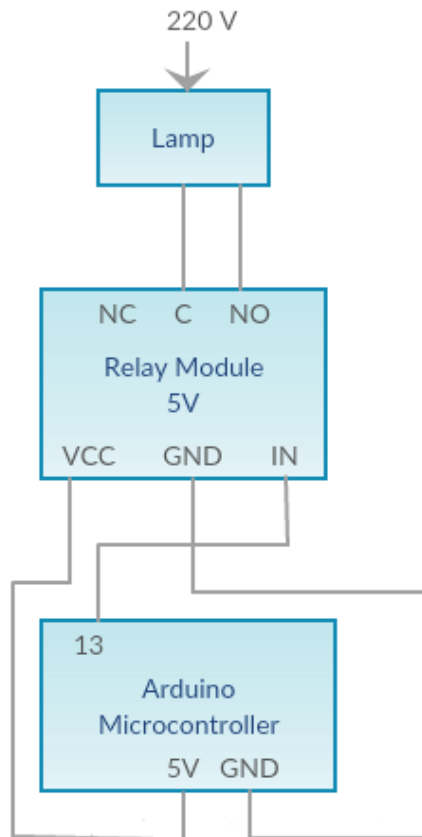


Figure 4.5: The Lamp Connection.

Figure 4.6 represents the detailed hardware connection for the fan.

Connect IN1, IN2 of the H-bridge to pins 7,8 on the arduino respectively. Combine the ground between the H-bridge and the arduino, connect the transformer to the input pins for the H-bridge. Finally outputs 1 and 2 of the H-bridge to the door motor.

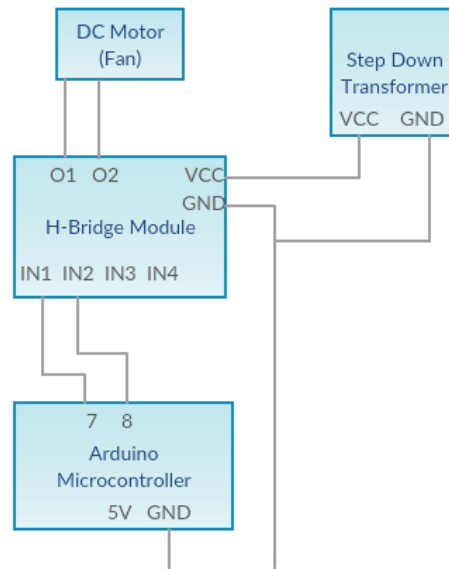


Figure 4.6: The Fan Connection.

Figure 4.7 represents the detailed hardware connection for the door.

Connect IN3, IN4 of the H-bridge to pins 5,6 on the arduino respectively. Combine the ground between the H-bridge and the arduino, connect the transformer to the input pins for the H-bridge. Finally outputs 3 and 4 of the H-bridge to the door motor.

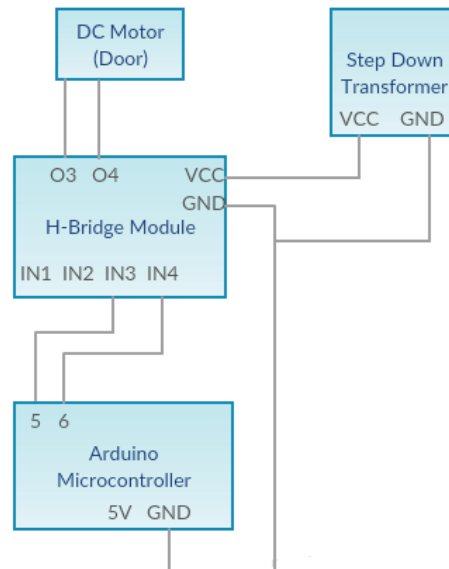


Figure 4.7: The Door Connection.

Figure 4.8 represents the detailed hardware connection for the system.

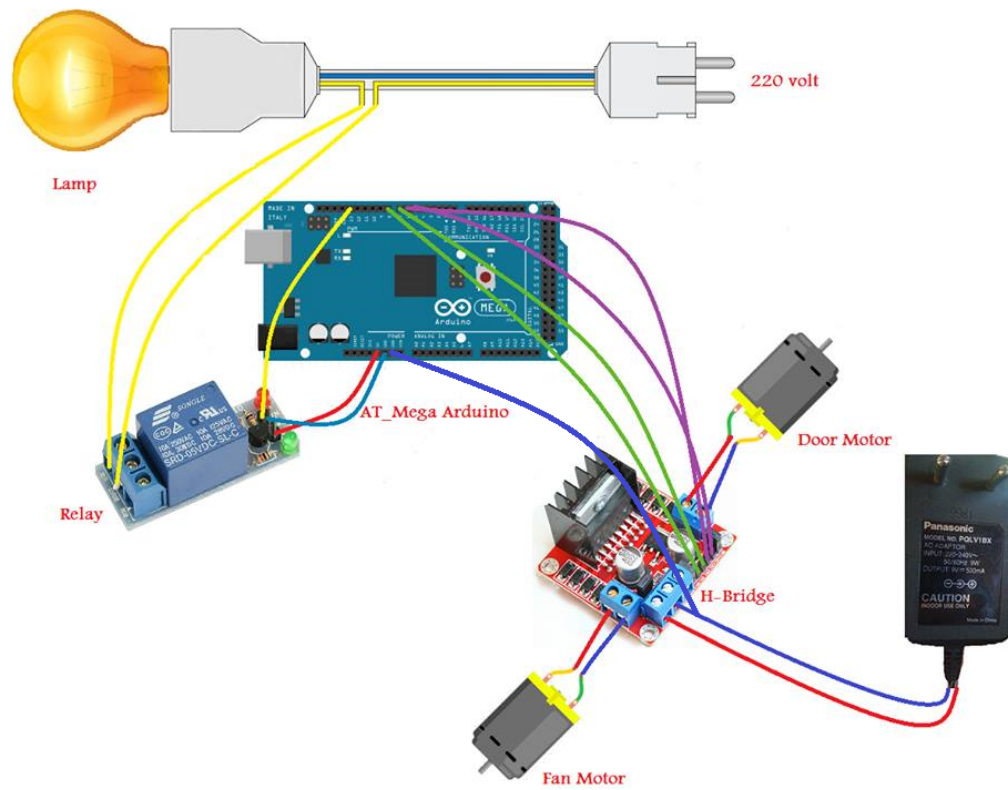


Figure 4.8: The System HardWare Connection.

Chapter 5

Software

5.1 Overview

In this chapter we will describe the software that we have used in our project, such as the operating system, Development environments that have been used to build the project and the set of tools and packages that help us to complete the work.

5.2 Description of the Software

Our System mainly depends on two active points, the Epoc headset that worn by the user, and the Arduino mega microcontroller connected to the devices. The Epoc headset reads the brain signals by electrodes, then send those signals to a laptop by USB receiver. The control panel is already downloaded; it takes the clear signals then convert it to asymbols by emokey in the control panel.

The symbols sent to the API then the API send it to Arduino software. Each symbol has a special indication, so we can control the devices by these different symbols.

In this section, the interfaces of C# app "Emotiv To Arduino Serial Communication" are presented, with detailed transition between the screens:

Figure 5.1 is the main screen of app. It contains 3 Buttons: the first one is friendly to paralyzed patients and allow to control the system from long distance, the second button allows any user to use the keyboard, and the third button to Exit the application.



Figure 5.1: The Main API.

If the user presses "patient" button, screen of figure 5.2 will appear on this screen to allow the user to select one of the available ports. This application can connect to multiple ports. After that, we have to choose the Baud rate, then press the "open port" Button as shown in figure 5.3. If the status is blue in the progress Bar, then the port is open. Otherwise, it warns the user. If connected, the keystroke passes to textbox which is updated automatically through a timer. The value is transmit afterward to Arduino. Once done, we can close the port. Also we can go back to main screen or Exit the application.

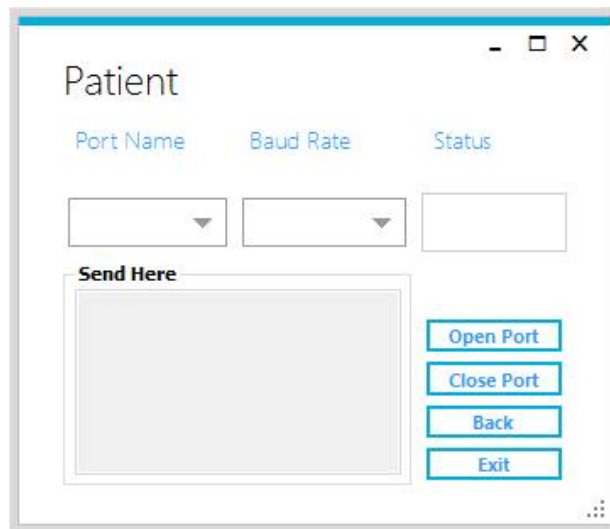


Figure 5.2: The Special Needs User API (1).

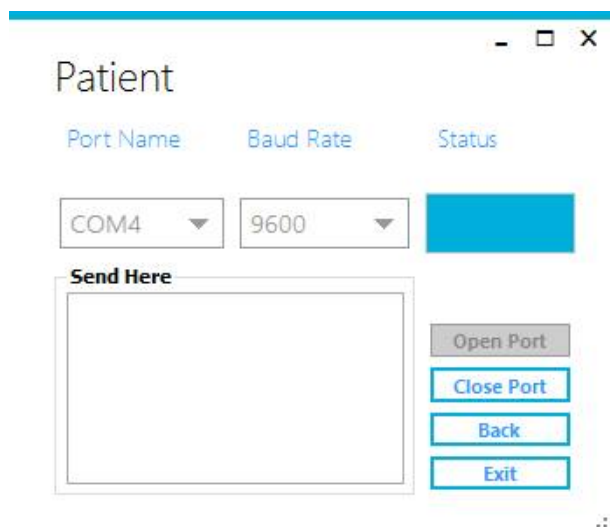


Figure 5.3: The Special Needs User API (2)

If the user press "user" button, screen shown in figure 5.4 will appear. This screen allows the user to select one of the available ports. This application support connecting to multiple ports. We must after that choose the Baud rate and select the "open port" Button as shown in figure 5.5. If the status is blue in progress bar, the port is open. Otherwise it warning the user, if

connect the keystroke pass to textbox then the user press send to send the keystroke to Arduino. We can read the Arduino feedback by press read button, we can close the port after finish. Also we can go back to the main screen or Exit the application.

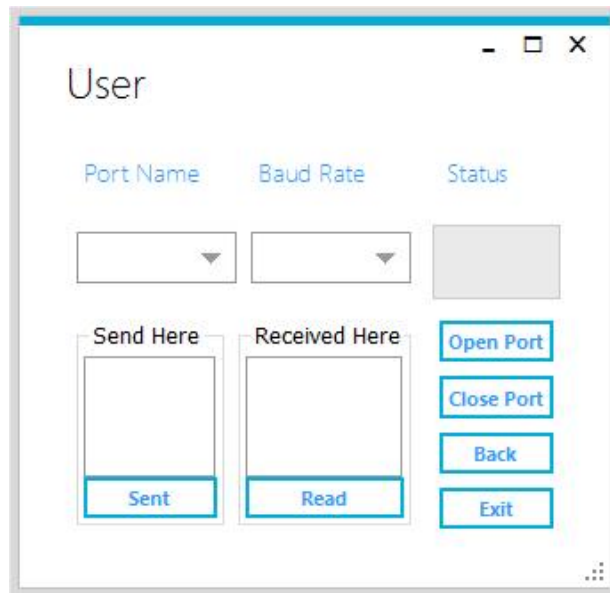


Figure 5.4: The Normal User API (1)

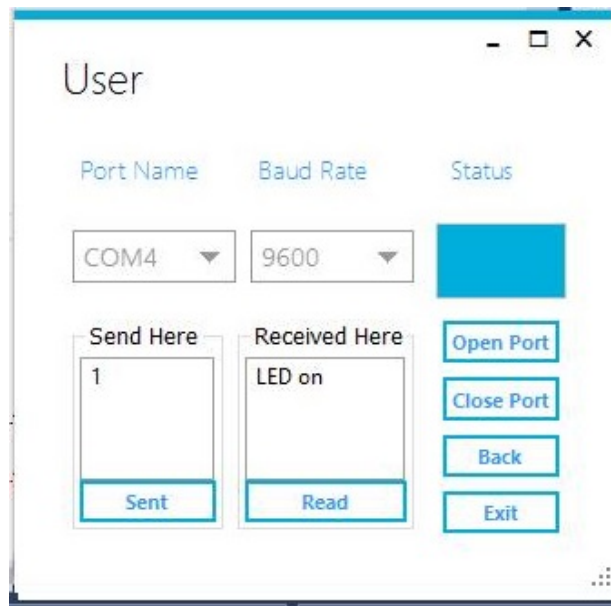


Figure 5.5: The Normal User API (2)

The source code in Appendix B.

For example: we want to turn on the lighting lamp.

- After the user wear the Epoc headset, he should smile.
- The smile saved as (1).
- Send this keystroke to Arduino software by the API.
- When the Arduino receives (1) on the serial input port, it allows the relay to pass voltage means turning on lighting lamp.

5.3 Information's about the Software Used to Develop the System

In this part we will talk about the programs that have been used in the system.

5.3.1 C # Programming Language

C sharp was used to design the interfaces of the system, which will tack the symbols then send it to the arduino software. The reason we have used C sharp over other IDE's is that C sharp provide many tools that make developing much easier.

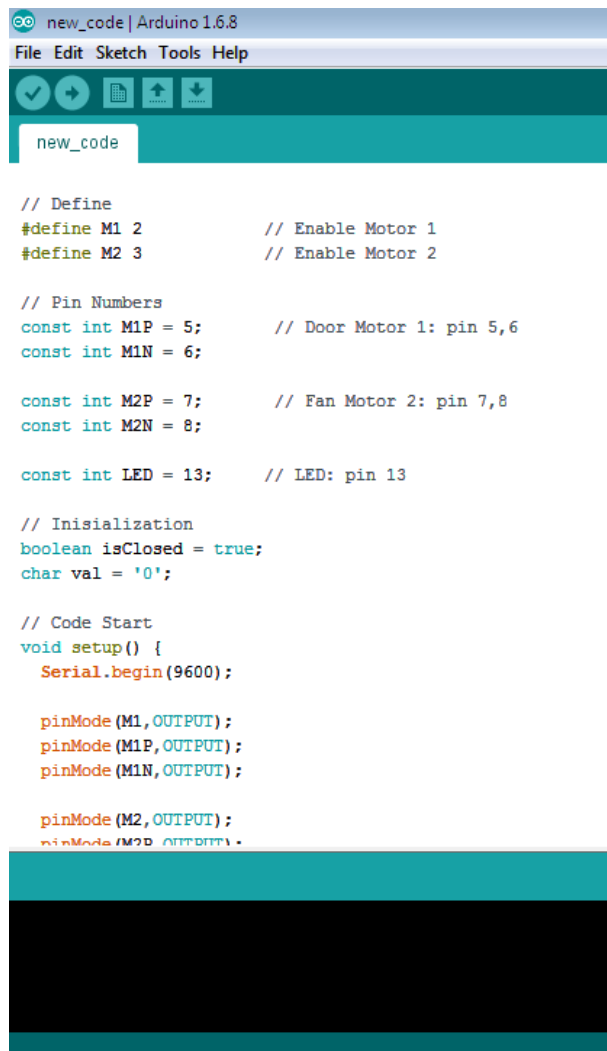
5.3.2 Proteus

Proteus program was used to draw the project plans and the reason for choosing this program above other programs is because it is an easy tool that provides a wide range of electronic devices.

Also it includes an integrated environment containing all the necessary tools to process a realistic simulation.

5.3.3 Arduino Software

Integrative developmental environment for writing software for the arduino. The reason for choosing arduino C program because it is much easier to deal with. And it has stronger abilities to deal with various electronic parts and Software as shown in figure 5.6, the full code in Appendix C.



```
new_code | Arduino 1.6.8
File Edit Sketch Tools Help

new_code

// Define
#define M1 2           // Enable Motor 1
#define M2 3           // Enable Motor 2

// Pin Numbers
const int M1P = 5;    // Door Motor 1: pin 5,6
const int M1N = 6;

const int M2P = 7;    // Fan Motor 2: pin 7,8
const int M2N = 8;

const int LED = 13;   // LED: pin 13

// Inisialization
boolean isClosed = true;
char val = '0';

// Code Start
void setup() {
  Serial.begin(9600);

  pinMode(M1, OUTPUT);
  pinMode(M1P, OUTPUT);
  pinMode(M1N, OUTPUT);

  pinMode(M2, OUTPUT);
  pinMode(M2P, OUTPUT);
```

Figure 5.6: The Arduino Software.

Chapter 6

Validation and Testing

6.1 Overview

In this chapter we will show and explain the results of the implementation of the system we did and the additional work we achieved in our project.

6.2 Headset Testing

6.2.1 Training the headset

We train the headset to recognize the signals as shown in the figure 6.1.

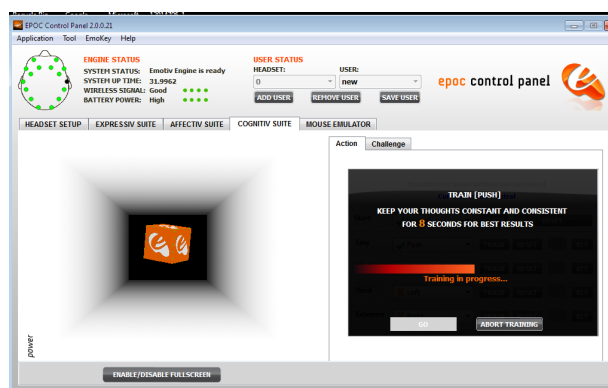


Figure 6.1: Training the headset

6.2.2 Generate the Symbols

We have tried to generate symbols using the brain signals from user, which it is transferred to the control panel wirelessly by the USB receiver.

Control panel chooses the clear signals, then save each signal as a specific number 'symbol' by emokey. The results appeared on the laptop directly as shown in figure 6.2.

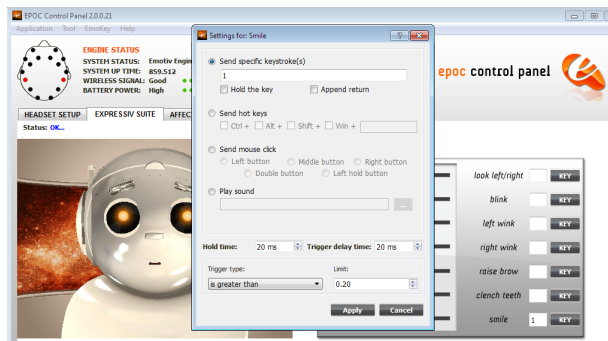


Figure 6.2: Generate the Symbols

6.2.3 Save Signals as Symbols

As shown in figure 6.3.

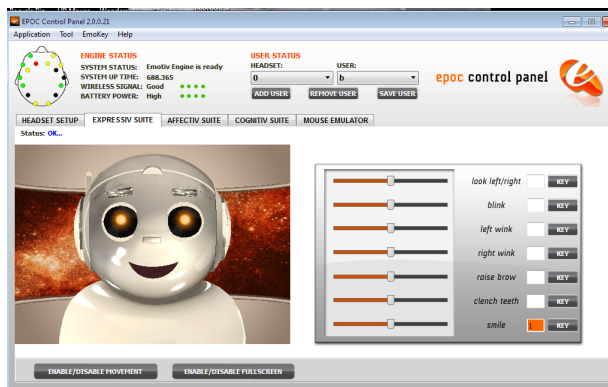


Figure 6.3: Save Signals as Symbols

6.2.4 The Appearance of the Symbols

The second test is that the symbols appears in a file as shown in figure 6.4

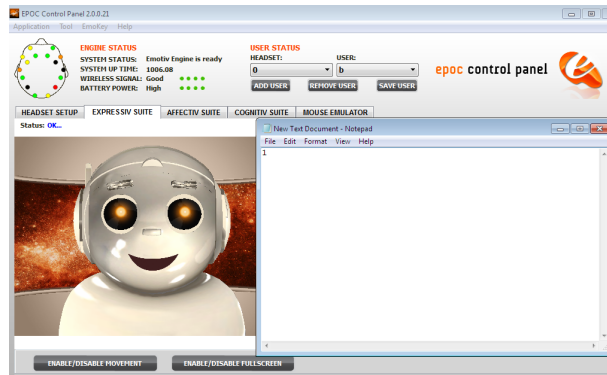


Figure 6.4: The Appearance of the Symbols

6.3 User Interface Application

We are build our application in C sharp programming language. After the control panel is already open, the application has a text box that receive the symbol and then the application send it to the arduino software successfully.

6.4 Arduino Testing

After the circuit was connected power supply was applied to the motors, and light the Arduino was programmed to control them by Arduino C. When the Arduino take the input command, it control the devises depend on these commands. The test was passes successfully and recorded in a video.

As shown in figures 6.5 and 6.6, the results of testing is different on a five different users, because of the difference of the brain signals between them.

| | smile | blink | Clench teeth | Left wink | Right wink | Rise brow | Look L/R |
|-------|------------------|------------------|------------------|------------------|------------------|------------------|--------------------|
| user1 | Success after 2s | Success after 1s | Success after 1s | Success after 4s | Success after 6s | Failed | Success after 4.5s |
| user2 | Success after 9s | Success after 1s | Success after 2s | Failed | Failed | Success after 1s | Failed |
| user3 | Success after 4s | Success after 1s | Success after 1s | Success after 9s | Failed | Success after 5s | Success after 3s |
| user4 | Success after 1s | Success after 1s | Success after 1s | Success after 1s | Success after 3s | Failed | Success after 2s |
| user5 | Failed | Failed | Success after 7s | Failed | Failed | Success after 2s | Success after 9s |

Figure 6.5: Expressiv suite

| | Push | Pull | Left | Right |
|-------|------------------|------------------|------------------|------------------|
| user1 | Success after 3s | Failed | Success after 2s | Success after 4s |
| user2 | Success after 1s | Success after 3s | Failed | Failed |
| user3 | Success after 5s | Success after 1s | Failed | Success after 3s |
| user4 | Success after 3s | Success after 2s | Success after 1s | Failed |
| user5 | Failed | Success after 2s | Success after 3s | Success after 3s |

Figure 6.6: Cognitiv Suite

6.4.1 Lighting Lamp

As shown in figure 6.7 the lamp is on when the user smile.



Figure 6.7: The Lamp is Light

As shown in figure 6.8 the lamp is turned off when the user blinking eye(s).



Figure 6.8: The Lamp is Turn OFF

6.4.2 The Door

As shown in figure 6.9 the door is opened when the user looks right.



Figure 6.9: The Door is Open

As shown in figure 6.10 the door is closed when the user looks left.



Figure 6.10: The Door is Close

6.4.3 The Fan

As shown in figure 6.11 the fan is turned on when the user wink right.

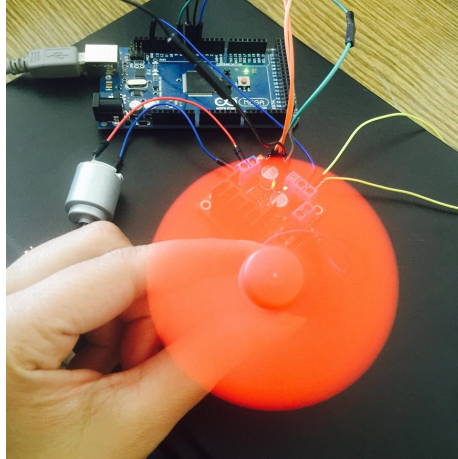


Figure 6.11: The Fan is Turn ON

As shown in figure 6.12 the fan is turned off when the user wink left.

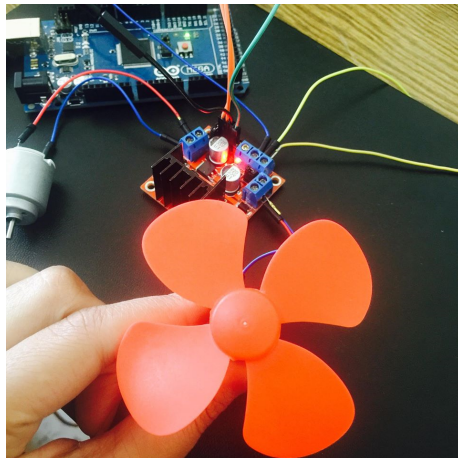


Figure 6.12: The Fan is Turn OFF

Chapter 7

Conclusion

7.1 Overview

In this chapter we will conclude the challenges, final results, and the future work.

7.2 Implementation Issues

We faced several problems while working on the system such as:

- We faced serious troubles while testing the motor movement, we put the fan motor and the door motor in the same H-Bridge while one of them need 5 volt and the other 9 volt. So we can't connect the two motors to the same H-Bridge so we use two motors with 5 volt in the same H-Bridge. Then we decide to use a two DC motors with the same voltage for each one (5 V).
- The Emotiv Epoc arrived at 26-4-2016, so we don't have a much time to work with it. However we want to birzeit university several times and watched the students there while working on it. Therefore, when it arrives, we had a previous experience and this reduce this challenge.
- The headset can't read the signals when the user have a thick hair so we need volunteers to testing it.

7.3 Future Work

- Control the devices with more than two brain signals.
- Control the light intensity and speed of opening door and speed of the fan by brain signals.
- Control more than one arduino.
- Control more devices with the brain signals.

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