ELSHEIKH ABDALLAH ELBADRI UNIVERSITY

FACULTY OF ENGINEERING

ELECTRICAL DEPARTMENT

CONTROL ASSISTANT SYSTEM FOR DISABLED BASED ON BCI AND VISUAL-BASED HCI

نظام مساعد لذوي الإحتياجات الخاصة إعتماداً على واجهة الدماغ والحاسب والتفاعل الحاسوبي البشري المبني على الرؤية (معالجة الصور)

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الآية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ

وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَىٰ عَالِمِ الْغَيْبِ

وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ)

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Abstract

In this present world, many people are coming across many problems; one of those problems is physically handicapped and aged people depending on others to complete their tasks. As a result of that, there are extensive needs to research for good and tolerable performance of new type of approaches that allowed the disables people to interact with environment. Developing new intuitive and more natural interfaces is one of the biggest challenges in human computer interaction –HCI science. Therefore, this research is aimed to investigate new techniques of HCI. HCI systems has different types of methodologies by which the disabled people could interact with environments. Visual-Based and Sensor-Based are the two methodologies proposed herein. Sensor-Based is a technique which known as Brain Computer Interface-BCI used for capturing brain signals, and visual-based is a technique –in the field of image processing- by which eye-blinking can be captured. These Two different methodologies are used in one combined and integrated system to carry out both brain and eye-blinking signals. In the Visual-Based system python platform is used to process the image of the system's user that is taken using a webcam. The process is done using cross-platform open source computer vision library and pre-trained facial landmark detector inside the opencv library called dlib. An old equation called EAR has been developed to increase the efficiency of recognizing which eye is actually blinking. For the BCI system, a NeuroSky Mindwave is used to capture the brain signals for both attention and meditation status. The NeuroSky then controlled the prototype of the wheelchair. Void obstacles and Road Tracking are additional features used with the wheelchair. The results showed good performance of visual-based HCI system, very good performance for the mechanism of the wheelchair with both void obstacles and road tracking features, but low performance for the BCI system.

المستخلص

في وقتنا الراهن يعاني الكثير من الأشخاص من مشاكل صحية تتعلق بالإعاقات الحركية سواء اعاقات ناتجة عن خلل في النظام الحركي أو بتر في احد الأعضاء أو جميعها بالتالي تحتاج هذه الشريحة من الأشخاص الى المساعدة والإهتمام. نتيجة لإحتياجات هذه الشريحة من المجتمع بدأت العديد من المنظمات والجهات البحثية بالإهتمام بالأبحاث المتعلقة بفئة المعاقين في ما يتعلق في الجانب الهندسي ومحاولة ابتكار وخلق تقنيات وطرق حديثة لتخفيف المتاعب على شريحة المعاقين لينخرطوا مع البيئة المحيطة باقل قدر من المتاعب. تطوير تقنيات وبحوث جديدة يعتبر أحد التحديات التي واجهت علماء علم التفاعل بين الحاسوب والبشر. الهدف من هذا البحث هي استخدام وجمع تقنيات حديثة في علم التفاعل بين الحاسب والبشر في نظام واحد لغرض مساعدة اكبر شريحة من المعاقين بتعدد إعاقاتهم لتمكنهم من العيش بأقل جهد وأكثر راحة ممكنه. هناك عدة منهجيات في علم التفاعل بين الحاسب والبشر، اتبعنا في نظامنا المقترح هنا طريقتين : الاولى عبارة عن تفاعل حاسوبي بشري مبني على معالجة الصور والثاني مبني على الحساس. بالنسبة للطريقة المبنية على الحساس تم استخدام حساس معتمد على واجهة الدماغ والحاسوب – نظراً لشهرته أصبح علم قائم بذاته- واستخدم حساس مسمى بالنيروسكاي لغرض التقاط اشارات الدماغ لكل من حالتي التركيز والاسترخاء الدماغي والتحكم بكرسي متحرك تشغيلاً وايقافاً. لحماية الكرسي والمعاق استخدم نظام متتبع للطريق وآخر متحسساً لأي عائق قد يسبب تصادم الكرسي. أما بالنسبة للنظام المعتمد على معالجة الصور فتم معالجة صور لإشارات العينين لإستخراج اشارات تحكم من رمش العينين. تم تحسين معادلة خاصة متعلقة بتحديد نسبة رمشة العين لإكتشاف الحالات الطبيعية من الحالات العابرة للرمش. من خلال التجارب والنتائج المتعلقة بالنظامين المدمجين نتج أداء جيد لنظام معالجة الصور، وجيد جداً للأداء الميكانيكي الخاص بالكرسي وأداء ضعيف جداً فيما يتعلق بإشارات الدماغ.

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Abbreviation list

BCI	Brain computer Interface.
BCIs	Brain computer Interfaces.
HCI	Human-computer Interaction.
EEG	ElectroEncephaloGraph.
APIs	Application Programming Interfaces.
GSM	Global System for Mobile Communication.
GPS	Glabal positioning System.
FFT	Fast Fourier Transform.
EMG	Electromyography.
EOG	Electrooculography.
ECG	ElectroCardioGraphy.
EKG	ElektroKardioGramm.
MEG	Magneto encephalography.
MEG	Magneto encephalography.
ALS	Amyotrophic Lateral Sclerosis.
SNP	Sip-and-Puff system.
TDS	Tongue Drive System.
GUI	Graphical user Interface.
APIs	Application Program Interfaces
I/O	Input/Output.
IDE	Integrated Development Environment.
ADHD	Attention Deficit Hyperactivity Disorder
PC	Personal Computer.
ROI	Region Of Interest.
EAR	Eye Aspect Ratio.

AC	Air Conditioner unit.
RF	Radio Frequency.
RGB	Read,Grean and Blue.
reg1	register1.
reg2	register2.

Chapter One

INTRODUCTION

1-1 Overview

In this present world, many people are coming across many problems; one of those problems is physically handicapped and aged people depending on others to complete their tasks. According to the World Health Survey around 785 million (15.6%) people with an age of about 15years and older live with a disability and the Global Burden of Disease estimate a figure of around 975 million (19.4%) persons. on these World Health Survey estimates that 110 million people (3.2%) have very significant difficulties in functioning. This leads to an increase for requirement of assistive devices, which are used to help people with disabilities restore lost functions. A wheelchair and home appliance are the foremost assistive systems for helping people who have an impediment in motor functionality. Researchers have developed wheelchair systems controlled by body part movements head or eyeball positions without need for a joystick. However, these control methods are not applicable to be used by people with complete loss of motor functionality due to the requirement of movements of body parts. In addition, the joystick wheelchair needs the capability of disabled person to move his/her hand at least. Therefore, the wheelchair control and home appliance systems based on brain computer interface and Visual-Based HCI are comfortable for the most disabled people with complete loss of motor functionality due to the requirement of movements of body parts. Besides, home appliance is also one of the things that researchers trying to make a great progress with for the sake of helping the people with difficulties.

Brain Computer Interface (BCI) technology is a powerful communication tool between users and systems. It does not require any external devices or muscle movements to complete interaction. Early BCI applications have focused towards disabled users who have motion or speaking worries. However, later on, BCI move into the world of fit and healthy people as well. BCI are involved in medical, smart environment, marketing and advertisement, educational, games and entertainment, security and authentication fields[a].

1-2 Problem formulation

There are extensive needs to research for good and tolerable performance of new type of approaches which allowed the disabled people to interact with environment. The traditional approaches which depend on traditional and modern control don't allow the disabled people to interact with environment without other helping. This is the unsolved problem that motivated this research work.

1-3 Research Objectives

According to the formulated problems the main objective of this research work is to build and realize a brain-controlled wheelchair steered by ongoing EEG reflecting user's thought and also build a home appliance system based on eye movement. The specific objectives of this research are illustrated in the following points:

- Design and implementation a prototype for a wheelchair based on BCI.
- Design and implementation a safety system to control the directions and avoid the obstacles.
- Design and implementation home appliance based on eye movement using Visual-Based HCI (Image Processing).

1-4 Research Methodology

Figure 1-1 shows the flow chart of the research methodology that will be carried out in this research

Figure (1-1) the flow chart of the research methodology

1-4 Research structure

Chapter One: Covers the research Introduction, problem formulation, objectives, and also the methodology followed herein.

Chapter Two: Covers the background material, literature and different surveys to understand the fundamentals of BCI and Visual-Based HCI systems.

Chapter Three: illustrate the theory of the Brain Computer Interface and the Visual-Based HCI, how they work, how far they can really go, what are the systems stages and steps which by the both systems turned to a practical science, and also illustrate the control technology that is followed in our proposed BCI system.

Chapter Four: This chapter provides the stages and steps by which the proposed system can be implemented and turned into being a practical model.

Chapter Five: The conclusions of the project and the future developments are suggested for better plan and execution of this project.

CHAPTER TWO

BACKGROUND AND LITERATURE REVIEW

Chapter Two

BACKGROUND AND LITERATURE REVIEW

2-1 Overview

Utilizing computers had always begged the question of interfacing. The methods by which human has been interacting with computers has travelled a long way. The journey still continues and new designs of technologies and systems appear more and more every day and the research in this area has been growing very fast in the last few decades. The growth in Human-Computer Interaction (HCI) field has not only been in quality of interaction, it has also experienced different branching in its history. Instead of designing regular interfaces, the different research branches have had different focus on the concepts of multimodality rather than unimodality, intelligent adaptive interfaces rather than command/action based ones, and finally active rather than passive interfaces [1].

This chapter intends to provide a literature review of the Brain Computer Interface which is a Sensor-Based Unimodal HCI System, and also give a literature background of the Eye-Blink Detection System based on Image processing which is considered to be a Visual-Based Unimodal HCI system. Besides, it gives a background for different control systems for both wheelchair and home appliance which are going to be the proposed applications in this research.

Also this chapter is basically to understand the main concepts and works that are related to our research. Disabled have dreamed for centuries to control their surroundings solely by their voice, eyes, tongues, mind, or any part of their bodies that still work. These dreams are slowly becoming reality due to a variety of HCI systems that detect neural activation patterns-BCI system- or eye movements -Eye blink detection system- and support the control of electromechanical devices by the signals of the Eyes or minds status. These ideas became very popular and there are a lot of researches that talk about them, so we collect more details view on researches related to the field of HCI.

2-2 The Human Brain

The basic three parts of the brain shown in Figure (2-1) are; forebrain, midbrain and hindbrain. Forebrain consists of cerebrum and the limbic system. Midbrain comprises of tectum and tegmentum while the hindbrain comprises of cerebellum, pons and medulla. Cerebellum deals with the balance, posture and coordination of motion of body pats (for example, the coordination of legs while walking). Midbrain relates to the auditory and visual activities. Cerebrum being the cortex is the most important part of the brain. It controls all the muscular activities from limbs movement to the eye blinking of a person. Whenever there is a muscular activity or a thought provoked by a person the neurons in the cerebrum gets activated. Such brain activity is recorded by the EEG sensors in the BCI based systems [11]. There are different patterns for various activities. Such activities are chosen which produces discrete patterns from others.

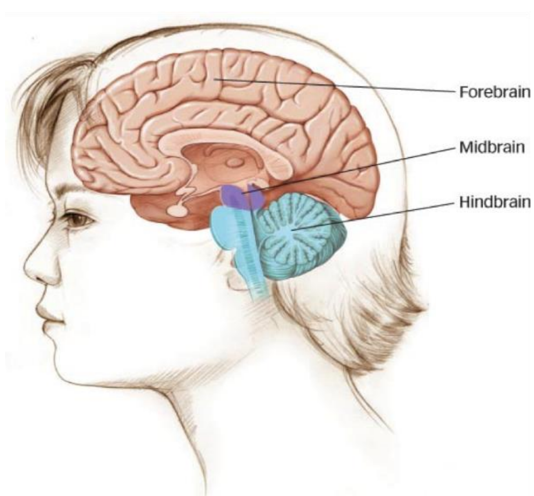


Figure (2-1):Human Brain

- ## 2-3 Bionic technology

It is one of those areas that is inspired by science fiction, and over the last couple of decades has really started to come alive. Bionic technology has been around for a number of years but relatively few people have heard of it. It is a combination of biology, robotics and computer science, and can be seen as any technology that uses or monitors the biological aspects of the body, in order to perform a function. You can have bionic eyes, ears, legs, arms, toes, feet and hands. In order to use biological signals we need to gather useful information from our bodies, which is done via electrodes. Use electrodes to gather electrical data. In most cases we can use the same electrodes for different aspects of Bionics, you just need to alter the frequencies you monitor and change the level amplification [2].

2-4 EEG Background and Why Brain Activity Can Be Measured

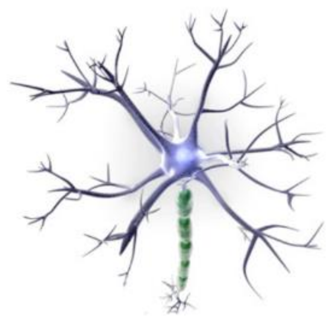


Figure (2-2):Artistic illustration of a single neuron and its synapses

An electroencephalograph (EEG) is the recorded electrical activity generated by the brain. In general, EEG is obtained using electrodes placed on the scalp with a conductive gel. In the brain, there are millions of neurons, each of which generates small electric voltage fields. The aggregate of these electric voltage fields create an electrical reading which electrodes on the scalp are able detect and record. Therefore, EEG is the superposition of many simpler signals. The amplitude of an EEG signal typically ranges from about 1 uV to 100 uV in a normal adult, and it is approximately 10 to 20 mV when measured with subdural electrodes such as needle electrodes.

The FFT (Fast Fourier Transform) is a mathematical process which is used in EEG analysis to investigate the composition of an EEG signal. Since the FFT transforms a signal from the time domain into the frequency domain, frequency distributions of the EEG can be observed. EEG frequency distribution is very sensitive to mental and emotional states as well as to the location of the electrode(s). Two types of EEG montages are used: monopolar and bipolar. The monopolar montage collects signals at the active site and compares them with a common reference electrode. The common electrode should be in a location so that it would not be affected by cerebral activity. The main advantage of the monopolar montage is that the common reference allows valid comparisons of the signals in many different electrode pairings. Disadvantages of the monopolar montage include that there is no ideal reference site, although the earlobes are commonly used. In addition, EMG and ECG artifacts may occur in the monopolar montage. Bipolar montage compares signals between two active scalp sites. Any activity in common with these sites is subtracted so that only difference in activity is recorded. Therefore some information is lost with this montage.

2-5 Brain Computer Interfacing

Brain-computer interfacing is a method of communication based on neural activity generated by the brain and is independent of its normal output pathways of peripheral nerves and muscles. The goal of BCI is not to determine a person's intent by eavesdropping on brain activity, but rather to provide a new channel of output for the brain that requires voluntary adaptive control by the user. Neuroscience, which is the study of the nervous system, including the spinal cord, nerves and of course the brain. It was thought to have started as far back as ancient Egypt [3]. It is this discipline that created the necessary foundations for BCI to grow into what it has become today. Our brain is made up of billions of nerve cells which are called neurons. Neurons have the amazing ability to gather and transmit electrochemical signals. Electroencephalography (EEG) is the recording of this electrical activity and this is what is used in BCI. Every animal has a brain, but the human brain is unique, it gives us a sense of who we are and what we feel. It allows us to think, smell, taste, listen and plan. Generally there are two forms of BCI, invasive and non-invasive. Invasive BCI requires you to have electrodes (which facilitate acquiring the electrical signal) surgically implanted through the skull and onto the brain, in order to monitor the activity. Why do people do this? Well one amazing application of this technology is to allow the blinded to partially recover their sight, with the aid of a bionic eye. Previously it was only possible to monitor the neural activity but now it is actually possible to communicate with existing brain tissue, with the potential of replacing brain damaged regions. It has been used BCI applications that can control robotic arms and hands so a cyborg civilization is too farfetched [4]. In general, when we talk about interfacing with a computer, we usually talk about usage of a keyboard or a mouse which in other words means controlled through physical activity but new type of controller which depends on brain activity by interfacing with computer. In order to get insight into brain activity we find several types of signals that firing by Human brain such as Electroencephalogram (EEG), Magnetoencephalography (MEG), Electromyography (EMG)and Electrooculography (EOG) [5]. EEG is electrical recordings from the scalp that are produced by the neurons present in the outer layer of the brain. The advantages of using EEG signals from the scalp are ease of use, non-invasive, reproducibility, low set up cost but extensive training is required before users can work and susceptibility to noise so we select Electroencephalogram (EEG) type of brain signals to use in this research. These EEG signals can be converted into control signals by using BCI system, which is used to perform signal processing, feature extraction, machine learning and classification to the EEG signals [2].

2-6 Classical BCIs from an HCI Viewpoint

BCIs are primarily considered to be means of communication and control for their users (Wolpaw et al. 2002). These "classical" BCIs can be divided into two subgroups, which we now summarize from the perspective of HCI.

- Directly controlled BCIs Some BCIs allow for direct communication with a technical system, by mapping consciously controlled mental activity onto a new artificial output channel. Thereby, they can bypass the natural outputs of the brain, which is integral for their clinical applications. Examples are BCIs based on sensorimotor imagery (Blankertz et al. 2007), where the type of mental imagery is mapped to a multi-valued control signal. Despite its power and novelty, applying this type of control to general Human-Computer Interfaces is a challenge. Complementing conventional (e.g. manual) means of human-computer interaction with it faces the problem that the user's resources for parallel conscious communication are limited, creating a conflict between BCI and conventional control. Second, brain activity which can be both consciously controlled and at the same time measured with present non-invasive equipment largely overlaps with the brain's primary output modality-muscular control-creating another resource conflict. This limitation may eventually vanish with further advances in detecting more subtle cognitive processes and commands. Finally, if taken as a replacement to manual control instead of a complement, BCIs are currently slower, more prone to errors, and more difficult to use.

- Indirectly controlled BCIs in the second group rely on conscious modulation of brain activity, as it arises in response to external stimulation. In these, the modulated activity is mapped to an artificial control signal. Examples are P300 spellers (Farwell and Donchin 1988): systems which detect a characteristic brain response, the P300, which is elicited

whenever an on-screen letter focused by the user lights up. Thus, brain activity is indirectly controlled by shifting attention. In this interaction technique, another resource of the user-the attention focus in visual, auditory, or tactile perception-is modulated for the purpose of communication, and thereby occupied. For this reason, this subgroup of BCIs, as well, is not easily applied meaningfully in Human-Computer Interfaces [6].

2-7 Visual-Based HCI based on Image processing

Vision-based eye-blink HCI have many possible applications, like fatigue monitoring, human–computer interfacing and lie detection. No matter what the purpose of the system is, the developed algorithm must be reliable, stable and work in real time in varying lighting conditions. This work can be done using serval methods by which the eye blink can be detected. In this research, we decides to choose Image processing field.

Image processing is a set of computational techniques for analyzing, enhancing, compressing, and reconstructing images. The main components are importing, in which an image is captured through scanning or digital photography; analysis and manipulation of the image, accomplished using various specialized software applications; and output. Image processing has extensive applications in many areas, including astronomy, medicine, industrial robotics, and remote sensing by satellites. Image processing for robot vision will improve products quality, save time and reduce labor cost. Computer vision is a field of robotics in which the programs attempt to identify objects represented in digitized images provided by video cameras that enable robots to “see”. A lot work has been done on stereo vision as a support to object identification and location within a three-dimensional field of view. Recognition of objects in real time, as would be needed for active robots in complex environments, usually requires computing power beyond the capabilities of present day technology. The operation of a computer vision system can be divided into three functions which is image acquisition and digitization, image processing and analysis, and interpretation.

These functions and their relationships are illustrated schematically in Figure (2-3):

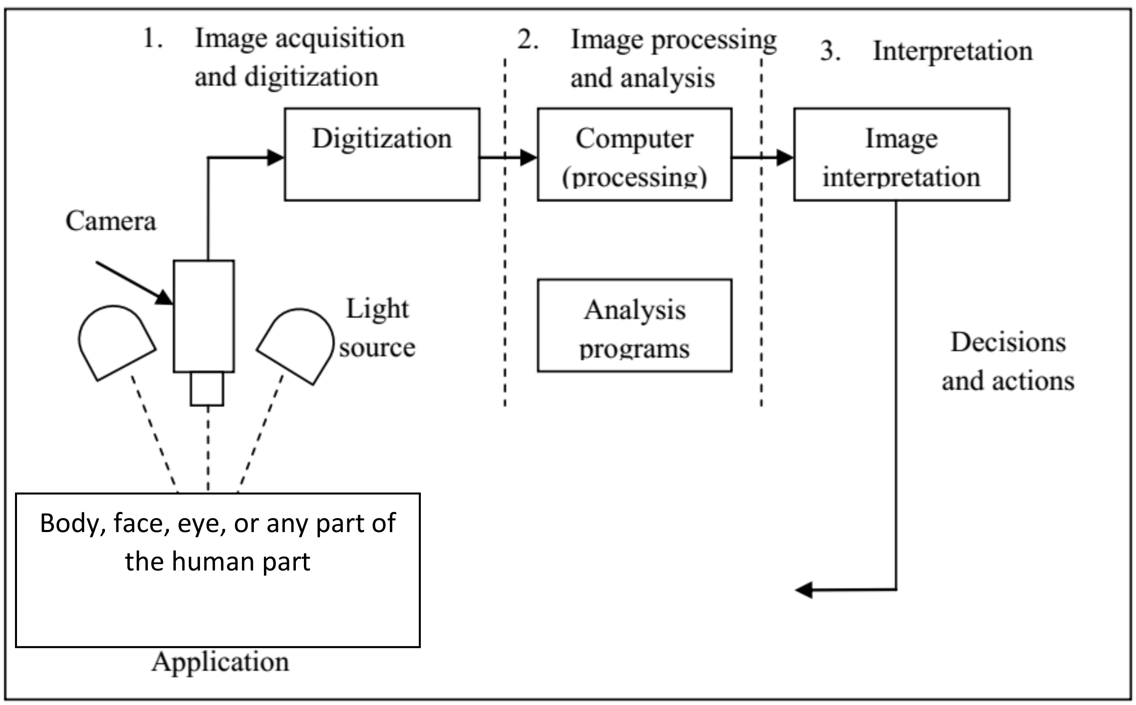


Figure (2-3):Functionality of Visual-Based HCI

2-8 Control Technologies related to disabled field

Different disability levels requires different assistive user control interfaces. Some of assistive interfaces can provide motion based command such as a joystick. However, such interfaces are not able to adapt to different control requirements. A conventional home appliance and wheelchair requires the mobility of the upper body. In many cases, this cannot help people who are paralyzed. Technologies like voice recognition provides a solution for people to communicate with computers which can be used to send out the operation commands for the users. Furthermore, to help people with other types of disabilities with even less control of their bodies, eye movement and electroencephalogram (EEG) are considered good approaches. With eyes and brain signals processing devices getting more and more commercialized, reading those signals are no longer restricted to research institutes. Products like EPOC Emotive [7] and Mind wave [8] or even low-cost cameras can make it very easy to access the brain signals at a relatively high accuracy level. With these technologies, it is possible to develop a user control interface for both wheelchair and home appliance systems to utilize the EEG signals for people who are suffering from disabilities like quadriplegia [9] Research in this field has seen a rise in the past decade to help victims of accidents who have been left without use of their arms and hands, or for those with degenerative disease such as Amyotrophic Lateral Sclerosis (ALS), as condition that leads to LIS [10]. These different methods of operation provide these users with much needed control of their locomotion, as is stressed by "A Literature Review of Smart Wheelchairs" [11].the various control system which are the more common solution are:

- **sip-and-puff system (SNP)**

In this system the user either draws in air, or blows air into a wand or tube. This system requires calibration for each user, once calibrated it will only recognize the specific user's sips and puffs. SNP recognizes four different commands, hard sip, soft sip, hard puff, and soft puff. shows the sip and-puff system in use [12].

- **Eye and Gaze Drive System**

This system was adaptable to any powered wheelchair by placing a camera in front of the wheelchair to capture the image of the user. The camera is connected to a computer that uses image processing. To navigate the computer estimate their gaze direction using the triangle formed by the nose and the eyes, and the frequency of the blink for the duration of the time traveled [13].

- **Tongue Drive System (TDS)**

Developed by the team at Georgia Tech. This system uses two magnetic sensors placed on side of the users head and magnetic tongue barbell. By placing the magnetic barbell inside specific sports of their mouth users are able to control the direction and speed of the wheelchair with better results than similar systems for users without the use of their hands [14].

- **Voice Control**

The MIT Intelligent Wheelchair Project is a successful example of implementing voice control technology in wheelchair [15]. Their voice controlled home appliance or a wheelchair which would allow a user to be able to tell the specific device either a lamb, fan, AC unit at home or even a wheelchair to go to a specific location, rather than control every twist and turn manually.

2-9 Previous work and how this project came into being

The research on the field of the new BCI systems goes back to the 1970s at the University of California which is led to the emergence of the expression brain computer interface, after that and at the mid-1990s, it marked the appearance of the first neuro prosthetics devices for disabled humans. And on the later decade, various Brain Computer Interface (BCI) systems have been developed during different time span .This research builds upon several previous projects and researches and the descriptions below give a concise brief for some of those projects.

- In Keerthana, et al. (2010) of VIT University developed a way of switching electrical appliances on and off using brainwaves. The research -"Controlling electrical devices with human brainwaves" [43]- uses a Neurosky Mindwave Mobile for brainwave sensing and transmission. The system flow of this project starts with the Mindwave Mobile. Raw brainwave data are fed into the Mindwave Mobile and put through a series of processing algorithms to make it suitable for microcontroller use. The resulting translated data is fed into a microcontroller that has an electrical appliance connected to it via a relay. Using brainwaves, the user is able to turn the electrical appliance on and off. Apart from the switching on and off of the electrical appliance, this project also tested the Mindwave Mobile's accuracy in terms of translating brainwave data into usable ones. A series of tests for varying intensities of Beta and Gamma waves was made and the Mindwave Mobile managed to pass all of them. This project did not use other features of the Mindwave Mobile such as blink detection. Limitations of this project include the max transmission range of Bluetooth and the limited range of brainwave-related data that the Mindwave Mobile can sense. The Mindwave Mobile is probably the most affordable EEG headset available to student developers, albeit having a less robust and comprehensive feature set.

- Manuel Adrian Aclan and his team (2012) at De La Salle University Philippines developed a short messaging system using Emotiv's super-expensive $800 EPOC headset. The main goal of this reaserch - "PC-based hands-free short messaging system through facial movements using Emotive EPOC" [44] - is to give people with motor disabilities a hands-free way of communicating via GSM. It works similar to Stephen Hawking's computer system where an infrared sensor mounted on his eyeglasses scans for any muscle movement in his cheek. Hawking's computer goes through a list of characters and the tensing of his cheek muscle serves as a way of selecting a specific character. While this method requires a ton of patience, it works given Hawking's severe motor limitations. Emotiv's EPOC headset is able to detect specific facial movements, giving the developer access to a wide range of possible controls. Specific facial movements are used for up, down, left and right directions. Upon the completion of a message, it is sent to the recipient via the GSM module. While this project is primarily aimed towards people with motor handicaps, it can also be used by anyone who wishes to have a hands-free way of communicating with others. The biggest limitation of this project is its cost. While Emotiv's EPOC headset can detect a larger range of brainwaves and facial movements, it is extremely expensive and therefore inaccessible to most student-developers. It costs $800 and taking into consideration shipping costs and other expenses, it could very well surpass the $1000 mark for only the EEG headset.

- Badr Mudhish, Hamed Ahmed, et all (2016) of Taiz university – Yemen developed a system on their final year project "Wheelchair control based on BCI" [2] using an Emotiv Headset with new GUI which made it easy to the user to interface with the wheelchair directly. They also used an Arduino board to interface with some safety sensors to measure the distance between the obstacles and the wheelchair for safety purposes, it is also used to interface the wheelchair motors with the computer.

- Shyam Narayan Patel (2015) developed a system for his summer study's final project called "Autonomous Camera based Eye Controlled Wheelchair system using Raspberry-Pi" [45]. A novel technique is implemented for the eye controlled based independent and cost effective system. The purpose of Eye movement based control electric wheelchair is to eliminate the necessity of the assistance required for the disabled person. And it provides great opportunity of the disabled to feel of independent accessible life. The implemented system will allow the disabled person to control the wheelchair without the assistance from other persons. In this system controlling of wheelchair carried out based on Eye movements. The camera is mounted in front of the user, to capture the image of any one of the Eye (either left or right) and tracks the position of eye pupil with the use of Image processing techniques. According to the position of the eye, wheelchair motor will be directed to move left, right and forward. In addition to this, for the safety purpose ultrasonic sensor is mounted in front of wheelchair to detect the obstacles and automatically stop the wheelchair movement. To make system cost effective for monitoring, a Raspberry pi board allowed to access the system without displaying unit.

- Sandesh Pai, Sagar Ayare, and Romil Kapadia (2012) developed a system for their summer study's final project "Eye Controlled Wheelchair"[46]. Their paper delivers a new method to guide and control the wheelchair for disabled people based on 'Human-Computer Interaction (HCI). An eye control device based on image processing is developed to assist mobility. The eye movement is detected using a camera which is attached to the wheelchair. This concept can be used for multiple applications, but this paper focuses the application to mobile and communication aid for handicapped patients suffering from quadriplegic and paraplegic diseases. The proposed system involves two stages; first eye movement detection and second, sending of control signals to the powered wheelchair.

2-10 Conclusion and our own framework

The framework proposed herein takes advantage of using a Neurosky MindWave headset to detect the human brain activity and convert these activities into electrical control signals so they can be used to control an electric wheelchair. Besides, this proposed framework takes advantage of using a web cameras to carry out eye blinks assessment in a work environment, instead of attending a clinic or using more invasive methods. The idea lies in analyzing the frames of a video, and classifying them in open or closed eyes in order to automatically detect the blinks. Moreover, the use of this framework does not imply the availability of any specific camera or expensive instrument, which often requires medical supervision. Therefore, our framework for the Eye-blinking system makes three important contributions:

- It is able to tackle eye blink detection in work environments.
- It does not require medical supervision.
- It provides reliable results from consumer videos acquired with low-cost cameras.

CHAPTER THREE

SYSTEM DESIGN

Chapter Three

SYSTEM DESIGN

3-1 Overview

This chapter is divided into two parts. First, the theory of the Brain Computer Interface, how it works, how far BCI can really go, what are the stages and steps which by the BCI turned to a practical science, and also illustrate the control technology that is followed in our proposed BCI system which is going to be applied on a prototype for an electronic wheelchair.

Second, we are also going to give a concise background, and the theory of the Image processing using an open computer vision library for the proposed Eye-blink system which is going to be applied on a home appliance.

3-2 Brain Computer Interface

Any natural form of communication or control requires peripheral nerves and muscles. The process begins with the user's thought. This thought triggers a complex process in which certain brain areas are activated, and hence signals are sent via the peripheral nervous system (specifically, the motor pathways) to the corresponding muscles, which in turn perform the movement necessary for the communication or control task. A BCI offers an alternative to natural communication and control. A BCI is an artificial system that bypasses the body's normal efferent pathways. Instead of depending on peripheral nerves and muscles, a BCI directly measures brain activity associated with the user's thought and translates the recorded brain activity into corresponding control signals for BCI applications. This translation involves signal processing and pattern recognition, which is typically done by a computer. Since the measured activity originates directly from the brain and not from the peripheral systems or muscles, the system is called a Brain–Computer Interface. A BCI must have four components. It must record activity directly from the brain (invasively or non-invasively). It must do so in real-time. Finally, the system must rely on intentional control. That is, the user must choose to perform a mental task whenever s/he wants to accomplish a goal with the BCI. Devices that only passively detect changes in brain activity that occur without any intent, such as EEG activity associated with workload, arousal, or sleep, are not BCIs. Although a traditional definition of BCI is "The goal of BCI technology is to give severely paralyzed people another way to communicate, a way that does not depend on muscle control." (Wadsworth Center).

Our definition of BCI is "A system which takes a biosignal measured from a person and predicts (in real-time / on a single-trial basis) some abstract aspect of the person's cognitive state[2]. " as shown in Figure (3-1).

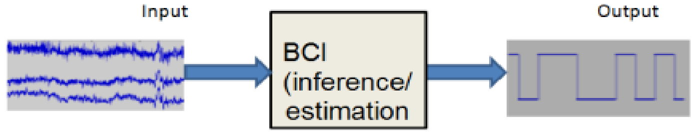


Figure (3-1) BCI definition

Three subtypes of BCI. Active BCI: "An active BCI is a BCI which derives its outputs from brain activity which is directly consciously controlled by the user, independently from external events, for controlling an application."Reactive BCI: "A reactive BCI is a BCI which derives its outputs from brain activity arising in reaction to external stimulation, which is indirectly modulated by the user for controlling an application." And Passive BCI: "A passive BCI is a BCI which derives its outputs from arbitrary brain activity without the purpose of voluntary control, for enriching a human-computer interaction with implicit information." For any BCI system the basic setup of its parts is in Figure (3-2).

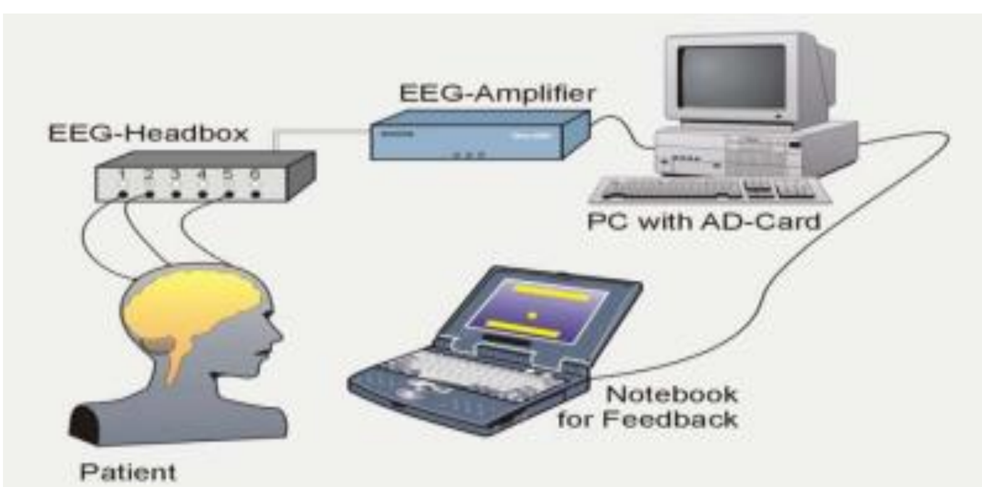


Figure (3-2) Basic and classic BCI *system*

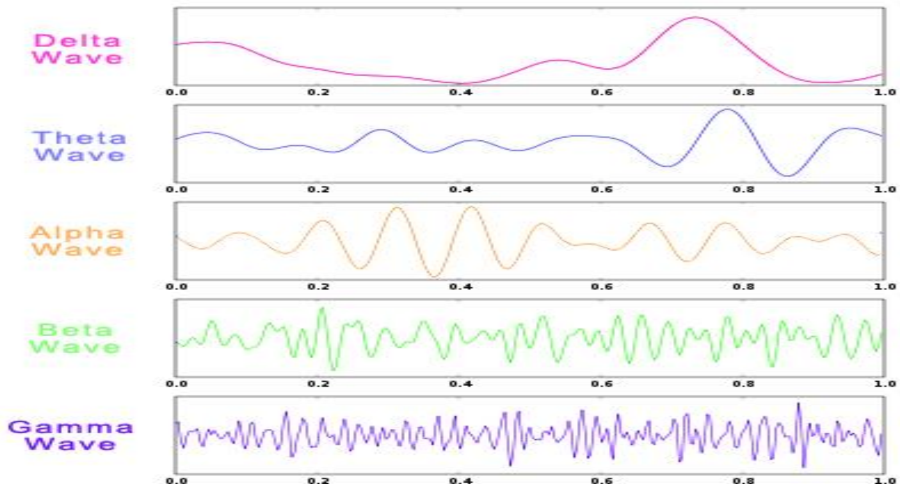
3-3 Types of BCI Signals

The brain generates an amount of neural activity. There are a plethora of signals which can be used for BCI. These signals are divide into two classes: spikes and field potentials [15]. Spikes reflect the action potentials of individual neurons and acquired through microelectrodes implanted by invasive techniques. Field potentials are measure of combined synaptic, neuronal, and axonal activity of groups of neurons and can be measured by EEG or implanted electrodes. The following is the classification of EEG signals based on their frequencies/bands [17, 16].

- **Delta** Signal. It is captured within the frequency range of 0.5–3.5 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep as well as in babies.

- **Theta.** The frequency of this signals ranges from 3.5 to 7.5 Hz. Theta is linked to inefficiency and daydreaming. In fact, the very lowest waves of theta represent the fine line between being awake or in a sleep. However, high levels of theta are considered abnormal in adults.

- **Alpha.** this signal frequency ranges from 7.5 to 12 Hz. Hans Berger [18] named the first rhythmic EEG activity he saw, the “alpha wave”. Range seen in the posterior regions of the head on both sides, being higher in amplitude on the dominant side. It is brought out by closing the eyes and by relaxation. Several studies have found a rise in alpha power after smoking marijuana.
- **Beta.** Beta is another brain signal in which its frequency ranges from 12 Hz to about 30 Hz. It is seen usually on both sides in a symmetrical distribution and it is most evident frontally. Beta waves are often divided into β1 and β2 to get more specific range. The waves are small and fast when resisting or suppressing movement, or solving a math task. It has been noticed in these cases that there is an increase of beta activity.
- **Gamma.** It is a signal with frequency range of 31 Hz and up. It reflects the mechanism of consciousness.



Figure(3-3) EEG Signals

3-4 BCI System

Forming a BCI system requires following three main steps as shown in Fig. below: Step 1 is the signal acquisition, Step 2 is the signal processing, and Step 3 is the data manipulation. Step 3: Using these obtained signals to control in external devices or computer depending on the application [19].

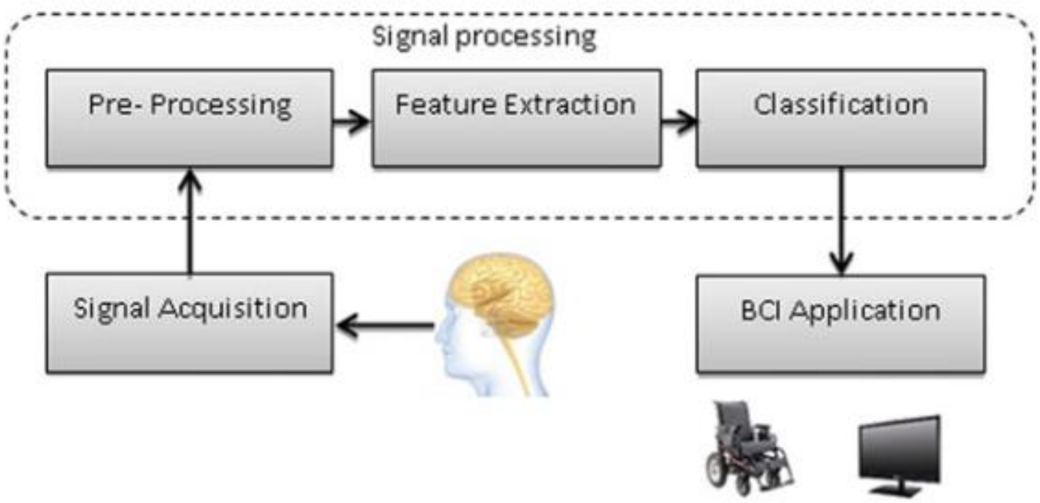


Figure (3-4) architecture of BCI System

3-4-1 Signal Acquisition

Signal acquisition process is required to capture the brain electric signals. The electric signals could be recorded from the scalp, the surface of the brain, or from the neural activity. Since the capture signals strength are usually low, they need to be amplified. Then, to be used by computer applications, they need to be digitized. In our proposed BCI system we used a noninvasive device to capture the brain signal called a Neurosky MindWave headset.

3-4-2 Signal Processing

In this step, obtained signals in step 1 are analyze to get the control signals. Signal processing could be done through some other sub operations as follows: Preprocessing the first part of signal processing is preparing the recording electric signal for processing like enhancement to make the features clear for detection. Some filtering techniques could be used in the preprocessing operation.

3-4-3 Feature extraction Simply

Feature extraction means extracting specific signal features. EEG recordings not only contain electrical signals from the brain, but also several unwanted signals. Those unwanted signals may bias the analysis of the EEG and may lead to wrong conclusions. Therefore, the digitized signals are subjected to feature extraction procedures.

3-4-4 Signal Classification

Translation algorithm The next stage, the translation algorithm, in which it translates the extracted signal features into device commands orders that carry out the user's intent. The signals are classified on both frequency and on their shape; the classification algorithm might use linear methods or nonlinear methods.

3-4-5 Data Manipulation

Once the signals are classified, the output is manipulated to suite the output device which is ,in our proposed BCI system, an electric wheelchair controlled by the brain signals that was captured in step 1 by the neurosky MindWave headset.

3-5 The Neurosky MindWave Headset

The neurosky Mindwave headset shown in figure (3-6) was launched in 2010/11 and has designed to identify and monitor electric signals generated by neural activity in the brain. It complements the neurosky mindset headset, released in 2009, which has been used to research ADHD, Alzheimer's and Cognitive Stress (NeuroSkyInc., 2010).The Mindwave consists of a headband, an ear-clip and a sensor arm containing EEG electrode which rests on the forehead above the eye (fp1 position, in accordance with the American Electroencephalographic Society's (1994) 10-20 system of electrode placement shown in figure (3-5) [20].

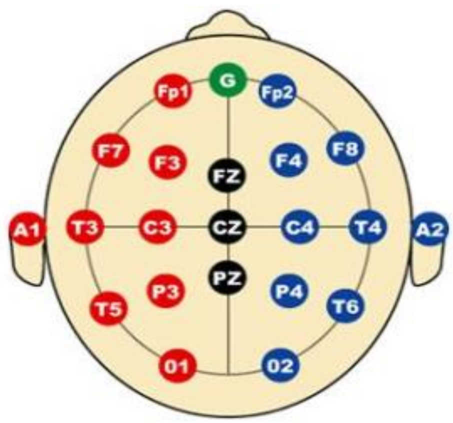


Figure (3-5) system of electrode placement

Figure (3-6) Neurosky MindWave Headset

The measurements of the MindWave are outlined as follows:

- Raw signal .
- EEG power spectrum: provides information on a user's brainwaves (Delta, Theta, Alpha, Beta and Gama).
- eSense meters for Attention and Meditation : Determines how effectively the user is engaging Attention (similar to concentration) or Meditation(similar to relaxation) by decoding the electrical signals and applying algorithm to provide readings on a scale of 0 to 100 .
- The eSense Meditation meter is related to active mental processing in the brain and indicates the intensity of a user's level of mental 'calmness' or 'relaxation'. Relaxing the body and closing one's eyes often helps the mind to relax and increases the meditation

meter level. Distractions, wandering thoughts, anxiety, agitation, and sensory stimuli may lower the Meditation meter level.

3-5-1 ThinkGear Technology

ThinkGear is the technology inside every NeuroSky product or partner product that enables a device to interface with the wearers' brainwaves. It includes the sensor that touches the forehead, the contact and reference points located in the ear clip, and the on-board chip that processes all of the data. Both the raw brainwaves and the eSense Meters (Attention and Meditation) are calculated on the ThinkGearchip.

3-5-2 ThinkGear data values

3-5-2-1 poor_signal Quality

This unsigned one-byte integer value describes how poor the signal measured by the ThinkGear is. It ranges in value from 0 to 255. Any non-zero value indicates that some sort of noise contamination is detected. The higher the number, the more noise is detected. A value of 200 has a special meaning, specifically that the ThinkGearelectrodes aren't contacting a person's skin. This value is typically output every second, and indicates the poorness of the most recent measurements. Poor signal may be caused by a number of different things. In order of severity, they are:

- Sensor, ground, or reference electrodes not being on a person's head (i.e. when nobody is wearing the ThinkGear).
- Poor contact of the sensor, ground, or reference electrodes to a person's skin (i.e. hair in the way, or headset which does not properly fit a person's head, or headset not properly placed on the head).
- Excessive motion of the wearer (i.e. moving head or body excessively, jostling the headset).
- Excessive environmental electrostatic noise (some environments have strong electric signals or static electricity buildup in the person wearing the sensor).
- Excessive non-EEG biometric noise (i.e. EMG, EKG/ECG, EOG, etc)

3-5-2-2 Attention eSense meter

This unsigned one-byte value reports the current eSense Attention meter of the user, which indicates the intensity of a user's level of mental “focus” or “attention”, such as that which occurs during intense concentration and directed (but stable) mental activity.

3-5-2-3 Meditation eSense meter

This unsigned one-byte value reports the current eSense Meditation meter of the user, which indicates the level of a user's mental “calmness” or “relaxation”

ThinkGear Packets

ThinkGear components deliver their digital data as an asynchronous serial stream of bytes. The serial stream must be parsed and interpreted as ThinkGear Packets in order to properly extract and interpret the ThinkGearData Values described in the chapter above.A ThinkGear Packet is a packet format consisting of 3 parts:

- Packet Header
- Packet Payload
- Payload Checksum

ThinkGear Packets are used to deliver Data Values (described above) from a ThinkGear module to an arbitrary receiver (a PC, another microprocessor, or any other device that can receive a serial stream of bytes). Since serial I/O programming APIs are different on every platform, operating system, and language, it is outside the scope of this document (see the platform's documentation for serial I/O programming). Here we will only cover how to interpret the serial stream of bytes into ThinkGear Packets, Payloads, and finally into the meaningful Data Values. The Packet format is designed primarily to be robust and flexible: Combined, the Header and Checksum provide data stream synchronization and data integrity checks, while the format of the Data Payload ensures that new data fields can be added to (or existing data fields removed from) the Packet in the future without breaking any Packet parsers in any existing applications/devices. This means that any application that implements AThinkGear Packet parser properly will be able to use newer models of ThinkGear modules most likely without having to change their parsers or application at all, even if the newer ThinkGear includes new data fields.

Packet Structure

Packets are sent as an asynchronous serial stream of bytes. The transport medium may be UART, serial COM,USB, Bluetooth, file, or any other mechanism which can stream bytes Each Packet begins with its Header, followed by its Data Payload, and ends with the Payload's Checksum Byte, as follows:

```
[SYNC] [SYNC] [PLENGTH]  [PAYLOAD...]     [CHKSUM]
_______________________  _____________  ____________
^^^^^^^^(Header)^^^^^^^  ^^(Payload)^^  ^(Checksum)^
```

The [PAYLOAD…] section is allowed to be up to 169 bytes long, while each of [SYNC], [PLENGTH], and [CHKSUM] are a single byte each. This means that a complete, valid Packet is a minimum of 4 bytes long (possible if the Data Payload is zero bytes long, i.e. empty) and a maximum of 173 bytes long (possible if the Data Payload is the maximum 169 bytes long).

Packet Header

The Header of a Packet consists of 3 bytes: two synchronization [SYNC] bytes (0xAA 0xAA), followed by a [PLENGTH] (Payload length) byte:

```
[SYNC] [SYNC] [PLENGTH]
_______________________
^^^^^^^^(Header)^^^^^^^
```

The two [SYNC] bytes are used to signal the beginning of a new arriving Packet and are bytes with the value 0xAA (decimal 170). Synchronization is two bytes long, instead of only one, to reduce the chance that [SYNC] (0xAA) bytes occurring within the Packet could be mistaken for the beginning of a Packet. Although it is still possible for two consecutive [SYNC] bytes to appear within a Packet (leading to a parser attempting to begin parsing the middle of a Packet as the beginning of a Packet) the [PLENGTH] and [CHKSUM] combined ensure that such a “mis-sync'd Packet” will never be accidentally interpreted as a valid packet (see Payload Checksum below for more details). The [PLENGTH] byte indicates the length, in bytes, of the Packet's Data Payload [PAYLOAD…] section, and may be any value from 0up to 169. Any higher value indicates an error (PLENGTH TOO LARGE). Be sure to note that [PLENGTH] is the length of the Packet's Data Payload, NOT of the entire Packet. The Packet's complete length will always be [PLENGTH] + 4.

Data Payload

The Data Payload of a Packet is simply a series of bytes. The number of Data Payload bytes in the Packet is given by the [PLENGTH] byte from the Packet Header. The interpretation of the Data Payload bytes into the ThinkGear Data Values described in Chapter 1 is defined in detail in the Data Payload Structure section below. Note that parsing of the Data Payload typically should not even be attempted until after the Payload Checksum Byte [CHKSUM] is verified as described in the following section.

Payload Checksum

The [CHKSUM] Byte must be used to verify the integrity of the Packet's Data Payload. The Payload's Checksum is defined as:

- summing all the bytes of the Packet's Data Payload
- taking the lowest 8 bits of the sum
- performing the bit inverse (one's compliment inverse) on those lowest 8 bits

A receiver receiving a Packet must use those 3steps to calculate the checksum for the Data Payload they received, and then compare it to the [CHKSUM] Checksum Byte received with the Packet. If the calculated payload checksum and received [CHKSUM] values do not match, the entire Packet should be discarded sin valid. If they do match, then the receiver may procede to parse the Data Payload .

3-6 Electrical Design for BCI system

A prototype has been designed to simulate an electrical wheelchair movements. This prototype is divided electrically into five parts:

- power supply.
- Embedded system – Microcontroller.
- Motors and driver.

- Sensors for Safety and protection.
- Communication part.

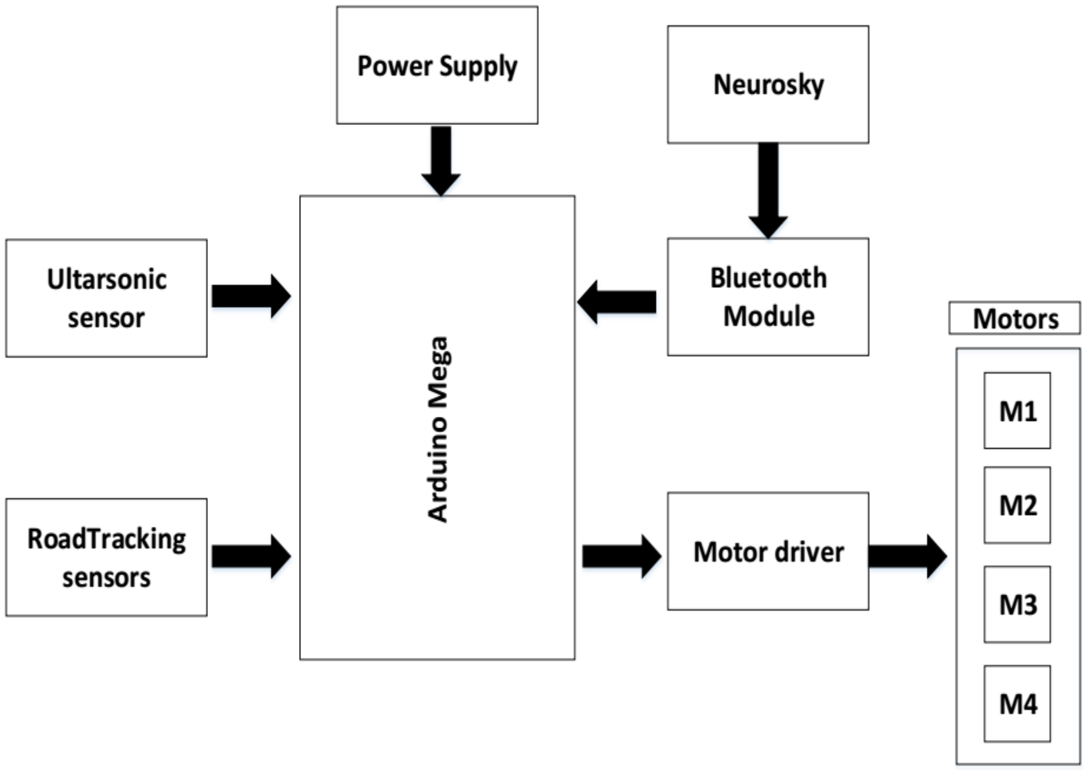


Figure (3-7) Architecture Diagram of BCI System

3-6-1 Embedded system

In our proposed system we used an Arduino Mega which is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs.Arduino projects can be standalone, or they can be able to communicate with software running on your computer .The boards can be assembled by hand or purchased pre-assembled; the open-source IDE can be downloaded for free.The Arduino programming language is an implementation of Wiring, a similar physical-computing platform, which is based on the Processing multimedia programming environment.

3-6-2 Arduino

Arduino simplifies the process of working with microcontrollers, and offers some advantages for teachers, students, and interested amateurs over other systems:

- Cross-platform- The Arduino software runs on Windows, MacintoshOSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- Simple, clear programming environment - The Arduino programming environment is easy-to-use for beginners, yet flexible enough for advanced users. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with the look and feel of Arduino.
- Open source and extensible software - The Arduino software is published as open source tools, available for extension by experienced programmers.
- Open source and extensible hardware - The Arduino shown in figure(3-8) is based on Atmel'sATMEGA8 and ATMEGA168 microcontrollers

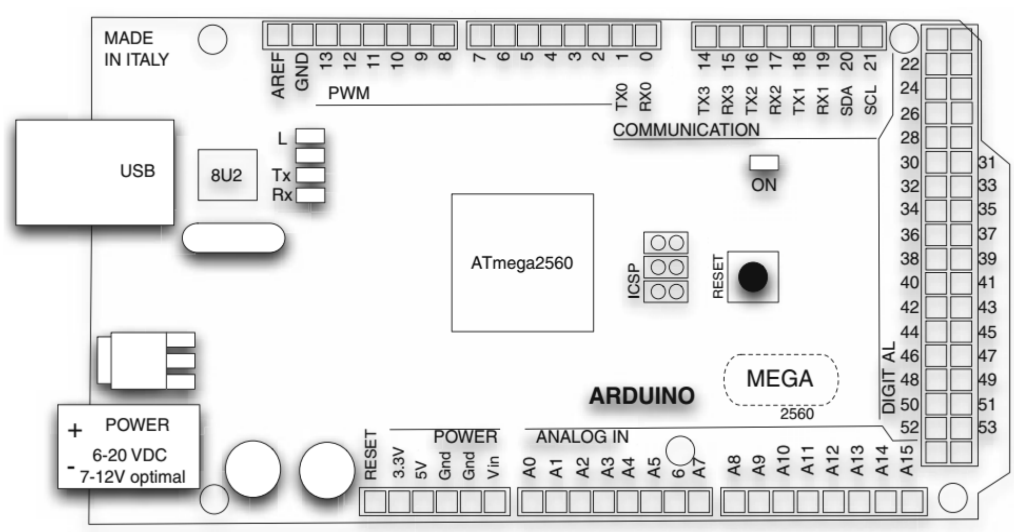


Figure (3-8) Arduino Mega

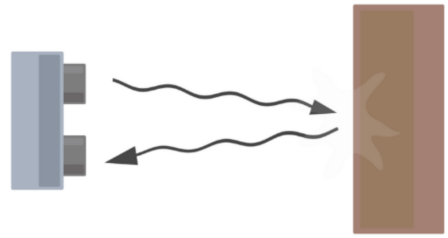
Table (3-1) Arduino Mega technical characteristics

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 Ma
DC Current for 3.3V Pin	50 Ma
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

3-6-3 Ultrasonic sensor

An Ultrasonic sensor is a device that can measure the distance to an object by using ultrasound waves. It measures distance by sending out an ultrasound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object. Since it is known that sound travels through air at about 344 m/s (1129 ft/s), you can take the time for the sound wave to return and multiply it by 344 meters (or 1129 feet) to find the total round-trip distance of the sound wave. Round-trip means that the sound wave traveled 2 times the distance to the object before it was detected by the sensor; it includes the 'trip' from the sonar sensor to the object AND the 'trip' from the object to the Ultrasonic sensor (after the sound wave bounced off the object). To find the distance to the object, simply divide the round-trip distance in half. In our proposed BCI system we use this sensor as a protection for the wheelchair to avoid crushing with any object laying in front of the wheelchair while it's moving forward on the road[21].

$$distance = \frac{speed\ of\ sound\ \times time\ taken}{2}$$



3-6-4 Infrared obstacles sensor (Road Tracking sensor)

It is an IR sensor that detects IR radiation falling on it. It works in direct, indirect, reflective and non-reflective surface. In our proposed BCI system, we used three IR sensors to cover the width of the Road and to increase the adjusting accuracy of the wheelchair on the Road. Figure below showed the IR sensors which are been used in our proposed BCI system.

Figure (3-9) Tracking Sensor

3-6-5 Motor driver

In our proposed BCI system, we used a module known as “L298N” which is a dual full H-Bridge IC that can serve as a motor controller. It can provide up to 2A current. It takes external power to run motors.

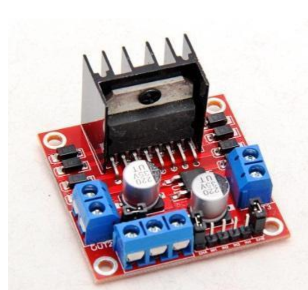


Figure (3-10) L298N DC Motor driver

3-6-6 Bluetooth module

Figure (3-11) Bluetooth Module

This Bluetooth module acts as a master device that automatically pairs with the headset once both devices are powered on. It has a serial port profile, and it is a class-2 Bluetooth module, which can format as either Master or slave. It is programmed with the MAC address and password of the Mindwave mobile headset. The electrical signals received by the HC-05 module are then transmitted to an Arduino microcontroller via serial communication. Once the Arduino microcontroller board is programmed, the serial monitor should be opened at baud rate 57600 and type the following commands sequentially:

1. AT+NAME=”Proposed BCI system”
2. AT+UART=”57600,0,0”
3. AT+ROLE=”1”
4. AT+PSWD=”00000”
5. AT+CMODE=”0”
6. AT+BIND=”XXXX,YY,ZZZZZZ” (Mindwave Unique Number- the MAC Address)
7. AT+IAC=”9E8B33”
8. AT+CLASS=”0”
9. AT+INQM=”1,9,48”

After we do the wiring connections which by we will be able to program the Bluetooth module to work as a massive device, we should get an “OK” after each command indicating that it has been successfully written to the device. The HC-05 Bluetooth module is now configured correctly to act as a master device and which that will automatically pair with the Neurosky Mindwave Mobile headset once both devices are powered on [22].

3-7 Eye-blink detection system based on Image processing

Detecting eye blinks is important for instance in systems that monitor a human operator vigilance, e.g. driver drowsiness [23, 24], in systems that warn a computer user staring at the screen without blinking for a long time to prevent the dry eye and the computer vision syndromes [25, 26, 27], in human computer interfaces that ease communication for disabled people [28], or for anti-spoofing protection in face recognition systems [29]. Existing methods are either active or passive. Active methods are reliable but use special hardware, often expensive and intrusive, e.g. infrared cameras and illuminators [30], wearable devices, glasses with a special close up cameras observing the eyes [31]. While the passive systems rely on a standard remote camera only. Many methods have been proposed to automatically detect eye blinks in a video sequence. Several methods are based on a motion estimation in the eye region. Typically, the face and eyes are detected by a Viola-Jones type detector. Next, motion in the eye area is estimated from optical flow, by sparse tracking [26, 27], or by frame-to-frame intensity differencing and adaptive thresholding. Finally, a decision is made whether the eyes are or are not covered by eyelids [32, 28].

A different approach is to infer the state of the eye opening from a single image, as e.g. by correlation matching with open and closed eye templates [33], a heuristic horizontal or vertical image intensity projection over the eye region [23, 34], a parametric model fitting to find the eyelids [35], or active shape models [36]. A major drawback of the previous approaches is that they usually implicitly impose too strong requirements on the setup, in the sense of a relative face-camera pose (head orientation), image resolution, illumination, motion dynamics, etc. Especially the heuristic methods that use raw image intensity are likely to be very sensitive despite their real-time performance. However nowadays, robust real-time facial landmark detectors that capture most of the characteristic points on a human face image, including eye corners and eyelids, are available, see Fig (3-12) .

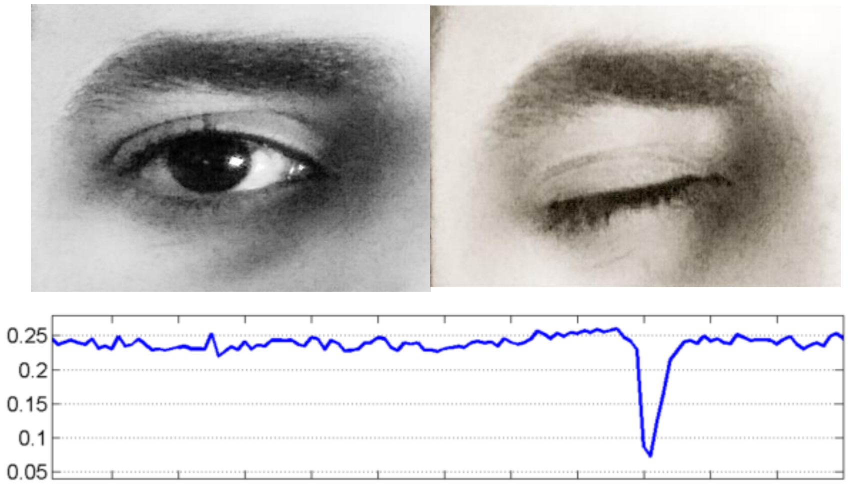


Figure (3-12) single eye blink detection

Most of the state-of-the-art landmark detectors formulate a regression problem, where a mapping from an image into landmark positions [37] or into other landmark parameterization [38] is learned. These modern landmark detectors are trained on "in-the-wild datasets" and they are thus robust to varying illumination, various facial expressions, and moderate non-frontal head rotations. An average error of the landmark localization of a state-of-the-art detector is usually below five percent of the inter-ocular distance. Recent methods run even significantly super real-time [39].Therefore, we propose a simple but efficient algorithm to detect eye blinks by using a recent facial landmark detector.

3-7-1 OpenCV library

OpenCV is a cross-platform open source computer vision library, mostly employed for its real time image processing performance. It aims to provide well-tested, optimized, open source implementations of state of the art image processing and computer vision algorithms. The library is written in C built on top of a core image library, which supports image structure and basic image manipulation, ensuring fast and portable code, and has been compiled for many embedded platforms [40].

3-7-2 facial landmarks and how they can be detected

Facial landmarks are used to label and identify key facial attributes in an image (source). Detecting facial landmarks is a subset of the shape prediction problem. Given an input image (and normally a region of interest (ROI) that specifies the object of interest), a shape predictor attempts to localize key points of interest along the shape. In the context of facial landmarks, our goal is detect important facial structures on the face using shape prediction methods. Detecting facial landmarks is therefore a two-step process:

- Step #1: Localize the face in the image.
- Step #2: Detect the key facial structures on the face ROI.

Face detection (Step #1) can be achieved in a number of ways: We could use OpenCV's built-in Haarcascades,We might apply a pre-trained HOG + Linear SVM object detector specifically for the task of face detection or we might even use deep learning-based algorithms for face localization. And to extract the face region we can then apply Step #2: detecting key facial structures in the face region.

The facial landmark detector included in library called dlib is an implementation of the research [41].This method starts by using:

- A training set of labeled facial landmarks on an image. These images are manually labeled, specifying specific (x, y)-coordinates of regions surrounding each facial structure.
- Priors, of more specifically, the probability on distance between pairs of input pixels.

Given this training data, an ensemble of regression trees are trained to estimate the facial landmark positions directly from the pixel intensities themselves (i.e., no "feature extraction" is taking place).

The end result is a facial landmark detector that can be used to detect facial landmarks in real-time with high quality predictions.

The pre-trained facial landmark detector inside the dlib library is used to estimate the location of 68 (x,y)-coordinates that map to facial structures on the face. The indexes of the 68 coordinates can be visualized on Fig(3-13):

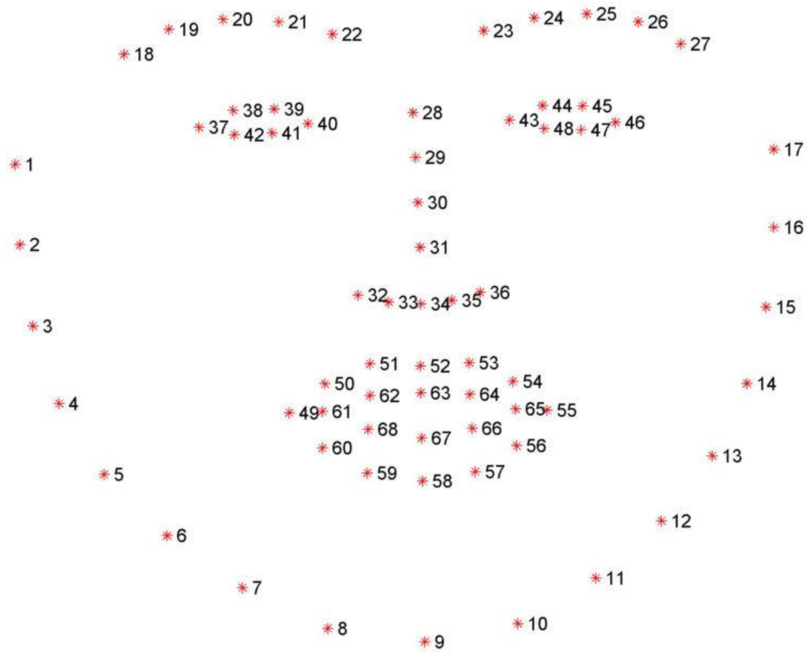


Figure (3-13) the indexes of the 68 coordinates

Examining the previous image, we can see that facial regions can be accessed via simple Python indexing (assuming zero-indexing with Python since the image above is one-indexed):

- The mouth can be accessed through points [48, 68].
- The right eyebrow through points [17, 22].
- The left eyebrow through points [22, 27].
- The right eye using [36, 42].
- The left eye with [42, 48].
- The nose using [27, 35].
- And the jaw via [0, 17].

upon the previous knowledge and develop, we are going to build a computer vision application that is capable of detecting and counting blinks in video streams using facial landmarks and OpenCV.

To build our blink detector, we'll be computing a metric called the eye aspect ratio (EAR), introduced by Soukupová and Čech in their 2016 paper, Real-Time Eye Blink Detection Using

Facial Landmarks [41].Unlike traditional image processing methods for computing blinks which typically involve some combination of:

- Eye localization.
- Thresholding to find the whites of the eyes.
- Determining if the "white" region of the eyes disappears for a period of time (indicating a blink).

3-7-3 EAR equation

The eye aspect ratio (EAR) is instead a much more elegant solution that involves a very simple calculation based on the ratio of distances between facial landmarks of the eyes. This method for eye blink detection is fast, efficient, and easy to implement. Based on the work by Soukupová and Čech in [41], we can then derive an equation that reflects this relation called the eye aspect ratio (EAR):

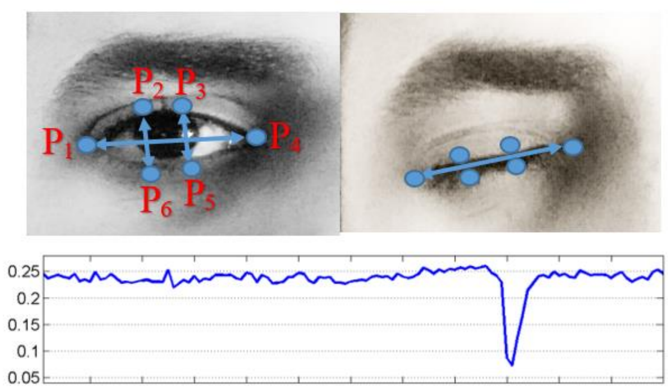


Figure (3-14) the eye aspect ratio landmarks

$$EAR = \frac{|P2 - P6| + |P3 - P5|}{2 * |P1 - P4|}$$

Where *p1, ..., p6* are 2D facial landmark locations

The numerator of this equation computes the distance between the vertical eye landmarks while the denominator computes the distance between horizontal eye landmarks, weighting the denominator appropriately since there is only *one* set of horizontal points but *two* sets of vertical points.

3-7-4 The interesting of EAR equation

The eye aspect ratio is approximately constant while the eye is open, but will rapidly fall to zero when a blink is taking place. Using this simple equation, we can avoid image processing techniques and simply rely on the ratio of eye landmark distances to determine if a person is blinking. As we can see in Figure (3-14) on the top-left we have an eye that is fully open - the eye aspect ratio here would be large(r) and relatively constant over time. However, once the person blinks (top-right) the eye aspect ratio decreases dramatically, approaching zero [42].

3-8 Electrical Design for the Eye-blinking system

A prototype has been designed to simulate a home appliance which is divided into the following parts and steps:

- Capturing the image using a Webcam
- Image processing using a personal Computer
- Secondary processing for the output signal coming from the PC to serve the outputs using an Arduino board.
- Serial Communication part
- GSM module
- Relays
- Loads (Lamp, and Fan)

The System Architecture in fig (3-15) illustrates the steps above and thegeneral functionality and work for the proposed Eye-blinking system

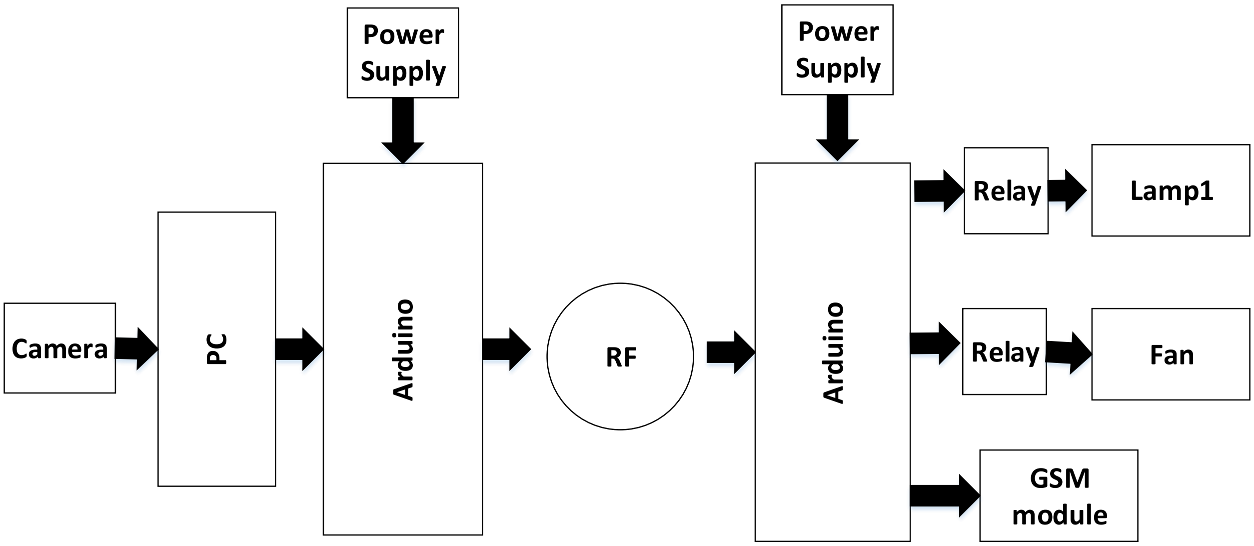


Figure (3-15) Eye-Blinking System Architecture Diagram

3-8-1 Relay

Relay shown in figure(3-16) is an electromechanical device and basically consists of an electromagnet and a number of contact sets. Relay is used in this system to control loads (lamp and fan).

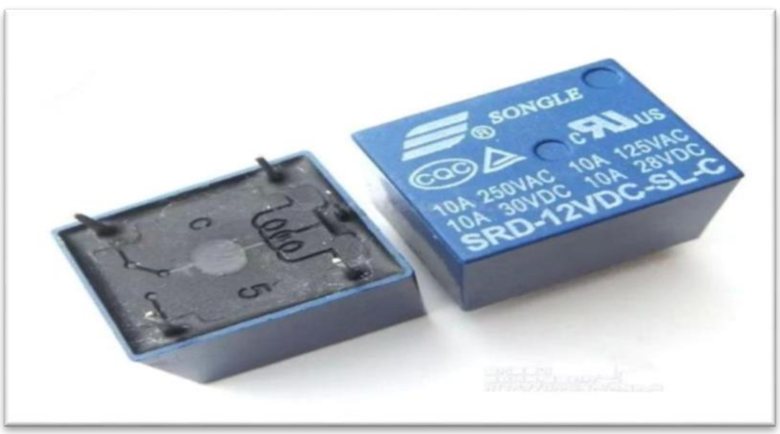


Figure (3-16) Relay

3-8-2 Camera

The web camera shown in figure (3-17) is used for capturing a stream of images for the face of the user to detect the blinking of eyes.

Figure (3-17) USB web camera

3-8-3 RF transmitter and receiver

RF module shown in figure(3-18), as the name suggests, uses radio frequency to send signals. It is very small in dimension and has a wide operating voltage range 3v to 12v. Basically the RF modules are 433 MHz RF transmitter and receiver modules. The transmitter draws no power when transmitting logic zero while fully suppressing the carrier frequency thus consume significantly low power in battery operation. When logic one is sent carrier is fully on to about 4.5mA with a 3volts power supply. The data is sent serially from the transmitter and the receiver and duly interfaced to two microcontrollers for data transfer.

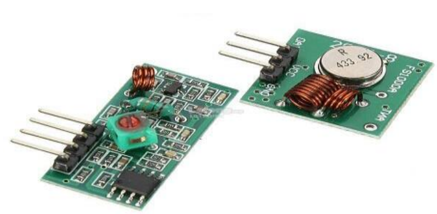


Figure (3-18) RF transmitter and receiver

3-8-4 Arduino IDE

The Arduino integrated development environment (IDE) shown in figure(3-19) is a cross-platform application (for Windows,Macos,Linux) that is written in the programming language java. It is used to write and upload programs to Arduino board.

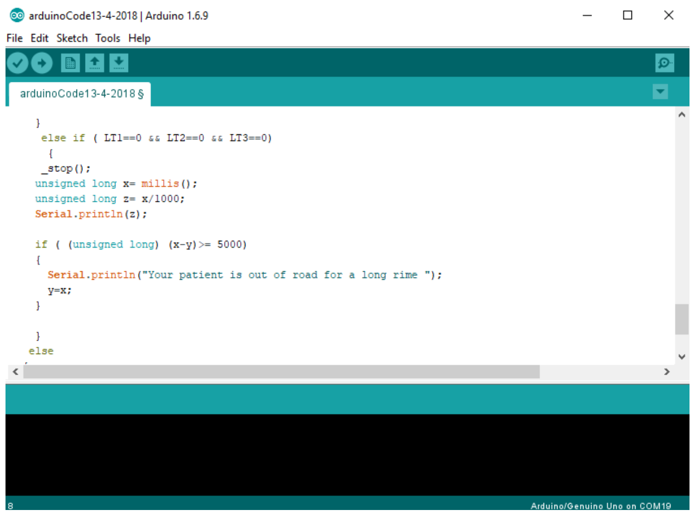


Figure (3-19) Arduino IDE

3-8-5 GSM SIM900a module

This is actual SIM900 GSM module shown in figure(3-20) (Global System for Mobile)module which is manufactured by SIMCom. Designed for global market, SIM900 is a quad-band GSM/GPRS engine that works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz. SIM900 features GPRS multislot class 10/ class 8 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 andCS-4. With a tiny configuration of 24mm x 24mm x 3mm, SIM900 can meet almost all the space requirements in User's applications. Unlike mobile phones, a GSM modem doesn't have a keypad and display to interact with. It just accepts certain commands through a serial interface and acknowledges for those. These commands are called as AT commands.

figure (3-20) SIM900A GSM Module

CHAPTER FOUR

RESULTS AND DISCUSSION

Chapter Four

RESULTS AND DISCUSSION

This chapter provides the stages and steps by which the proposed system can be implemented and turned into being a practical model.

4-1 BCI system

The first part of this project is an electric wheelchair controlled by the brain of the human being. This wheelchair is received an attention signal from a brain via a NeuroSky mobile headset. This signal is considered to be as an ON signal for the wheelchair system. Then, the ultrasonic sensor that is located in front of the wheelchair- measures the distance between the wheelchair and any part in front of it that might inhibit the movement. Whenever the distance is in a safe value, the wheelchair can start moving. Besides the ultrasonic sensor, the infrared sensors that located downward and abreast before the wheelchair determine the movement- which way to go. These IR sensors adjust the direction according to the width of the road which represented by a line stick in the floor.

4-2-1 The main flowchart for the proposed BCI system

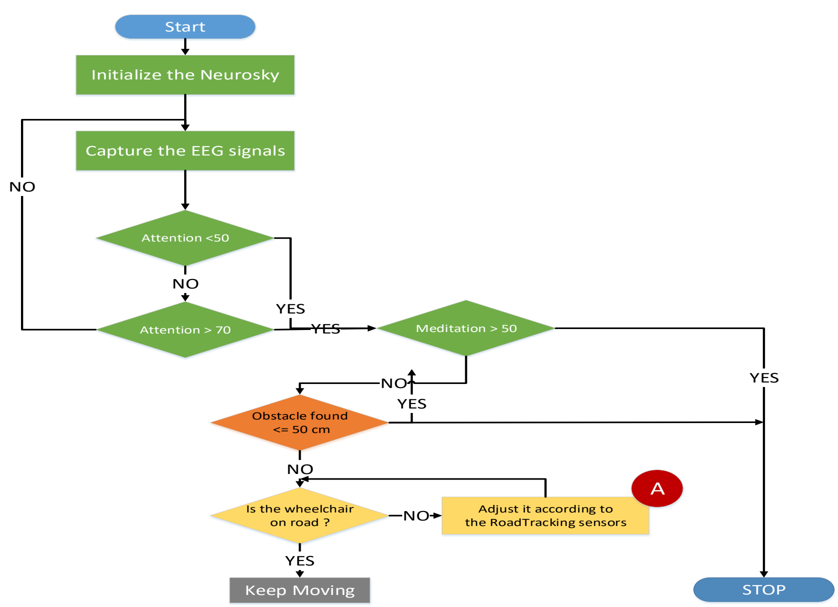


Figure (4-1): main BCIs

As shown in the flowchart figure (4-1) and according to the different signals and functions, we can divide the algorithm into 3 sections: NeuroSky, ultrasonic, and Infrared.

4-2-1-1 Algorithm 1

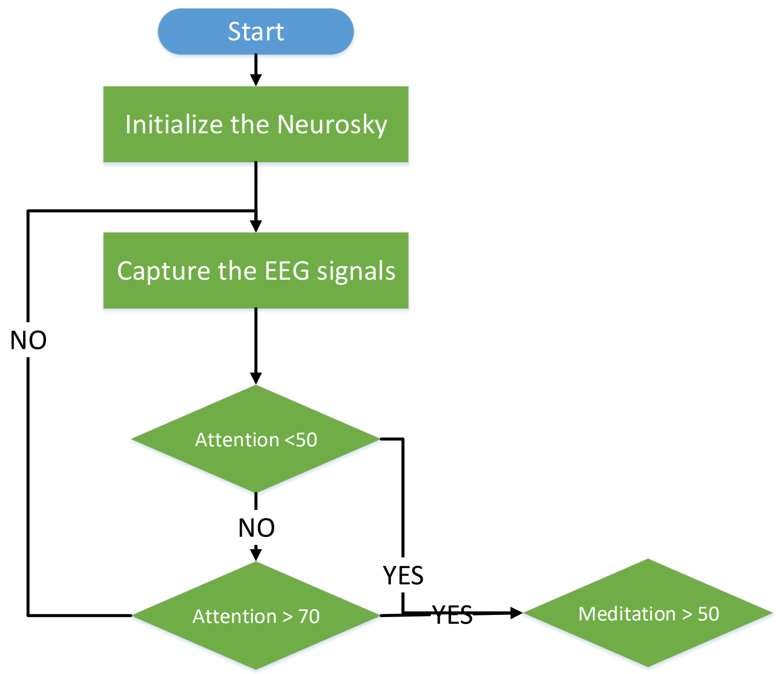


Figure (4-2): capturing brain signals

Input: Brain signals.

Output: eSense meter values.

This part of algorithm gives the general actions for the brain Signal Acquisition. To go deep inside every stage in this part of algorithm, we are going to divide these stages into steps. These steps illustrate how to get the eSense meter values – output- from the brain signals –input- softwarily.

Step1: Microprocessor Setup Begin Serialization at Baud rate at 57600.

Step2: while serial available do.

Step3: Read serial data and echo the same byte out the USB serial:

Step4: Look for sync bytes:

if ReadOneByte() = 170 then

payloadLength = ReadOneByte()

if payloadLength > 169 then

return

for each i=0; i<payloadLength; do

Read payload into memory:

payloadData[i] = ReadOneByte()

generatedChecksum += payloadData[i]

end for

Step5: if user is not wearing the device do:

Print poorQuality = 200; attention = 0;

meditation = 0;

Step6: If a user is wearing the device, do parse the payload for poorQuality, attention and meditation.

Step7: if the attention >70, go and check the meditation. If the meditation > 50, that means the brain gives two conflict signals. The signal should be attention >70 and meditation < 50 to move to the next stage- as an ON signal- which is an ultrasonic sensor. Otherwise, the wheelchair stays on an OFF mode.

4-2-1-2 Algorithm 2

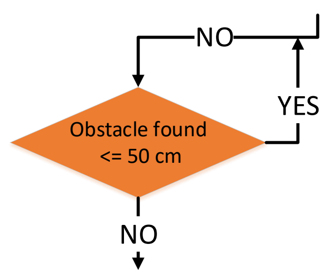


Figure (4-3): checking the obstacles

This algorithm is about an obstacle avoidance. As illustrated in the previous section, Ultrasonic sensor module (HC- SR04) is used and it provides ranging of 2-400 cm non-contact measurement with accuracy 3mm. This module includes an ultrasonic transmitters, receiver, and control circuit. The basic principle of work as pointed figure(4-4) :

1- Using IO trigger for at least 10us high level signal
2- If the sensor automatically sends eight 40 kHz and detect whether there is a pulse signal back .
3- If the signal back, through high level, time of high output IO duration is the time from sending.

Test distance = (high level time * velocity of sound (340 m/s)) /2.

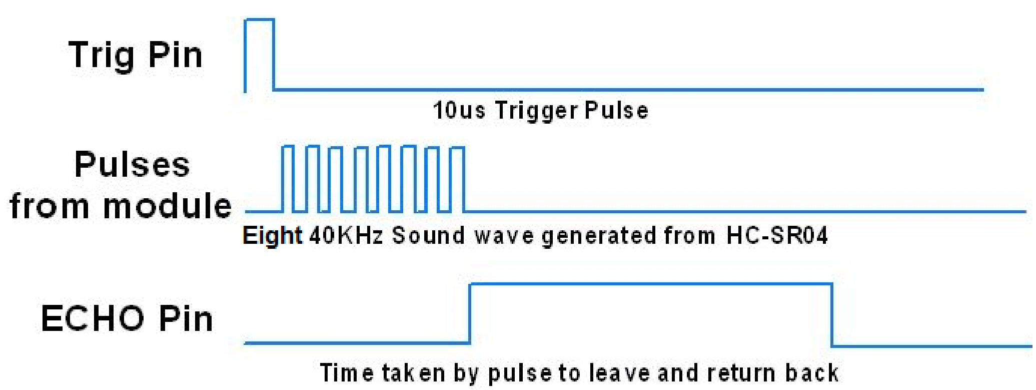


Figure (4-4): Time diagram for the ultrasonic

4-2-1-3 Algorithm 3

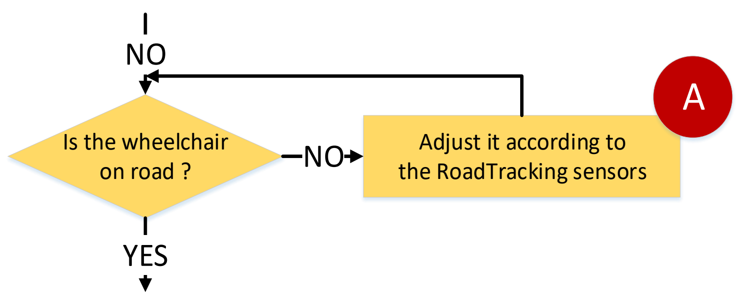


Figure (4-5): checking the wheelchair

The adjusting process (A) can be illustrated in depth using the sub flowchart Figure (4-6)

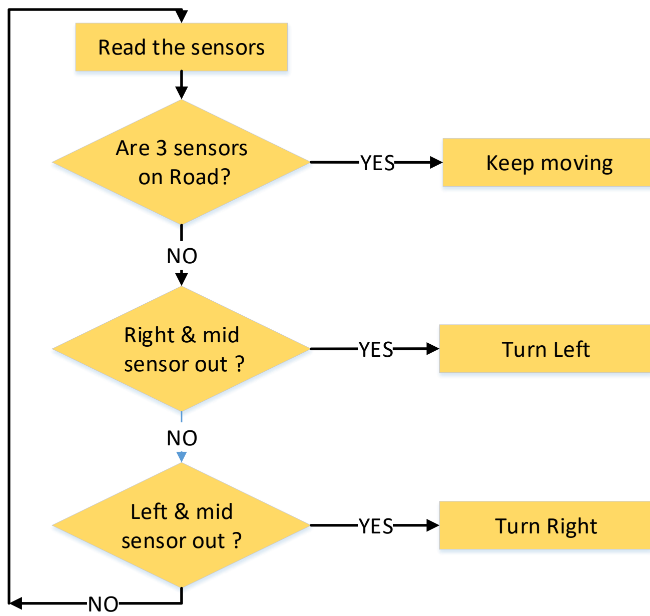


Figure (4-6) : adjusting process

As shown in figure (4-6), three infrared sensors are used to increase the accuracy and get the best and fast result of adjusting the direction of the wheelchair. These three sensors should have 2^3 probabilities, but three of these eight ones are showed in the sub flowchart figure (4-5), only to drive the idea home.

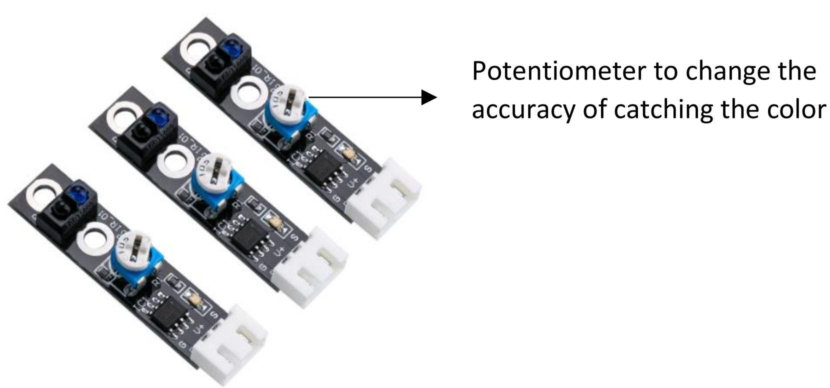


Figure (4-7): Infrared sensors

These eight probabilities and the actions for every one can be shown in table (4-1)

Table (4-1): the probabilities of the actions

Sensor 1 (left)	Sensor 2 (mid)	Sensor 3 (right)	action
0	**0**	**0**	Stop (wheelchair is out of road)
0	**0**	**1**	Right
0	**1**	**0**	Forward
0	**1**	**1**	Forward
1	**0**	**0**	Left
1	**0**	**1**	Stop (mid sensor need to be fixed or the road color is not appropriate for the wheelchair)
1	**1**	**0**	Forward
1	**1**	**1**	Forward

Note: the 1 represents that the sensor detects the black color and the 0 represents the white color (any other color can be used to paint the road; all you need is just adjust the potentiometer of the sensor to catch the color you have).

The road- sidewalk- should be special and appropriated with disabled people. This sidewalk should have two specific color – white and black as example- and specific width as well.

The road- sidewalk- should be special and appropriated with disabled people. This sidewalk should have two specific color – white and black as example- and should have specific width as well.

4-3 Eye-blink detection system

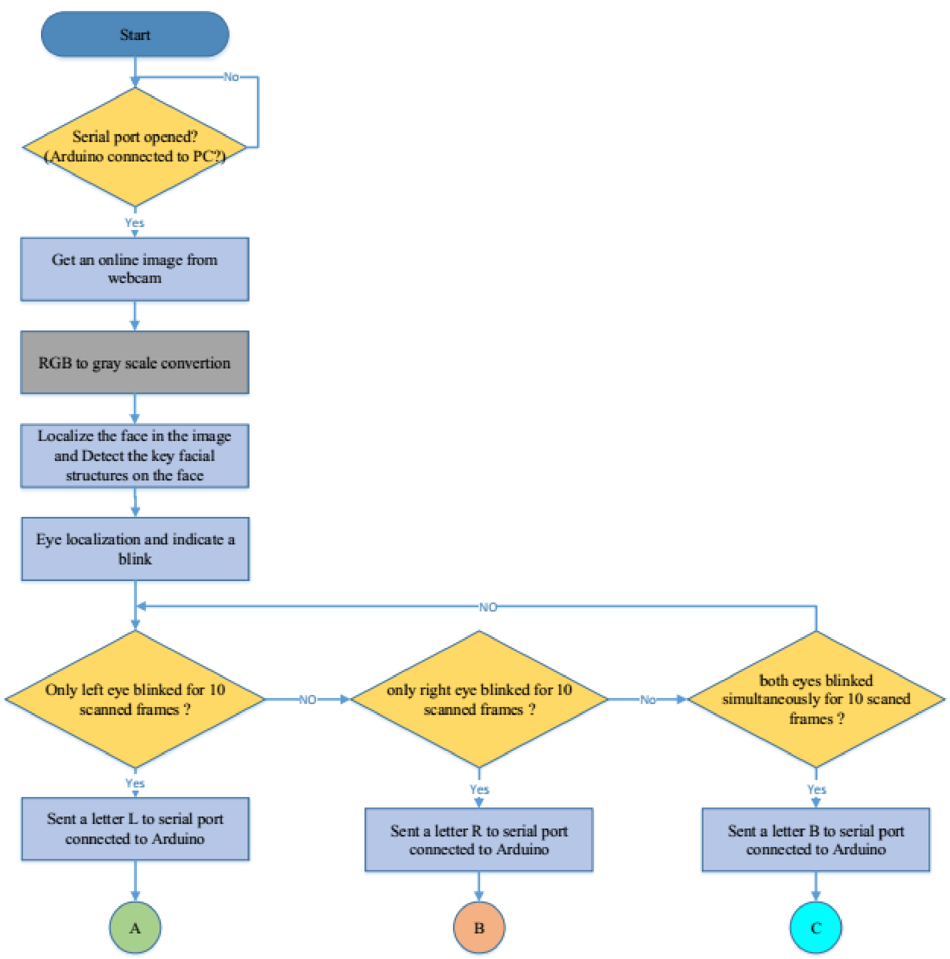
The second part of this project is a home appliance system controlled by the blinks of the human being's eyes (left-blink, right-blink, and both-blinks). This system captures an online image (Video) for the patient via a webcam. This webcam is connected to a PC located in front of a patient.

After capturing the images, the PC is used to process these images to extract the eye blinks -how the process really works can be found in chapter 3- then and via the serial communication – USB port- the PC sends three signals depending on which eye is really blinking. These signals are left-blink to control a lamp, right-blink for an Air Conditioner unit (AC), and both-blink for sending a GSM message to the person who is taking care of the patient to let him/her know that the patient is in need of something or it can be used for an emergency call.

The signals are received via Arduino UNO board connected directly and continually via USB port to the PC. After that and via a RF-433MHz transmitter module, the Arduino UNO board sends the signals to the control panel -built specially for this project- this panel is supplied by another Arduino UNO, RF 433MHz receiver module, relays, GSM module, and power supply.

Note: The applications (lamp, AC unit, and the emergency message) are just proposed ones for this project and they can be any other applications for the sake of the patient needs.

4-3-1 The flowchart of Eye-blink system



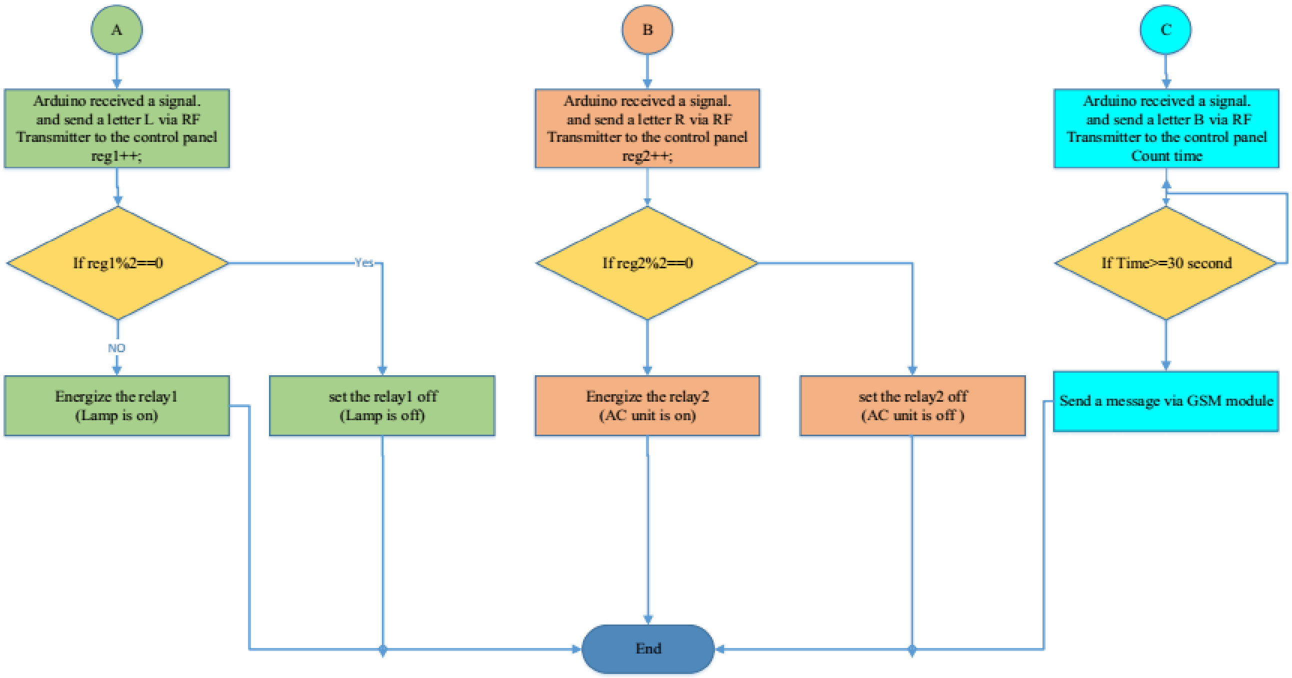


Figure (4-8) : main flowchart for Visual-based HCI system

The algorithm shown in Figure (4-8) is divided into three sections; the first section is about the capturing the picture and do the primary processing and extract the signals from the eyes. The second is about taking this signals from the serial port and transfer them as they are to the control panel. The third section is about receiving these signals and do the secondary process for the signals to guess what they are meant for.

4-3-1-1 Algorithm 1

The Figure (4-9) shown the algorithm and we are going to illustrate the flow of the signal step by step

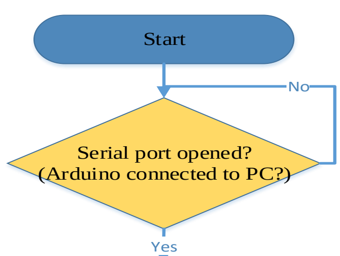


Figure (4-9): checking the

The algorithm in this part checks if the system is connected to the PC or not. The system meant here is the Arduino board that is responsible for receiving the signals form the webcam through the PC.

If the serial opened (system connected), then the algorithm would move to the next step.

Step 2

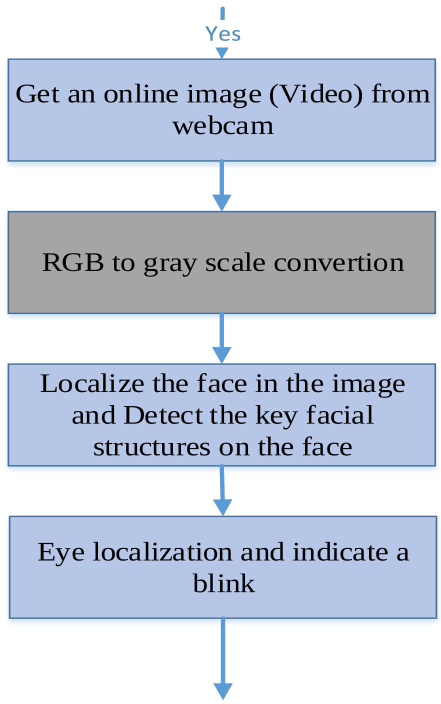


Figure (4-10): Image processing

In this step, the PC gets an online image (Video) from the webcam and puts the image in a frame.

cap = cv2.VideoCapture(cam);

By using both the detector and the shape predictor (that is included inside of a library called “dlib”), facial landmarks of the image can be predicted.

detector = dlib.get_frontal_face_detector();

predictor = dlib.shape_predictor('shape_predictor_68_face_landmarks.dat');

After predicting the facial landmarks, the eye localization took place and then the blink can be indicated by applying the EAR equation (covered in chapter 3)

```
(xs,ys) = shape[0]

(xe,ye) = shape[3]

(xul,yul) = shape[1]

(xdl,ydl) = shape[5]

(xur,yur) = shape[2]

(xdr,ydr) = shape[4]

d1 = np.sqrt(np.square(xul-xdl) +np.square(yul-ydl))+np.sqrt(np.square(xur-xdr) +np.square(yur-ydr));

d2 = np.sqrt(np.square(xs-xe) +np.square(ys-ye));

rate = d1/(2.0*d2)
```

4-3-1-2 Algorithm 2

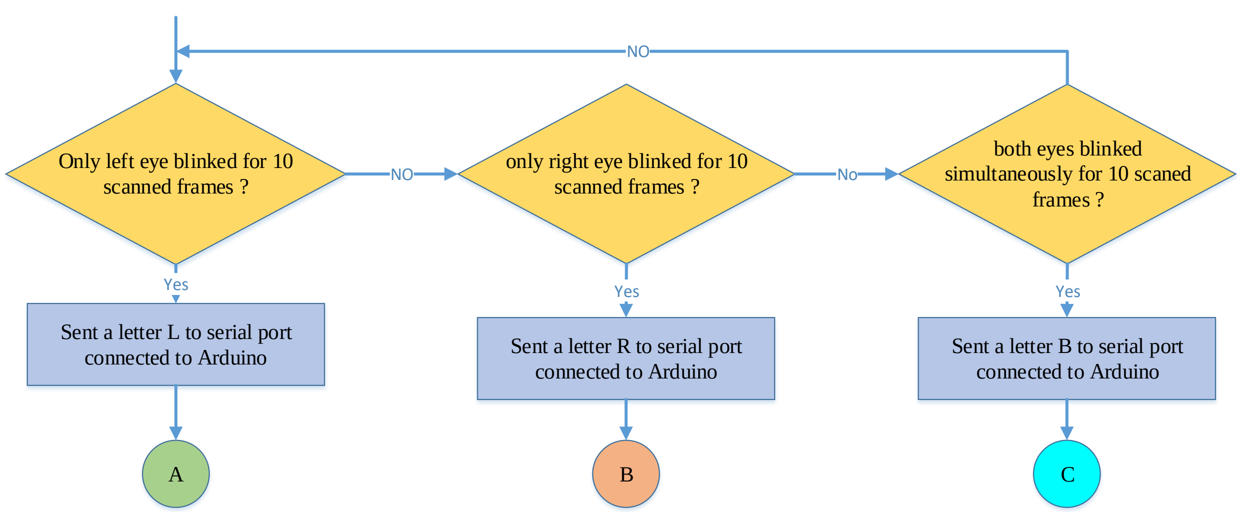


Figure (4-11): Serial output processing

In this part of algorithm, the image is scanned for 10 frames. What 10 frames mean is to check the image for 10 times (for about 3-4 seconds) for each signal to decide if the coming signal is an intent one or just a normal eye-blinking. Because the normal eye blinking takes less than a second (almost 2-3 frames) and we do not want such blinks to be taken. Besides, we can choose less frames (6 or 7) to get a fast response but sometimes we might get unwanted signals.

If the signal still the same for the 10 frames, the system takes the signal as an intent one. Otherwise, the system ignores the signal and check again.

The method by which the algorithm can differentiate these signals (Left blink, Right blink, and Both blinks) is illustrated below.

First let us look back on the index of the 68 coordinates (as covered on chapter 3) shown in figure (4-12)

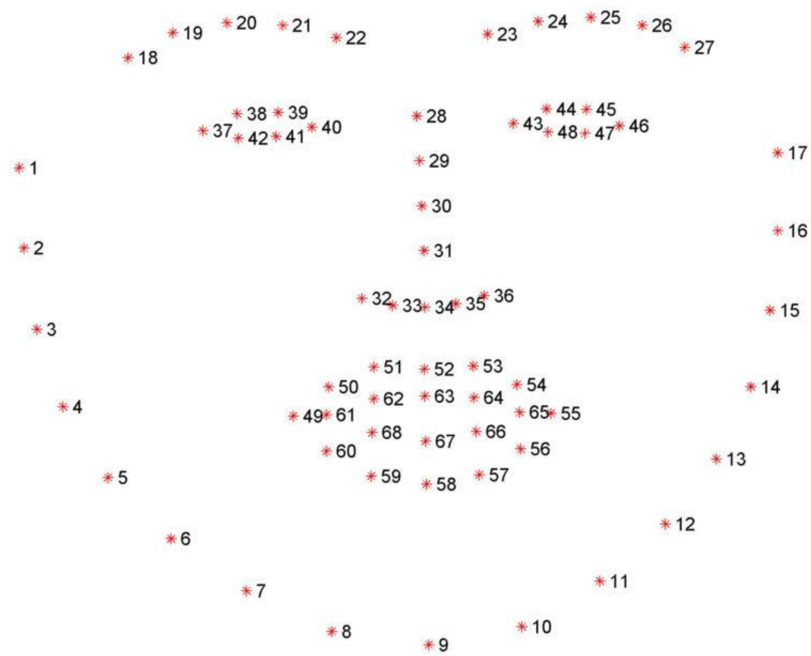


Figure (4-12): The index of the 68 coordinates

As we can see, the right eye using [36, 42] and the left eye with [42, 48] indexing. We figured out a mathematical method by which the algorithm can know which eye is blinking.

First, we have the distance “shape [36:42]” for the right eye and the distance “shape [42:48]” for the left one. The algorithm calculates the difference between them, takes the absolute value of the result, and then compare this result with a reference called Deference (by experiment, we suggest that the deference should equal 0.015) and this reference should be less than the difference between the two distance.

Second, the distance for each eye (shape [36:42]” **and** “shape [42:48]”) should be compared with another parameter called threshold (by experiment, we suggest that the threshold should equal 0.3). If the threshold is more than one of these two distance (shape [36:42]” **OR** “shape [42:48]”), it drives us to know that there is a blink but we do not know so far which one of these eyes is blinking exactly.

Third, the algorithm take the two distance and compare between them. The bigger distance is the one that blinked. Otherwise, for both-blink, the threshold should be less than the two distance.

4-3-1-3 Algorithm 3

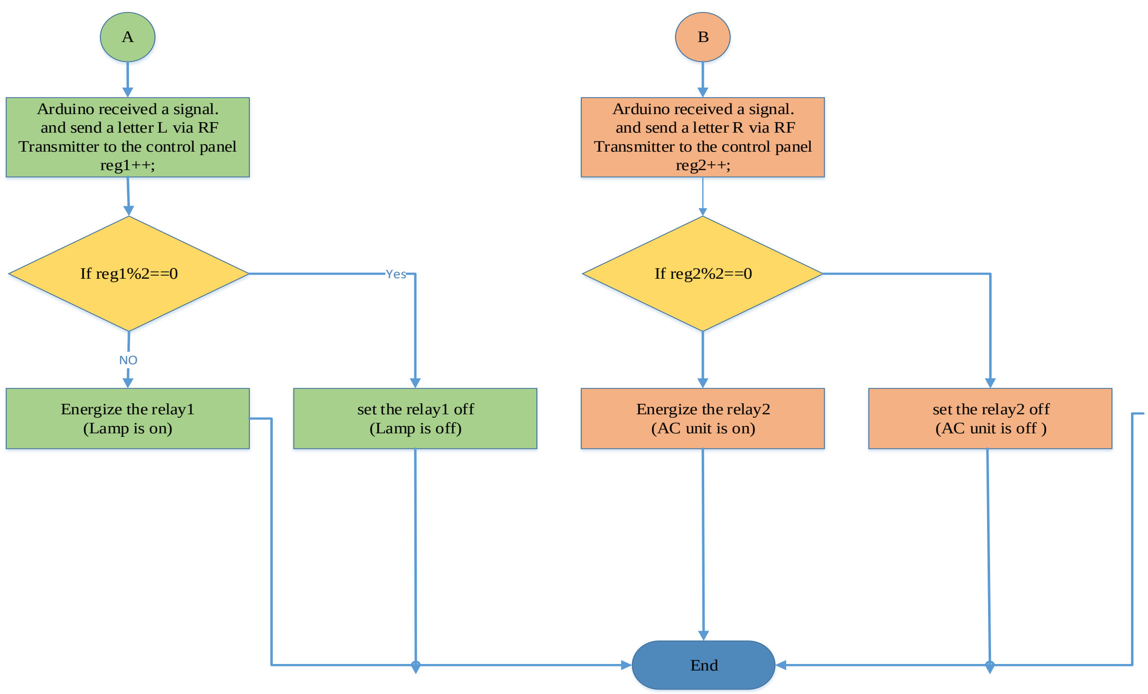


Figure (4-13): Taking the action stage

This part of algorithm is applied on the control panel's controller that is responsible for receiving a signal via RF receiver from the Arduino that is connected to the PC and according to the coming signal the loads would be energized and vice versa.

As you can notice, we use a register (reg1, and reg2) to count the coming signal and by which the ON-OFF action would be decided. All loads, at first, are in an OFF mode so any signal coming should be for setting the loads ON and the next signal would be to reset the loads to an OFF mode. Therefore, we choose the odd number (1st, 3rd signal, and so on) to set the load on and the even to reset. For our proposed Eye-blink system, we use the left blink signal to control a lamp and the right blink to control an AC unit.

3-1-4 Algorithm 4

This part is almost the same as the previous one. The only difference is that we don't put a register to count the coming signal (both blink) because the both blink signal in our proposed system is used for sending an emergency message so using a register would not be useful. Instead of a register, we use a timer to organize the sending message process.

If the patient needs for a help, all he/she needs to do is blinking both eyes for about 2-3 seconds (10 frames) and a message will be sent to the person who is responsible for the patient health. The timer, then, will start timing and ignore any other signal for the next half minute

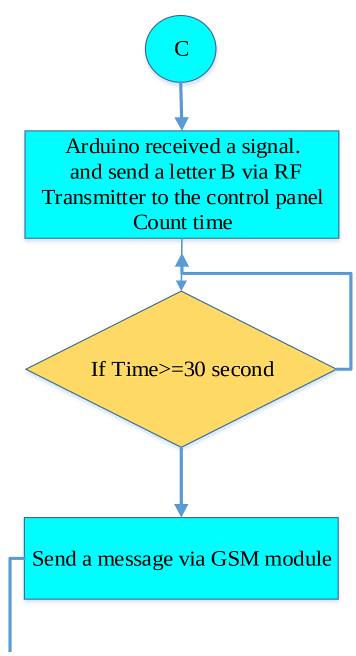


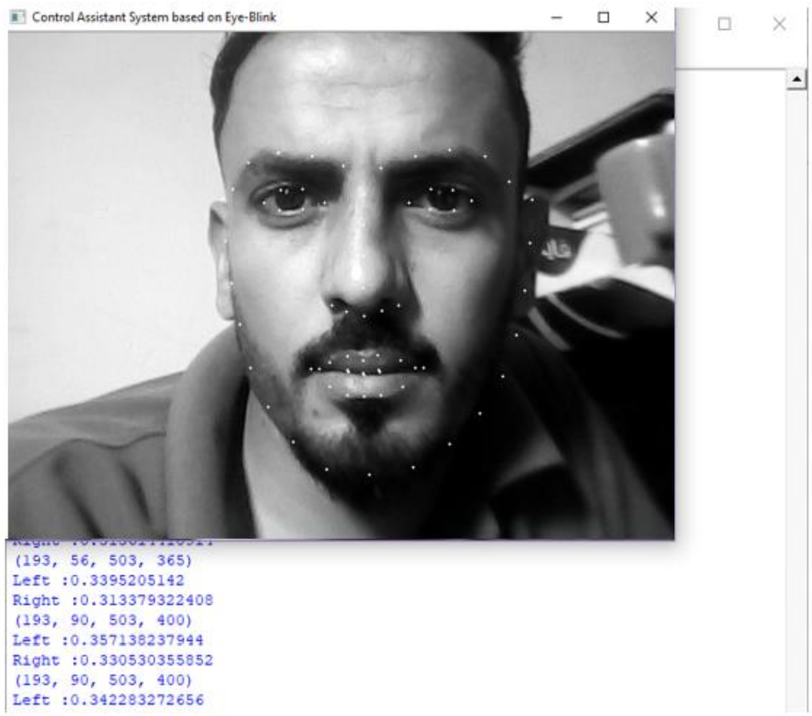
Figure (4-14): SMS action flowchart

4-4 Results for the Eye-blink system

4-4-1 Visual-Based HCI system

4-4-1-1 No blink

Image processing (Input) **Control panel (output)**



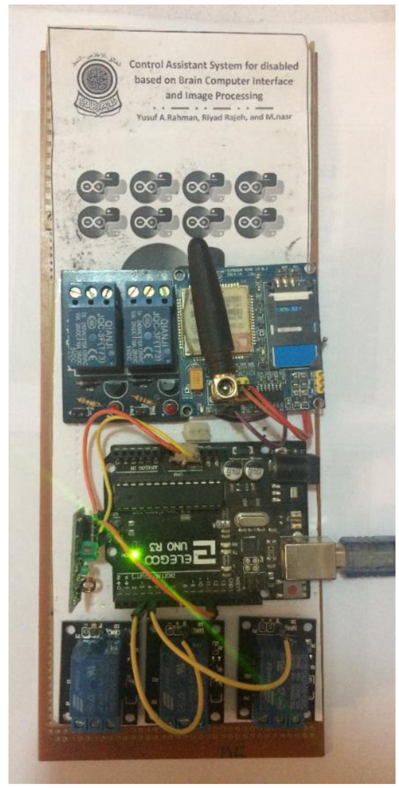


Figure (4-15): No blink result

No blink, no action takes place.

4-4-1-2 Left blink

Image processing (Input) **Control panel (output)**

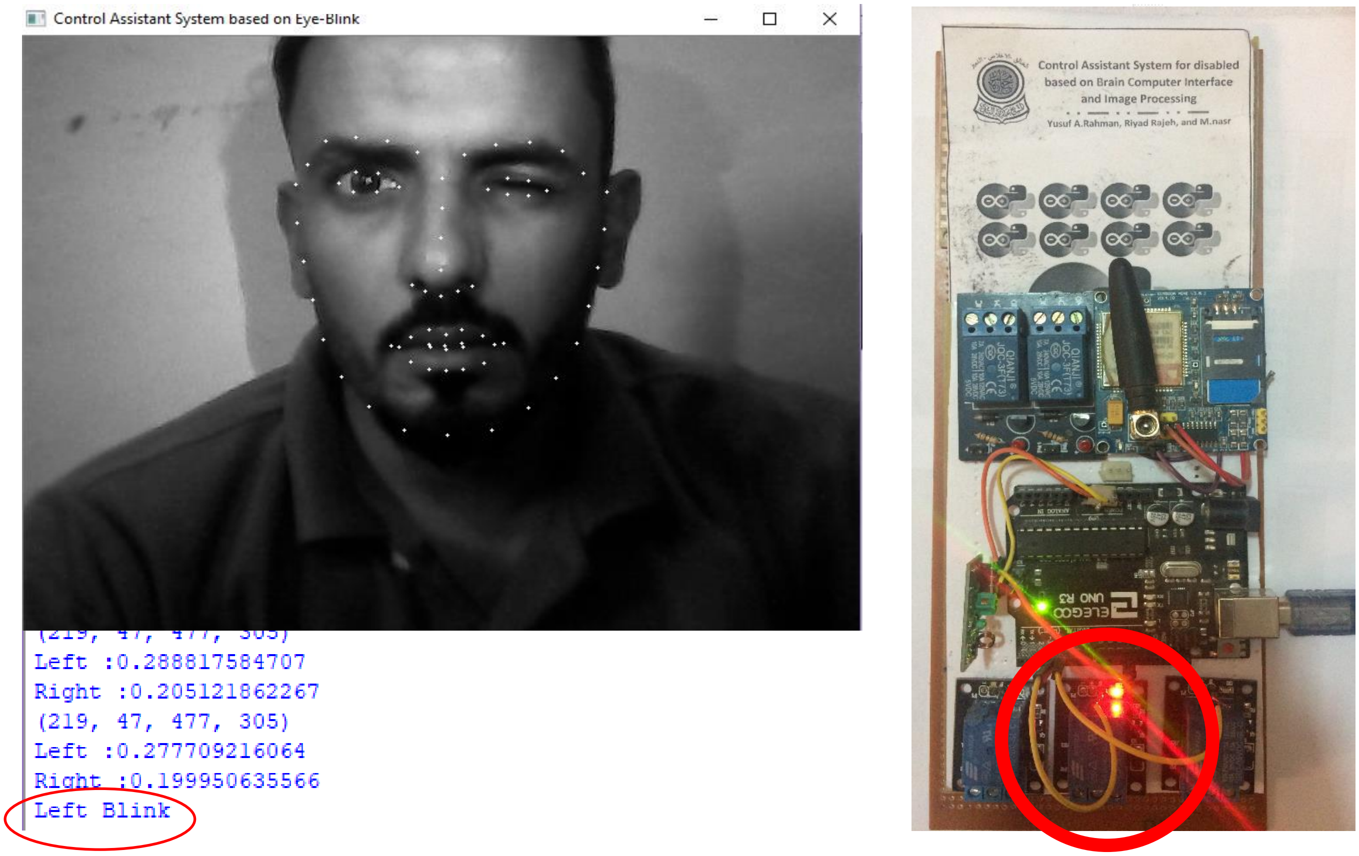
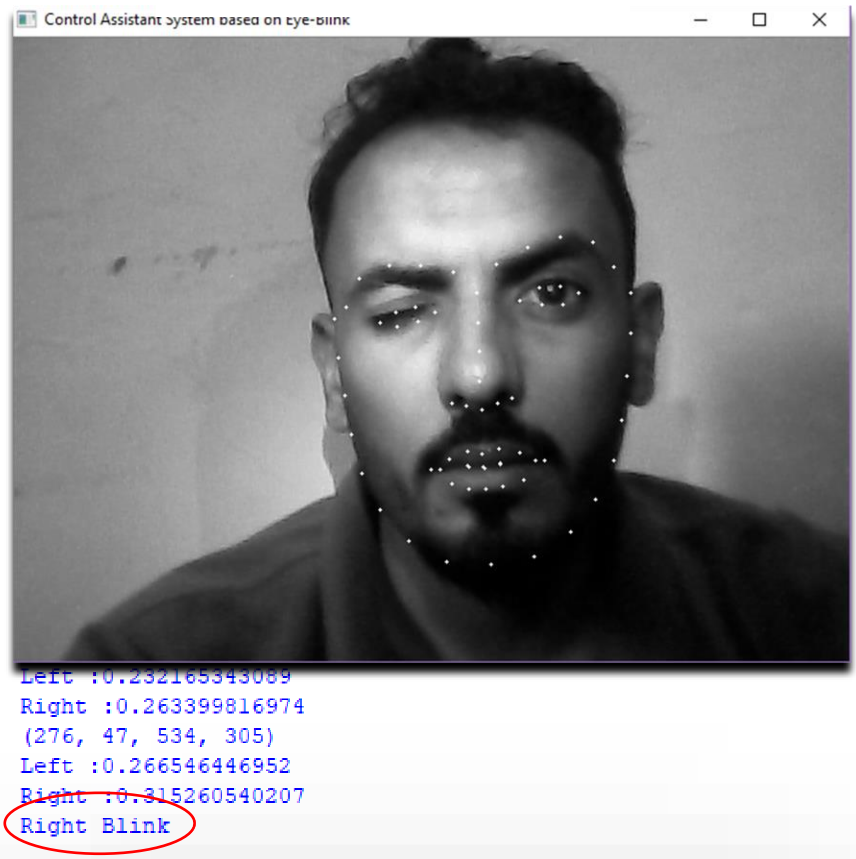


Figure (4-16): Left blink result

When the left eye blinked, one of the relays on the control panel got energized and the load connected to its open contact would get operated. Moreover, for the next left blink, the same relay would be Off and so the load connected to it.

4-4-1-3 Right blink

Image processing (Input) **Control panel (output)**



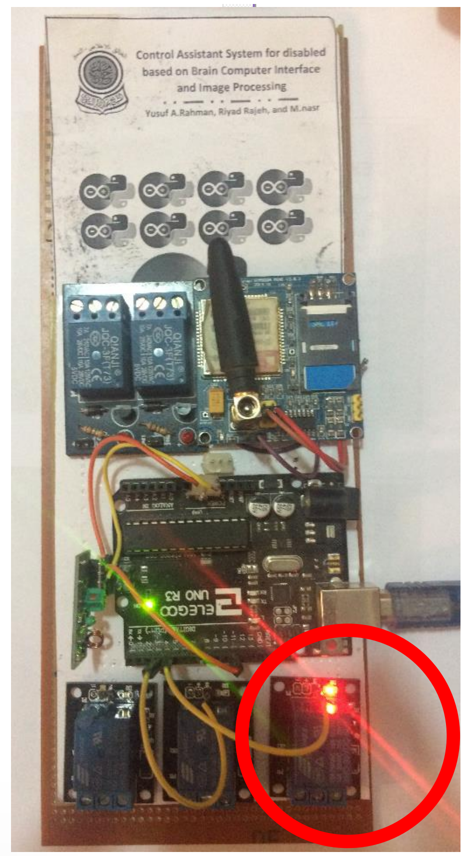


Figure (4-17): Right blink result

When the right eye blinked, the other relay on the control panel got energized and the load connected to its open contact would get operated. Moreover, for the next right blink, the same relay would be off and so the load connected to it.

4-4-1-4 Both blink

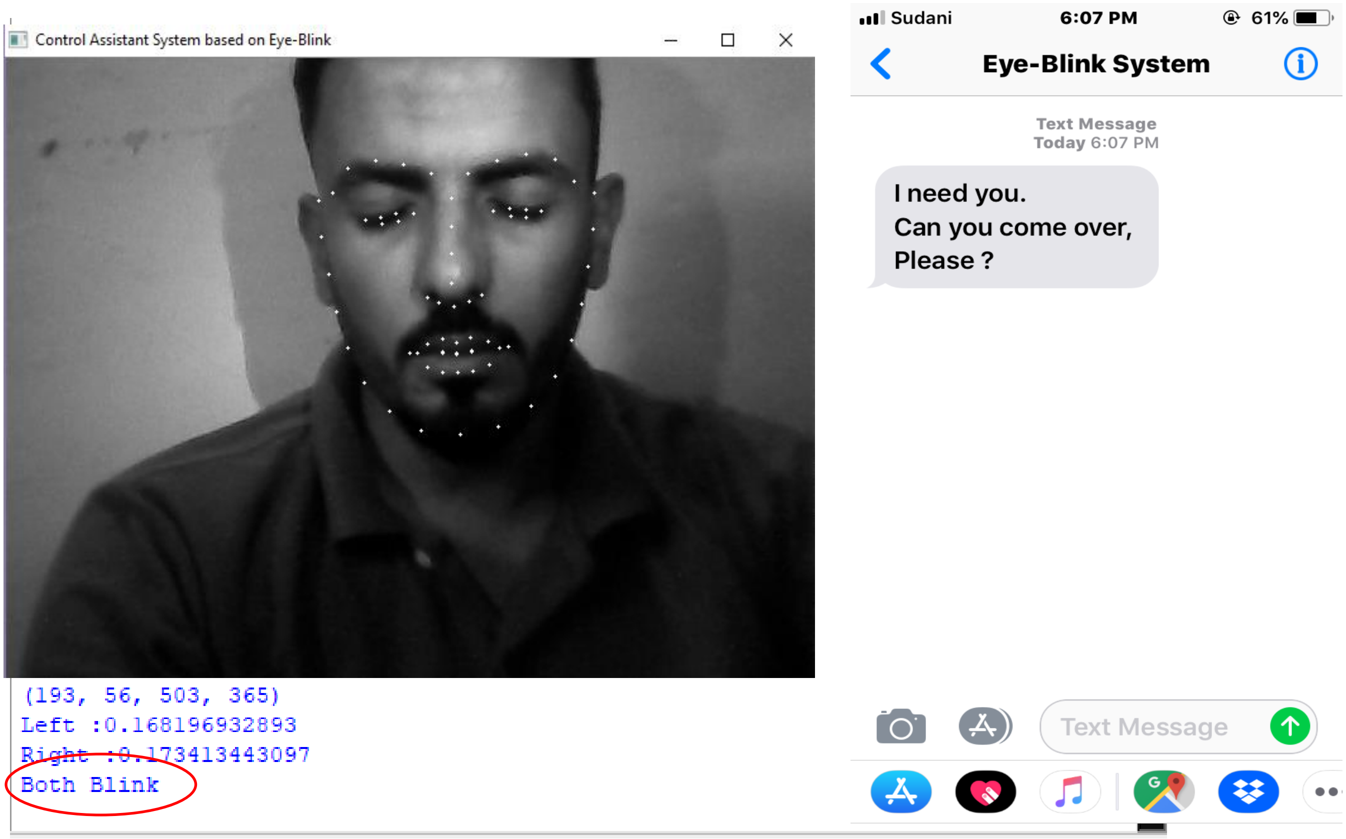


Figure (4-18): Both blink result

When both eyes blinked, the system would send a SMS message to the person who takes care of the patient to tell him/her that “I need you. Can you come over, Please?”. You can add any other message for the sake of the patient needs.

The system accepts only one both-blinked signal every 30 seconds i.e. the patient cannot send several messages whenever he/she wants. He/She needs to wait 30 second (or more) after the first message.

4-5 Results of the BCI system

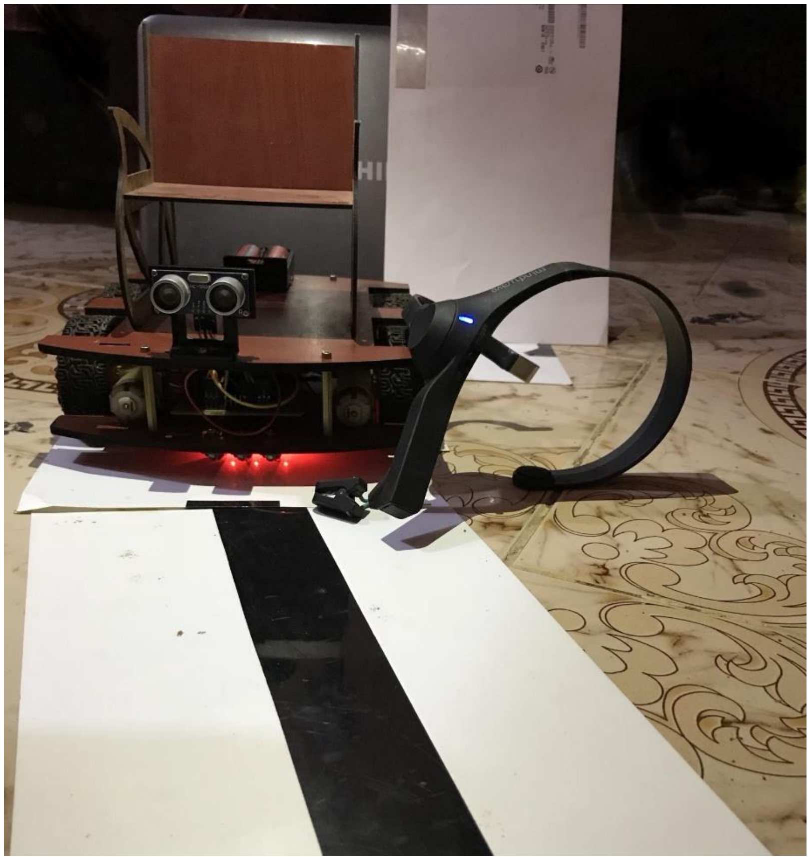


Figure (4-19) BCI system

The results showed that the wheelchair should be moved according to the attention signal of the brain and stop according of the meditation signal. However and due to the poor performance and the Bluetooth connection issues of the neuroSky that used in this project, the wheelchair couldn’t get a signal of the brain from the NeuroSky mindwave. Despite this issue, the mechanism of the prototype gives good performance as a response of both Obstacles avoidance and Road Tracking sensors.

4-6 Discussion

The proposed framework in this research is how to build an integrated system that is based on untraditional different types of techniques to achieve a special algorithm or method by which an assistant system for disabled people can be controlled. This project combines two different techniques that are based on HCI science in one completed and integrated system. These two techniques are BCI and visual-based HCI for the eye-blinking status. The combination of these two techniques proposed in this project is used to come up with a new method that has not proposed before. Both techniques are worked individually in a parallel way in the same time. Individually means that both BCI (sensor based HCI system) and eye-blinks detector (Visual-based HCI system) are working separately in one integrated system.

Results from the performance tests demonstrate that this project can support a wide range of behaviors, including close approach to obstacles, Road following, home appliances control, and emergency call or message. However, the performance test results also demonstrate that different behaviors could require very different (and mutually exclusive) configurations of the control software. Our initial results with using the NeuroSky headest are not promising because of the poor signal we get. Besides, the initial results with using the webcam in the Visual-Based HCI system is promising and giving reliable solutions. If the patient is not using the wheelchair, the system can be also useful for indoor usages such as controlling things and appliances.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

Chapter Five

CONCLUSION AND RECOMMENDATIONS

5-1 Conclusion

A combination of two techniques to capture both Brain and eyes signals to control one integrated system is proposed. Recent researches takes these two techniques individually. We design a prototype for an electric wheelchair that is also included with a webcam. The movement of the wheelchair is controlled by brains' signals that are captured via a device called "NeuroSky Mindwave headset". Besides, the system can also control the appliances at home, hospital room or any other places by using the eyes blinks. These eyes blinks are captured using a webcam and processed via a PC. Softwarely in the Visual-Based HCI, we show that the landmarks are detected precisely enough to reliably estimate the level of the eye opening. The proposed algorithm therefore estimates the landmark positions, extracts a single scalar quantity – eye aspect ratio (EAR) – characterizing the eye opening in each frame.

5-2 Recommendations

- Use a multi-channel Mindwave sensor instead of the NeuroSky Mindwave headset used in the BCI system to increase the accuracy and get various signals rang.
- Design GUI for the Visual-Based HCI system .
- Use an Embedded system to do the image processing part instead of the PC used in proposed system herein.

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Appendix A : Source Codes

- **BCI system Arduino Code (without the NeuroSky part)**

```
#include <NewPing.h>
#define LT1 digitalRead(11)
#define LT2 digitalRead(4)
#define LT3 digitalRead(2)
#define ENA 10
#define ENB 5
#define IN1 9
#define IN2 8
#define IN3 7
#define IN4 6
#define ABS 82
#define TRIGGER_PIN  12 // Arduino pin tied to trigger pin on the ultrasonic sensor.
#define ECHO_PIN     3 // Arduino pin tied to echo pin on the ultrasonic sensor.
#define MAX_DISTANCE 200 // Maximum distance we want to ping for (in centimeters).
Maximum sensor distance is rated at 400-500cm.
unsigned long y=0;
NewPing sonar(TRIGGER_PIN, ECHO_PIN, MAX_DISTANCE); // NewPing setup of pins and
maximum distance.
void setup(){
  Serial.begin(9600);
  pinMode(LT1, INPUT);
  pinMode(LT2, INPUT);
  pinMode(LT3, INPUT);
}
void forward(){
  analogWrite(ENA, ABS);
  analogWrite(ENB, ABS);
  digitalWrite(IN1, HIGH);
```

```
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  Serial.println("go forward!");
}
void left(){
  analogWrite(ENA, ABS);
  analogWrite(ENB, ABS);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  Serial.println("go left!");
}
void right(){
  analogWrite(ENA, ABS);
  analogWrite(ENB, ABS);
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  Serial.println("go right!");
}
void _stop(){
   digitalWrite(ENA, LOW);
   digitalWrite(ENB, LOW);
   Serial.println("Stop!");
}
void loop()
{
```

```
 delay(50);                      // Wait 50ms between pings (about 20 pings/sec). 29ms should be the
shortest delay between pings.
  unsigned int uS = sonar.ping(); // Send ping, get ping time in microseconds (uS).
  Serial.print("Ping: ");
  unsigned int d =uS / US_ROUNDTRIP_CM;
  Serial.print(d); // Convert ping time to distance in cm and print result (0 = outside set distance
range)
  Serial.println("cm");
   if ( d < 20 )
        {
    _stop();
    }
    else if   ((LT1==1 && LT2==1 && LT3==1) ||
               (LT1==0 && LT2==1 && LT3==0)||
              (LT1==1 && LT2==1 && LT3==0) ||
              (LT1==0 && LT2==1 && LT3==1))
      {
     forward();
         }
       else if ( LT1==1 && LT2==0 && LT3==0)
    {
    left();
         }
    else if ( LT1==0 && LT2==0 && LT3==1)
    {
    right();
       }
     else if ( LT1==0 && LT2==0 && LT3==0)
      {
     _stop();
    unsigned long x= millis();
```

```
  unsigned long z= x/1000;
  Serial.println(z);
      if ( (unsigned long) (x-y)>= 5000)
  {
    Serial.println("Your patient is out of road for a long rime ");
    y=x;
  }
      }
 else
{
  Serial.println("NONE");
}
}
```

Visual-Based HCI system

- **Image processing part using python platform**

```
import cv2
import dlib
import matplotlib.pyplot as plt
from imutils import face_utils
import numpy as np
import serial
import os
frames = 10
thresh = 0.3
cam=1
difference = 0.015
global regleft
global regright
global regboth
regleft =0
```

```
regright=0
regboth=0
dr = 9600
serialport = 'COM8'
ser =serial.Serial(serialport, dr, timeout=1)
def rect_to_bb(rect):
        x = rect.left()
        y = rect.top()
        w = rect.right()
        h = rect.bottom()
        return (x, y, w, h)
#---------------
def left():
     print('Left Blink')
     print regleft
     ser.write('L')
def right():
     print('Right Blink')
     ser.write('R')
def both():
     print ('Both Blink')
     ser.write('B')
def sysdown():
   print ('System Down!')
   ser.write('S')
def isblinking(shape):
   (xs,ys) = shape[0]
   (xe,ye) = shape[3]
   (xul,yul) = shape[1]
   (xdl,ydl) = shape[5]
   (xur,yur) = shape[2]
```

```
    (xdr,ydr) = shape[4]
    d1 = np.sqrt(np.square(xul-xdl) +np.square(yul-ydl))+np.sqrt(np.square(xur-xdr)
+np.square(yur-ydr));
    d2 = np.sqrt(np.square(xs-xe) +np.square(ys-ye));
    rate = d1/(2.0*d2)
    return rate
cap = cv2.VideoCapture(cam)
detector = dlib.get_frontal_face_detector()
predictor = dlib.shape_predictor('shape_predictor_68_face_landmarks.dat')
cv2.startWindowThread()
cv2.namedWindow('h')
cl = 0
cr = 0
cc = 0
cb = 0
rr= dlib.rectangle(0,0,480,620)
for ii in range(10):
        re,img = cap.read()
while (True) :
    re,img = cap.read()
    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
    try :
        d = detector(gray)
        bb = rect_to_bb(d[0])
        print (bb)
        shape = predictor(gray, d[0])
        shape = face_utils.shape_to_np(shape)
        print ("Left :" + str(isblinking(shape[36:42])))
        print ("Right :" + str(isblinking(shape[42:48])))
        if abs(isblinking(shape[36:42])-isblinking(shape[42:48]))>difference and
(isblinking(shape[36:42])<thresh or isblinking(shape[42:48])<thresh):
```

```
        if isblinking(shape[36:42])>isblinking(shape[42:48]):
            cl+=1
        else :
            cr+=1
    elif isblinking(shape[36:42])<thresh and isblinking(shape[42:48])<thresh:
        cb+=1
        cc +=1
    else:
        cc=0
        cl=0
        cr=0
        cb=0
    if cc>20:
        print ('Sys Down')
    if cb>=frames:
                both()
        cl=0
        cr=0
    elif cr>=frames:
        right()
        cr=0
    elif cl>=frames:
        left()
        cl =0
    for (x,y) in shape:
        cv2.circle(gray, (x,y), 1, (255, 0, 0), -1)
    cv2.imshow('h',gray)
    k= cv2.waitKey(30) & 0xff
    if k==27:
            break
except:
```

```
        print ('error')
cap.release()
ser.close()
cv2.destroyAllWindows()
```

- **signal processing using Arduino IDE – stage 1**

```
#include <RH_ASK.h>
#include <SPI.h> // Not actually used but needed to compile
RH_ASK driver;
void setup()
{
Serial.begin(9600);  // Debugging only
if (!driver.init())
Serial.println("init failed");
}
void loop()
{
 while (Serial.available() > 0)
  {
 char d=Serial.read();
 Serial.println(d);
 if (d=='l')
 {
 delay (500);
const char *msg = "L";
driver.send((uint8_t *)msg, strlen(msg));
driver.waitPacketSent();
delay(1000);
 }
else if (d=='r')
 {
   delay (500);
```

```
const char *msg = "R";
driver.send((uint8_t *)msg, strlen(msg));
driver.waitPacketSent();
delay(500);
}
else if (d=='b')
 {
   delay (500);
const char *msg = "B";
driver.send((uint8_t *)msg, strlen(msg));
driver.waitPacketSent();
delay(500);
}
  }}
```

- **Control panel Arduino code –stage 2**

```
#include <RH_ASK.h>
#include <SPI.h> // Not actualy used but needed to compile
#include <SoftwareSerial.h>
SoftwareSerial SIM900A(7,8);
RH_ASK driver;
#define lamp1 3
#define fan 4
#define other 5
#define led 13
char cam ;
int a=0;
int b=0;
int c=0;
void setup()
{
Serial.begin(9600);  // Debugging only
```

```
SIM900A.begin(9600);
if (!driver.init())
Serial.println("init failed");
}
void SendMessage(){
  SIM900A.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
  delay(3000);
  SIM900A.println("AT+CMGS=\"0964772738\"\r"); //Mobile phone number to send message
  delay(3000);
  SIM900A.println(" I need you. Can you come over, please!?");
  delay(1000);
  Serial.println ("Finish Preparing");
  SIM900A.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void loop()
{
uint8_t buf[12];
uint8_t buflen = sizeof(buf);
if (driver.recv(buf, &buflen)) // Non-blocking
{
int i;
// Message with a good checksum received, dump it.
  if ( *buf=='L')
 {
        a++;
        int x =a;
          if ((x%2)==0)
          {
          digitalWrite(fan, LOW);
          Serial.println("fan is off");
```

```
      }
     else {
     digitalWrite(fan, HIGH);
     Serial.println("fan is on");
     }
 }
else if ( *buf=='R')
{
    b++;
     int y =b;
     if ((y%2)==0)
     {
     digitalWrite(lamp1, LOW);
     Serial.println("lamp is off");
           }
     else {
     digitalWrite(lamp1, HIGH);
     Serial.println("lamp is on");
     }
   }
 else if ( *buf=='B')
   {
    SendMessage();
    Serial.println ("SMS Sent");
   }
  else {
    Serial.println("chech cam port");
  }
 }}
```

Appendix B : Some final Project Images