**Development of a Multi- Control Module for a Brain Computer Interface using Non-Invasive Electroencephalogram (EEG) for Home Automation**

**PROJECT: Synapse**

A Design Project Proposal presented to the

School of Engineering

Asia Pacific College

In Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Computer Engineering

by

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March 2018

**ADVISER’S RECOMMENDATION SHEET**

The design project entitled

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And submitted in partial fulfillment of the requirements of the Methods of Research subject and Bachelor of Science in Computer Engineering degree, has been pre-approved, examined and recommended for Title Defense.

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Adviser

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Date

# **TABLE OF CONTENTS**

[TITLE PAGE i](#_Toc469594485)

[APPROVAL SHEET ii](#_Toc469594485)

[TABLE OF CONTENTS iii](#_Toc469594485)

LIST OF APPENDICES iv

**Chapter 1: THE PROBLEM AND ITS BACKGROUND**

Introduction

Problem Statement

Design Objectives and Constraints

Scope and Delimitation

Significance of the Study

Conceptual Framework

Definition of Terms

**Chapter 2: REVIEW OF RELATED LITERATURE AND STUDIES**

Foreign and Local Literature

Foreign and Local Studies

# **LIST OF APPENDICES**

|  |  |
| --- | --- |
| Appendix A: | OCFM Table |
| Appendix B: | Minutes of the Meeting |
|  |  |

**Chapter 1**

**THE PROBLEM AND ITS BACKGROUND**

* 1. **Introduction**

In the year 1929 Hans Berger, a German psychiatrist, made a historical breakthrough when he successfully recorded the electrical activity of the human brain for the first time. What he developed was the world’s first human electroencephalogram (EEG) [1]. An EEG is a test that records the electrical activity of your brain; an EEG device is designed to acquire, process, and display the EEG signals as waveforms. During the procedure, electrodes consisting of small metal discs with thin wires are pasted onto your scalp. The electrodes detect tiny electrical charges that result from the activity of your brain cells, typically, in a non-invasive way [2]. However, in the recent years newer technology and studies has innovated the EEG device resulting to noise reduction for the output, higher accuracy ratings, a classification of brain waves, and in the most recent years, availability to the public [3].

The advancement of the EEG device also opens new possibilities for this old technique of recording an individual’s brain activity. A major focus these days are brain-computer interfaces (BCIs). BCI is a collaboration between a brain and a device that enables signals from the brain to direct some external activity [4]. BCIs are communication and control systems that have no dependence on the brain’s normal neuromuscular output channels [5]. The research community has initially developed BCIs with biomedical applications in mind, leading to the generation of assistive devices, commonly for the physically challenged or the disabled replacing lost motor functionality [6,7].

However, the scope of research has been further widened to include non-medical applications. More recent studies have targeted normal individuals by exploring the use of BCIs as a novel input device and investigating the generation of hands-free applications [4,6]. A BCI system requires five basic components (shown in Fig 1). They include signal acquisition, signal preprocessing, feature extraction, classification, and the external device. The signal acquisition component is responsible for recording the brain waves and sending them to the preprocessing component for signal enhancement and noise reduction. The feature extraction component generates the discriminative characteristics for the improved signal, decreasing the size of the data applied to the classification component. Classifiers are translating the produced features into device commands [7,8].

**Figure 1.1 Components of BCI system**

There are many techniques of signal acquisition ranging from invasive means like ECoG (electrocorticography), a similar idea to EEG, also using surface electrodes—except they put them under the skull, on the surface of the brain which isn’t a very popular choice because of the surgery needed [9]. Another is the functional magnetic resonance imaging (fMRI), it isn’t typically used for BCIs, but it is a classic recording tool—it gives you information about what’s going on inside the brain. The problem is, an fMRI tracks blood flow, which has problems with the preciseness, the non-portability of the device, and the delay of about a second— which equates to a long time in the world of neurons [10,11].

The most commonly used and researched signal acquisition technique being paired with BCIs today is the EEG because of its recent designs that allow less obstruction, its portability, non-invasiveness, and availability to the public [3,12,13]. Studies about EEG-based BCIs have explored its possibility and its effectivity as an input method to control different things [14]. The extent of the things that it can control include the field of robotics; where it was used to control a wheelchair [15], a prosthetic arm [16, 17], the field of computer systems; where an EEG based BCI controlled 2-D cursor control [18] and an adaptive P300 speller [19] which was further researched and made a BCI based internet browser [20] and a BCI based mail client [21] possible.

* 1. **Problem Statement**

Every research on EEG-based BCIs or BCIs in general was limited due to various problems [3]. One of the most common one was the low information transfer rate (ITR). The ITR is a widely used evaluation metric for command BCI systems. It depends on the number of choices, the accuracy of target detection, and the average time for a selection. The higher the number of categories the signal can be classified, the lower the accuracy of the intended output of the command [22]. The accuracy ratings for those systems with up to two command recognitions were higher compared to those BCIs having more than two command recognitions, ranging from 70% up to 99% accuracy [27-29]. These problems result to BCIs having a limited number of control. Likewise, as the number of controls increases, the reliability of the BCI declines.

There are several techniques to increase the BCI’s number of controls. H-BCIs or hybrid BCIs are a new approach that creates a more reliable BCI that takes advantage of two or more BCI systems but can be difficult to merge technologies like an EEG-based and an fMRI-based BCI due to the location of the needed devices [30, 36], some include a powerful algorithm to categorize thoughts, another is to develop an artificial intelligence that will learn on its own over time to do the same as the fore mentioned algorithm, one more is the training procedure where in the user training for the BCI needs to be further developed to maximize the time for users to control their thoughts [23-25] but said techniques require more time, knowledge, and experience in BCIs. Since previous studies where the accuracy in a two-command recognition BCI were high, the proponents aim to develop a module that acts as a menu using an EEG-based BCI to operate a home automation system.

* 1. **Design Objectives and Constraints**
     1. **General Objective**

To develop a module that can receive and interpret signals from the brain using a non-invasive EEG to operate a home automation system.

* + 1. **Specific Objective**
       1. To create a high-throughput BCI system that maximizes the number of possible outputs given the small number of inputs.
       2. To design a reliable BCI system.
       3. To create a transferable BCI system.
    2. **Metrics Description and Scale Measurements**

**Table 1.1** Metrics Description and Scale Measure

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Objectives** | **Definition** | **Metrics** | **Scale** | |
| **Throughput** | Ability of the system to produce a high number of automation controls | Number of controls | **7-8** | **Excellent** |
| **5-6** | **Above Satisfactory** |
| **4** | **Satisfactory** |
| **2-3** | **Fair** |
| **1** | **Poor** |
| **Reliability** | Ability of the system to give the consistent results | Test-retest reliability coefficients  through Intraclass Correlation | **1** | **Perfect Reliability** |
| **≥ 0.9** | **Excellent Reliability** |
| **≥ 0.8 < 0.9** | **Good Reliability** |
| **≥ 0.7 < 0.8** | **Acceptable Reliability** |
| **≥ 0.6 < 0.7** | **Questionable**  **Reliability** |
| **≥ 0.5 < 0.6** | **Poor Reliability** |
| **< 0.5** | **Unacceptable Reliability** |
| **0** | **No Reliability** |
| **Transferability** | Ability of the system to be used by different people | Percentage of test subjects that can use the system | **90% – 100%** | **Excellent** |
| **76% – 89%** | **Above Satisfactory** |
| **62% – 75%** | **Satisfactory** |
| **48% – 61%** | **Fair** |
| **48% – 0%** | **Poor** |

Table 1.1 shows the metrics for each specific objective of the proposed system. The first objective is to create an effective system. The baseline for the throughput is based on a BCI home automation system based to the proponent’s system [29]. Where they manipulated the states of devices to turn on or off based on their created BCI.

The reliability of the system will be based on several tests of each command of different users. The reliability will be measured through Test Retest reliability using the Intraclass correlation that measures the reliability of ratings or measurements for data that has been collected as groups or sorted into groups since the next objective deals with a population of test subjects.

The transferability baseline was based on a study aimed at researching how many people can successfully operate an EEG-based BCI where the results ended up with roughly 93% of the test subject population successfully operating the BCI with a somewhat low accuracy of 60% [26].

**1.3.5 Constraints**

* Utilizing a non-invasive commercially available EEG device.
* Wireless transmission of brain signal to machine.
  1. **Scope and Delimitations**
     1. **Scope**
* The signals will be categorized into either the trigger command or the neutral state.
* The menu will have an auto scrolling function for the choices that the user may choose to select using the trigger command.
  + 1. **Delimitations**
* Reducing any cost related entities used in the project is none of concern.
* The EEG device will send signals via the device’s predesigned mode of wireless output.
* Reducing the response time of the system will not be of concern.
  1. **Significance of the study**
* **To a disabled person**

Although not directly a medical application of BCIs, this project will still benefit the disabled part of community. This study, if integrated into already existing medical applications of BCIs, can extend even further the functions or things other BCIs can’t do now. This will greatly affect disabled persons because despite some of their parts being disabled, through this project, can regain some of their lost control and functions.

* **To the Academe**

The project will benefit the academe for it can be a demonstration on what BCIs are and what they are for; thus, making BCIs more understandable. It may also expose them in the field of research of BCIs or study that may take their interest in the related field.

* **To the Community**

The project will benefit the community. The study aims to open EEG-based BCIs for control of devices through its proposed multiple controls. The project may be well developed enough one day that it can easily be an alternative system for control for already existing technology that is used every day by the society and offering an alternative control for systems**.**

* **To the Future Researchers**

The project will benefit future researchers for it may spark interest for the field of research of making other methods or techniques for not only EEG-based BCIs but for BCIs in general. The proponents may encounter some problems while developing the project, these problems will be recommended to be solved as improvements for other future researches. The project can also be used for reference and citations for related studies.

* 1. **Conceptual Framework**

**Figure 1.3 Conceptual Framework of the Study**

Figure 1.3 shows the input, process, and output of the proposed system. The system will receive the input from the EEG device on the user and will transmit the signal via the built in means of the EEG device. The signal will then be processed by an algorithm and be assigned to the commands. The commands will then be used to control the menu module which includes the control for the home automation.

* 1. **Definition of Terms**

|  |  |
| --- | --- |
| **Terms** | **Definitions** |
| **Electroencephalogram (EEG)** | The method used by the proponents to monitor the electrical activity coming from the brain |
| **Brain-Computer Interface (BCI)** | Interface used by the proponents that enables the direct communication pathway between the brain to a device that is to be controlled |
| **Throughput** | Ability of the system to have a high number of command that is provided by brain signals coming from the EEG device used |
| **Transferability** | Ability of the system to be transferred and used by different people |
| **Reliability** | Ability of the system to provide consistent results during the testing phase |
| **Home Automation** | Home functions and features remotely controlled by the commands extracted from the brain signals of the EEG device user |
| **Signal Acquisition** | The process used by the proponent to get the signals from the brain and convert it into digital numeric values that can be understand by the system |
| **Signal Processing** | A technique of processing the data acquired for further analyzation by the system |
|  |  |

**Chapter 2**

**REVIEW OF RELATED LITERATURE AND STUDIES**

**2.1 Local Studies**

**2.1.1. A Study on Ocular and Facial Muscle Artifacts in EEG Signals for BCI Applications [30]**

The researchers focused on increasing and studying the means of adding other ways of detecting EEG signals as input reference in the BCI. They observed and analysed the significance and relation of the signals can be adapted. The facial gestures are: left wink, right wink, blink, smile, clench and raise eyebrow. They were observed by the researchers as a possibility of using it as an input process in other system. They also focused on the well-defined signals that the facial gestures can make. The results of the study were meant for the detection of the facial gesture as input for home automation and a communication system for amputees/physically disabled person. They used Emotiv Epoc and Arduino Duelimanove.



**Figure 2.1 Emotiv Epoc**

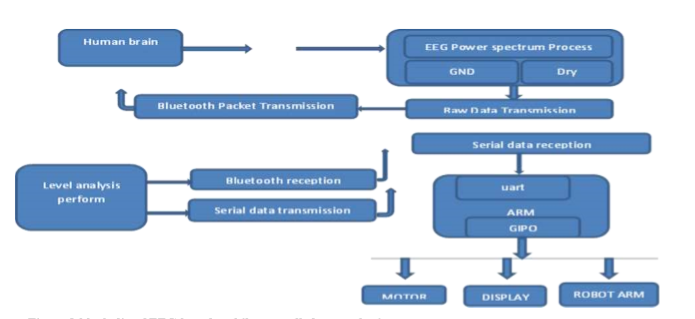
This study used the Emotiv Epoc neuroheadset. It is a non-invasive high resolution, neuro-signal acquisition and processing wireless neuroheadset containing 14 saline sensors. The output data have a DC offset of about 4000µV. The headset connects to a computer via Bluetooth using a USB dongle.

Emotiv Epoc Neuroheadset electrode placement system is derived from the 10-20 Electrode Placement standards. The headset consists of 16 electrodes where CMS (Common Mode Sense) and DRL (Driven Right Leg) are reference electrodes. We also used the Arduino Duemilanove board that includes an ATmega328 for its microcontroller. Electrode Placement System of Emotiv Epoc 6 analog inputs and 14 digital pins that can be configured either as input or output pins. It can easily be connected to the computer using the USB connection. It can be powered up either using an external power supply through the power jack or through the USB connection.

**2.2 Foreign Studies**

**2.2.1. EEG Based Brain Controlled Mobile Arm Pick and Place robot. [31]**

Using the neuron of the brain, the brain wave signals can be examined. In this study, signals from the brain are captured measuring the following: attention value and the blinking our eyes. This is connected via Brain computer interface (BCI). The pattern of brain signal has different amplitude and frequencies. Using Bluetooth, the sensor transmits the signal into packets. Wherein ARM7 processor is used for the interface. The BCI used for straight communication between brain and robot and the raw data gathered is converted into signal using MATLAB GUI platform. Through the BCI interface we control the whole robot. The main aim of the project is for the physically disabled person to become independent on others in their daily life time for their purposes.



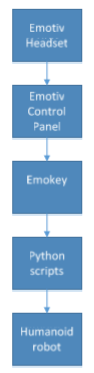
**Figure 2.2 - Block Diagram of EEG based mobile controlled arm**

Arm Processor:

The ARM processor is a 32-bit microprocessor. It is mainly working based on Von Neumann, which gives and gets the instruction in the one bus. It has 16 registers and 7 processors. These processors operate on low power but has high performance. The processor has 2 ports and they are widely used for internal and external usage. It has chip timers and has built in Analog and Digital converter. The ARM processor receives the signals and process it to the Driver Circuit. It controls the arm and movement of the robot. The ARM7 execute 3 pipelines and they are: 1) Fetch, 2) Decode 3) Execute. Hence the ARM7 gets the signal and make the motor to work and move the arm of the robot for pick and place actions and used to move the robot as we want. The arm 7 processor is the main controlling core of the robotic device.

**2.2.2. Humanoid Robot control with EEG brainwaves. [32]**

This study presents the implementation a controllable humanoid robot with human brainwaves as control input. This control technique is done with real-time measurements of the brain activity with electroencephalography and recognition of the signal types. The recognized signals are sent as control input to a custom build humanoid robot. The presented hardware of the robot combines main controller, 17 servo motors and a servo controller, while the brain activity signals are measured with Emotiv Epoc + Electroencephalography (EEG) headset.

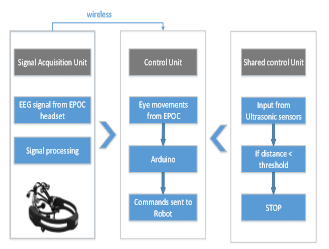


**Figure 2.3 - Main components of the system**

The first block represents the Emotiv Epoc + EEG Headset. This is one of the best cheapest options for real time electroencephalography on the market so far, offering 14 channels of incoming electroencephalography data with 2 reference channels and wireless signal transmission.

**2.2.2. Eye Controlled Mobile Robot with Shared Control for Physically Impaired People. [33]**

This study focuses on physically impaired and disabled people whom are integral part of human society. Modern aiding devices the can support such individuals can help them contribute to the society in a more productive way. The situation is even worse for patients with locked-in syndrome who cannot move their body at all. These problems were the motivation to develop an eye controlled robot to facilitate such patients. Readily available commercial headset is used to record electroencephalogram (EEG) signals for classification and processing. Classification based control signals were then transmitted to robot for navigation. The robot mimics a brain controlled wheelchair with eye movements. The robot is based on shared control which is safe and robust. The analysis of robot navigation for patients showed promising results.



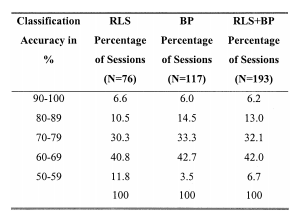
**Figure 2.4 - Shared Control System Model**

All the above-mentioned setup is implemented using cheap and readily available components. An image of the developed robot is shown in figure 2. The robot has custom made wheels which are developed to make it very stable and aligned to move in a straight path. The wheels are also light weight and already have an O ring which has reduced its surface friction.

**2.2.3. How Many People Are Able to Operate an EEG-Based Brain-Computer Interface (BCI)? [26]**

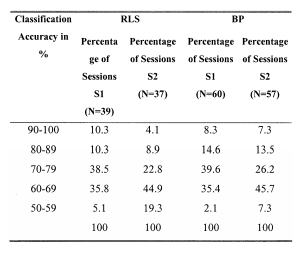
Ninety-nine healthy people participated in a brain–computer interface (BCI) field study conducted at an exposition held in Graz, Austria. Each subject spent 20–30 min on a two-session BCI investigation. The first session consisted of 40 trials conducted without feedback. Then, a subject specific classifier was set up to provide the subject with feedback, and the second session—40 trials in which the subject had to control a horizontal bar on a computer screen—was conducted. Subjects were instructed to imagine a right-hand movement or a foot movement after a cue stimulus depending on the direction of an arrow. Bipolar electrodes were mounted over the right-hand representation area and over the foot representation area. Classification results achieved with 1) an adaptive autoregressive model (39 subjects) and 2) band power estimation (60 subjects) are presented. Roughly 93% of the subjects were able to achieve classification accuracy above 60% after two sessions of training.

It is interesting that in about 20% of the sessions (about 20% of subjects), the two brain states were distinguished with an accuracy of greater than 80% after only 20–30 min of training, as shown in Table I. Further, 70% of the sessions were classified with an accuracy of 60%–80%, and only in 6.7% was a marginal discrimination between brain states possible (see Table I for details). The BCI system uses two types of experimental sessions: 1) training sessions where data are collected to set up a subject-specific classifier (with or without feedback) and 2) sessions where the classifier is used to classify a subject’s EEG online while motor imagery is requested (with feedback). Table II divides the classification results into sessions without feedback (S1) and sessions with feedback (S2) for RLS and BP. An interesting result is that nonfeedback sessions have a higher accuracy than feedback sessions. S1 of RLS and BP have almost the same performance, but results for S2 differ. Feedback sessions with BP show better results.



**Table 2.1**

Percentage of sessions which were classified with a certain accuracy for RLS algorithm and Band Power (BP) estimation. “N” specifies the number of sessions. “RLS+BP” shows the result for both algorithms.

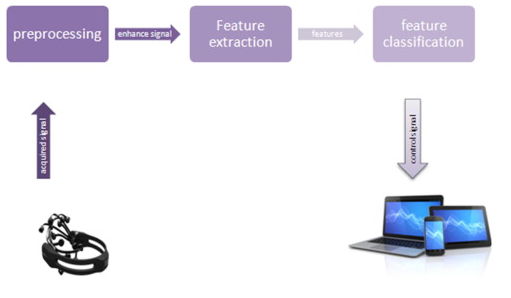


**Table 2.2**

Percentage of sessions which were classified with a certain accuracy for RLS algorithm and BP estimation. “N” specifies the number of sessions and “RLS + BP” shows the results for both algorithms.

**2.2.4. Brain computer interfacing: Applications and challenges [3]**

Brain Computer Interface (BCI) technology became a formidable device that ensures communication with the users and systems. Muscle movements and usage of external devices/technology is not required to accomplish the interaction of entities inside the BCI system. Because of advancing technology and intelligent researchers, BCIs with biomedical implementation has initially begun. It was dedicated for physically disabled persons/ amputees to restore their ability to move. It was predicted that the BCI will go further with the involvement of normal human being with medical applications.



**Figure 2.5 BCI System**

One of the scope of this study is to go beyond further to the non-medical applications of the BCI. Researchers have been investigating with the use of BCI as a hands-free application/technology. The problems encountered reduces the commands of the user that restricts the utilization of the BCI. Problems have been stated below that up till now, researchers are having a hard time to solve this existing problem with the BCI:

Usability challenges

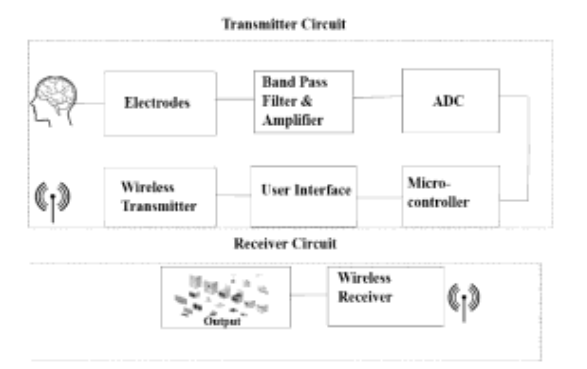
Usability of the devices makes it so limited to a certain person that has undergone an extensive training. Thus, makes transferability of the device is inevitable.

 Information transfer rate

Information transfer rate focuses on the number of instructions that the BCI can offer to an individual. It also goes further in to the accuracy of selection and the average time of it.

**2.2.5. Using Brain Computer Interface for Home Automation [42]**

Home automation was developed by these researchers that involved the communication of the brain and the home appliances etc. Simply, the project made was an EEG automated home system. They integrated it by having a BCI that serves as a pathway between the brain and the technologies inside the house. The research considered only alpha, beta and theta waves from the brain. The reason of this study is to minimize the physical efforts exerted by a person and become helpful for a disabled person. The system has four stages: Detecting the brainwaves using EEG cap, Amplify brain signals and remove noise, convert these signals and send it to a computer/microcontroller that can decode the signal which will trigger the automation of the switch of a certain appliance inside a house.



**Figure 2.6 System Design**

The study has two main parts of the system, namely the electrodes and amplitude circuit. Stated below are the detailed functionality of each stage.

1. Electrodes

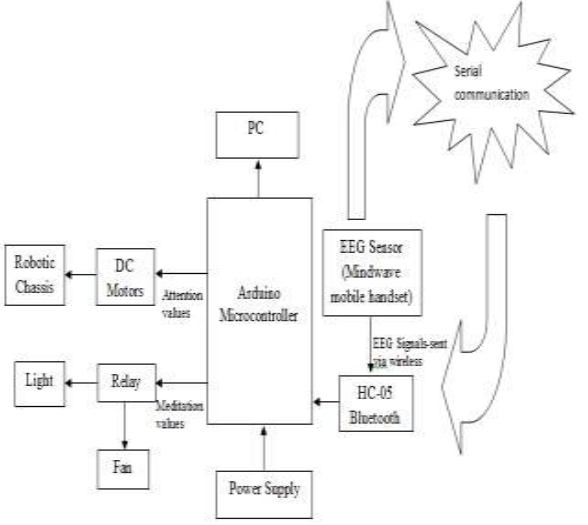
Non-invasive scalp sensors were used to measure the electrical activity of the brain. The motor cortex area and other particular areas of the brain are placed with specific electrodes that will determine the brain signals and activities.

1. Amplitude and filter circuit

Brain signals read by the sensors are very low in voltage and has unwanted noise. Amplifier and filter circuits are need to get a more sensible signals that has been amplified and filtered out noise.

**2.2.6. EEG-Based Brain Controlled Robo and Home Appliances [40]**

The researchers conducted a study and made a project about EEG. They came up with the idea of using the data gathered from the brain using the EEG, automation of robotic and home appliances is possible. They have included a BCI also in their project. This is to translate the brain activity into digital form which can be performed now by the computer. Neurosky technology was also used. eSense, an algorithm developed by Neurosky, was used to determine mental states gathered from the brain activity of a certain person. The ThinkGear mindwave was used to fetch the user’s brainwave activities and signals. It is also capable of removing muscle movements and atmosphere noise. The brainwaves gathered from the ThinkGear are now transmitted to the Microcontroller that will perform the certain control. The attention level of the brain was used for the robotic and the meditation level of the brain was used for the home appliances. The purpose of the study is to allow paralyzed people to control in their home which in lines with robotics and electronic home appliances.



**Figure 2.7 Block Diagram**

There are two different implementation used in presenting this project, namely the Robotic Arm and the home automation with the integration of IOT (Internet of Things). Brain-Computer Interface is a system that interconnects the user’s commands through the EEG and the computer. The EEG sensor gathers signals and data from the brain using Mindwave mobile handset. The specific values of the signals appear on the computer application. Then it will be loaded onto the microcontroller for the automation and movement of the outputs. There are only 2 values were used to manipulate the system, Attention values are for the operation of the Robotic Arm and Meditation values are for the control of the home automation.

**2.2.7. Feasibility of BCI Control in a Realistic Smart Home Environment [29]**

Imagine you could control everything with your mind. Brain Computer Interfaces (BCIs) make this possible by measuring your brain activity and allowing you to issue commands to a computer system by modulating your brain activity. BCIs can be used in many applications: medical applications to control wheel chairs or prosthetics or to enable disabled people to communicate and write text; general public applications to control toys, video games or computer applications in general. One of the more recent fields of applications of BCIs are smart homes and the control of their appliances. Smart homes allow the automation and adaptation of a household to its inhabitants. In the state of the art of BCIs applied to smart home control, only younger healthy subjects are considered and the smart home is often a prototype (single room or appliance). BCIs have never been applied and evaluated with potential end-users in realistic conditions. However, smart homes are of the interest to disabled people or to elderly people with mobility impairments who are able to operate appliances within the house autonomously) Studies on disabled users are just as rare as studies in realistic smart homes (with healthy subjects or otherwise). However, the expectations and needs of healthy subjects are biased, as they cannot fully conceive of the difficulties of disabled people and thus of their needs, so performing experiments both with healthy and disabled subjects is of interest for smart home research.

The purpose of the work is to evaluate the feasibility of BCI control in three steps:

Evaluate the feasibility of BCI control in a realistic smart-home environment in a state of the art setting on healthy subjects as an extrapolation of the potential results for disabled subjects. We propose an appliance control (toggle—light, TV, water kettle, shutters) scenario that allows us to evaluate task accuracy and performance. Then, we administer a usability (USE) questionnaire:

a. Usefulness

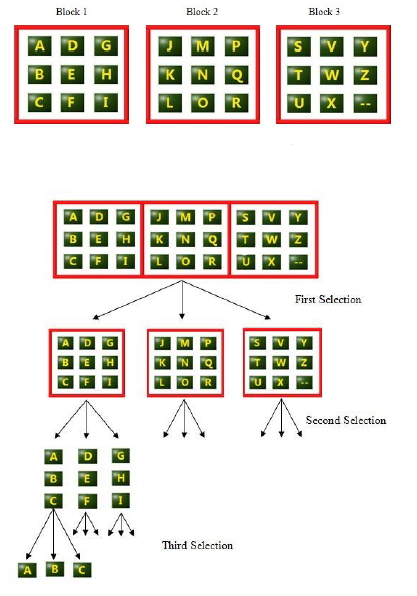
b. Ease of use

c. Ease of learning

d. Satisfaction

**2.2.8. Virtual Keyboard BCI using eye blinks in EEG [41]**

The study focused on creating a BCI system that can use EEG as a control in a Virual Keyboard. The virtual keyboard is made using Labview application. The signal that they used was eyeblinks signals that can search through the virtual keyboard. Eye blinks became the selection signal that the EEG transmits into the computer. The used the kurtosis coefficient and amplitude characteristics of the eye blink to detect the certain signals that they need to translate into a command.



**Figure 2.8 Selection scheme of the Virtual Keyboard**

The researchers applied the method of dividing the virtual keyboard into blocks so that selection of specific characters will be much easier for the user. They also included time interval each time you select a character, in this way, eye blinks are dependent to what time where the selection will be held.

**2.3 Foreign Literature**

**2.3.1. NeuroSky Mindwave [34]**

The NeuroSky Brainwave is often use for researches due to its availability in the market and the cheap price. Brainwaves are tiny electrical impulses released when a neuron fires in the brain. NeuroSky’s brain-computer interface (BCI) technology works by monitoring these electrical impulses with a forehead sensor. These neural signals are input into our ThinkGear chip, and interpreted with our patented Attention and Meditation algorithms. The measured electrical signals and calculated interpretations are then output as digital messages to the computer, toy, or mobile device, allowing you to see your brainwaves on the screen, or use your brainwaves to affect the device’s behavior.

**2.3.2. Electroencephalogram (EEG) [35]**

An Electroencephalogram or EEG is a test that senses irregularities in the brain waves, or in the electrical activity of your brain. During the process, electrodes containing of small metal discs with thin wires are fixed onto the scalp. The electrodes sense tiny electrical charges that result from the activity of your brain cells. The charges are amplified and appear as a graph on a computer screen, or as a recording that may be printed out on paper. Your healthcare provider then interprets the reading.

**2.3.3. Home automation [37]**

Home automation was a term first used in the mid-80s, during the boom of ‘domotics’, when we found the development of advanced electronic systems that empowered automating –hence the name- special house features. The view, however popular, never reached the mass market, largely for financial reasons, since both facility and care were fairly costly. More than two decades have had to go by before technology could finally catch up with the idea and make it a reality.

Now’s home automation, however, has little to do with its forerunner. It came to life in the consequences of another groundbreaking theory: the ‘Internet of Items’, which signified the beginning of a brand-new age in technology. The coming of the Internet of Things –or IoT- has enabled the development of extremely straightforward to install, fully wireless home automation systems that can be managed from the other side of the world simply using a smartphone, something which was unthinkable back in the early years of domotics. But the real game-changer for the sector is that now those technologies are eventually affordable and so attainable for the mass market.

**2.3.4 Smart Home [37]**

The term ‘smart home‘ has its beginnings in home automation, but it is a much broader concept that encompasses a larger assortment of features, technologies, and businesses, all of them joined and related to each other through the IoT. We can, therefore, say that modern home automation is the enabler of the smart house, a new whole joined-living theory that not only empowers users to monitor and control their houses from a cellular telephone application but also manage their home security, provide remote health care for elderly relatives or even save energy, which will be to mention merely several features, since when speaking of smart home technologies, where everything’s interconnected, the odds are boundless.

**2.3.5 Brain Computer Interface [38]**

A brain computer interface, also known as mind-machine interface, is a direct communication interface between an external device and the brain, bypassing the need for an embodiment. The signal directly goes from the brain to the computer, rather than going from the brain through the neuromuscular system to the finger on a mouse.

Brain interface devices used these days require deliberate conscious thought, while prospective future applications are expected to work effortlessly. Present research is focused on non-invasive BCI, unlike the traditional BCI model that requires implanting a mechanical device in the brain, which then tends to control it as a natural part of the body.

BCIs are directed at augmenting, assisting, or repairing sensory-motor or human cognitive functions. It combines technologies from the fields of electrical engineering, computer science, biomedical engineering, and neurosurgery.

**2.3.6. Intraclass Correlation [39]**

Intraclass correlation measures the reliability of ratings or measurements for clusters — data that has been collected as groups or sorted into groups. A related term is interclass correlation, which is usually another name for Pearson correlation (other statistics can be used, like Cohen’s kappa, but this is rare). Pearson’s is usually used for inter-rater reliability when you only have one or two meaningful pairs from one or two raters. For more, you’ll want to use the ICC. Like most correlation coefficients, the ICC ranges from 0 to 1.

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**APPENDIX A**

**OCFM TABLE**

**Appendix A**

**OCFM Table**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Characteristic** | **Objectives** | **Constraints** | **Functions** | **Means** |
| **Create an effective BCI system** | **X** |  |  |  |
| **Create a transferable BCI system** | **X** |  |  |  |
| **To design a reliable BCI system** | **X** |  |  |  |
| **Commercially unavailable Non-Invasive EEG** |  | **X** |  | **X** |
| **Wireless transfer of brain signal** |  | **X** |  |  |
| **Signal Processing** |  |  |  | **X** |
| **Signal Classification** |  |  |  | **X** |
| **Control of menu** |  |  | **X** |  |
| **Home Automation** |  |  | **X** |  |

**APPENDIX B**

**MINUTES OF THE MEETING**

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**ASIA PACIFIC COLLEGE**

**SCHOOL OF ENGINEERING**

**COMPUTER ENGINEERING**

**SY 2017-2018, TERM 3**

**Minutes of the Meeting**

**Electroencephalogram (EEG)**

**Date**: February 03, 2018  
**Time** **Start**: 03:24 PM   
**Time** **End**: 03:46 PM  
**Venue**: 8th floor, Room 806

**Group Members**:

Bundoc, Ferdinand Lance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Fernandez, Patrick Justin \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Ingo, Dayle \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Morales, Eris \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Adviser**:

Engr. Sergio Peruda \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Agenda**:

* **Pre-approved Topic (EGG)**

**Topic:**

* EGG was released from the public (2010/2012)
* Scholars can use EEG from 2010/2012 up till now
* From 2010 – current year, 7 signals can be sensed but 3 can only be used.

Those 3 are:

* + - * Focus
      * Meditation
      * Eye Blinking
* Emotions are now being also used lately in EEG.
* There are now studies about emotions that test the stress level of a certain person.
* Focus on EEG and exploit the resources then innovate.
* Pair up EEG with another technology but EEG must be primary not a secondary technology.
* Use the commercially marketed EEG devices.
* EEG controlled Robot with 3 controls.
* Prove the output of the topic.
* Limit the project into what it can only do and prove that it really can.
* Use non-invasive with training mode EEG.
* Must be a solution to a societal need.
* Limit the cost of the project.
* Brain to Brain communication that can send 2 words as a building block.
* Signal of brain has a small voltage that can be easily interrupted by noise.
* Focus on only one specific output/topic.

**Tasks for next meeting:**

* Figure out the purpose of the study
* Focus on answering “What and why”.
* Problem Definition (Draft)
* Critique Paper related to EEG (20 papers)
* Powerpoint presentation to be presented in class next meeting.

****

**ASIA PACIFIC COLLEGE**

**SCHOOL OF ENGINEERING**

**COMPUTER ENGINEERING**

**SY 2017-2018, TERM 3**

**Minutes of the Meeting**

**Electroencephalogram (EEG)**

**Date**: February 05, 2018  
**Time** **Start**: 04:34 PM   
**Time** **End**: 05:06 PM  
**Venue**: 8th floor, Room 806

**Group Members**:

Bundoc, Ferdinand Lance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Fernandez, Patrick Justin \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Ingo, Dayle \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Morales, Eris \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Adviser**:

Engr. Sergio Peruda \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Agenda**:

* **Problem Statement**
* **Finalization of Topic**

**Problem Statement:**

* Check recommendation of other study to formulate problem.
* Don’t rely on already produced technologies on EEG.
* Think of something new about EEG that can solve a certain problem.

**Topic:**

* Brain to brain communication
  + - EGG based with a middle ground device that will send to the other EEG.
    - Words are outputted through earphones
    - Problem – No brain to brain communication yet.
    - 10 words only
* Mind controlled robots
  + - Has all the same conceptual design – nothing new.
    - Only different outputs

**Tasks for next meeting:**

* Print out a study and create project definition
* Identify objective (Since no client)
* 5 paper published (for problem statement)
* 5 paper published (for recommendation)

**Recommendation of software**

* Labview



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**SY 2017-2018, TERM 3**

**Minutes of the Meeting**

**Electroencephalogram (EEG)**

**Date**: February 05, 2018  
**Time** **Start**: 03:27 PM   
**Time** **End**: 04:17 PM  
**Venue**: 4th floor, Faculty Center

**Group Members**:

Bondoc, Ferdinand Lance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Fernandez, Patrick Justin \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Ingo, Dayle \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Morales, Eris \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Adviser**:

Engr. Sergio Peruda \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Agenda**:

* General Objectives
* Specific Objectives
* Topic
* Problem Statement
* Metrics
* Constraints
* Scope and Delimitations
* Significance of The Study
* Chapter 2 (RRL)

**Problem& Topic:**

* Accuracy of Data
* Accuracy rating ranges from 80% to 99% (Humanoid Robot)
* No problem in accuracy rating
* Maximum controls of the Humanoid robot are 3.
* EEG as a control device
* Problems in EEG is different from problems using EEG.
* Problems in EEG = create an own EEG device
* Focus on problems using EEG.
* Maximization of the 3 controls.
* 1 control = 1 signal of the brain.
* “Menu” selection process using 3 signals
* Software based to enhance the number of controls
* Limited number of controls
* Training mode is long enough to process.
* EEG is brain specific.
* With only limited number of control, training time will decrease and will be easy to learn.

**Objectives**

**General Objective**

* To develop a module that can receive and interpret signals from the brain using a non-invasive EEG.

**Specific Objectives**

* Increase throughput
* Increase transferability
* Reliable system

**Metrics**

* Number of controls
* Number of users
* Maintenance of the signal accuracy

**Constraints**

* Utilize a commercially/own-designed EEG device
* Non-invasive
* Wireless transmission of brain signal

**Title**

* Development of a Multi-Command Control Module for Brain Computer Interface using Non-Invasive Electroencephalogram (EEG)

**Scope and Delimitations**

* + Coverage of the study
  + Set the boundaries/ the system can do but decided not to do.
  + A chance that the system to fail.

**Significance of the Study**

* + Must start with the Direct beneficiary
  + Academe, Community, Future Researchers

**Video Pitch**

* Not exceeding/below 3 mins
* Video pitch about the topic/study

**Chapter 2**

* All stated in problem, objectives, metrics and scope must be reflected.
* Supporting studies based on research
* Must also be supportive to the Chapter 1.

**Tasks Next Meeting:**

* Draft Chapter 1
* Introduction
  + - * Introduce Technology
      * EEG
      * BCI
      * Existing Technologies
      * Problem Statement
      * General Statement (Solution)