Design and Implementation of EEG Based Home Appliance Control System

Conference Paper · April 2021

DOI: 10.1109/ICICT4SD50815.2021.9396982

4 authors:

Tafhim Bin Nasir
Islamic University of Technology

Md. Abdul Mukit Lalin
American International University-Bangladesh

Niaz Kabir
American International University-Bangladesh

Md Razaul Karim
Bangladesh Agricultural University

2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD), 27-28 February, Dhaka

Design and Implementation of EEG Based Home Appliance Control System

Tafhim Bin Nasir [1], Md. Abdul Mukit Lalin [2], Kabir Niaz [3], Md. Razaul Karim [4]
Department of Electrical & Electronic Engineering (EEE)
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
[1]tafhimbinnasir@gmail.com, [2]abdul.mukit.lalin@gmail.com, [3]niazkabirenan@gmail.com ,
[4]razaul.rupok@gmail.com

***Abstract*— This paper represents the design and implementation of the Home Appliance control system using the Human brain wave. Brain-computer interfacing (BCI) technology is followed for developing the system. Neurosky Mindwave Mobile 2 headset is used for collecting the desired brain data. This headset collects brain data and sends the data wirelessly to the main PCB circuit board using a Bluetooth module. The headset gives the output of attention level and number of eye blink based on EEG waves. According to the attention level and eye blinks, the system controlled Light, Fan, TV, Buzzer. This system has two controlling modes with four different attention levels. In the first mode, the system can control light, fan, television, and buzzer. In this mode, the user can only power on or Power off these Appliances. Whereas in the second mode, the system can control television volume and channel. This system is mainly designed to help Physically Challenged People who can not move their body parts and are incompetent in speaking. Simplicity in design architecture and cost-effectiveness makes this system very much applicable in real-life usage.**

Keywords— Brain, Double Eye Blink, EEG, BCI, Neurosky Brain Wave, Attention Level, Home Automation

I. INTRODUCTION

According to the world health organization, it is observed that almost one billion or 15% of the world population experience some form of physical disability. Moreover, this rate is higher for developing countries, which is very alarming [1]. Out of this number, a significant portion is thoroughly unfit to do any physical movement. These physically disabled people face difficulties in meeting the demand of the present world. For this, in the recent past, a vast amount of research work has been gone through to aid physically disabled people so that they could survive this competitive modern world. Among these several research, Brain-Computer Interface technology (BCI) is one of the major options to get out of these difficulties.

The principal methodology of Brain-Computer Interface technology (BCI) is to use brain activity to control an external device [2]. A human brain contains approximately 100 billion neurons [3]. In our activity, behavior, and thinking, these neuron masses are always communicating with each other, which results in electrical pulses. Brain waves are produced by these electrical pulses generated in neurons [4]. Brain-Computer Interface (BCI) technology uses these electrical pulses to control external devices and other things.

Brain wave data could be acquired from the brain using the electrode. With the usage of the electrode, Invasive and Non-Invasive are the two varieties of brain wave techniques present in the current time. In the Invasive technique, Sensor electrodes are placed into the brain in which a surgical operation is needed at the implementation time. Whereas, in the Non-invasive type, the electrode is placed over the scalp area, which means there is no need for surgical operation [5]. Non-invasive is a technique with less amount of risk and very cost-effective for practical implementation [5].

Brain wave activity or electroencephalogram (EEG) is relatively small and always measured in microvolts [6]. EEG signal frequency varies according to the human's mental condition. For this, the EEG signal is classified with different brand frequency. Infra-Low wave (<.5 Hz) [4], Delta wave (0.5-3Hz), theta wave (3-8 Hz), alpha wave (8-12 Hz), beta wave (12-38 Hz), gamma wave (38- 42 Hz) are main frequencies of human EEG wave [6]. Delta wave and theta wave are usually generated at dreamless sleep and the most profound meditation [4]. Alpha wave is generated when the human brain is quietly following the thought of thinking or calculating anything [4]. Beta brain wave shows dominance when human is in regular activities such as busy in some task, problem-solving, judgment, focused on mental activity. Beta brain wave has been divided into three bands. Low Beta (12-15 Hz), Midrange Beta (15-22 Hz), High Beta (22-38 Hz) are the classification of beta waves [4].

This paper is all about showing the new procedure of designing and implementation of brain wave controlled Home Appliance control system. Brain data is acquired using the non-invasive type technique. NeuroSky Mind wave Mobile 2 headset is used in acquiring EEG data. The overall design of this system architecture is unique compare to other related research works. This work would be beneficial for physically disabled people in controlling different types of the domestic appliances.

II. LITERATURE REVIEW

A lot of research work has gone through based on Brain-Computer Interface technology. Not only that, previously, a significant amount of research work is accomplished based on the Home Appliance control system. In some paper, the devices are controlled based on the voice of human [7] whereas, in some paper, it is seen that devices are controlled using IOT technique [8]. Here, in this paper, the devices are controlled by the brain wave. Brain data is also could be acquired by different EEG headsets. According to the selection of the EEG headset, the overall control algorithm varies. Here in this work, the system architecture is designed keeping in mind of using the NeuroSky headset module.

III. SYSTEM DESIGN

A. NeuroSky Headset

The brain data is acquired with NeuroSky Mindwave Mobile 2 headset. At the time of controlling the Home Appliance, this headset has to be placed on the user's head. This headset has an EEG electrode, which is placed inside the sensor arm. This EEG electrode acquires all kinds of raw EEG data from brain activity. Also, this headset has an ear clip-on left side. This ear clip is used as ground or references [9].

Fig. 1. NeuroSky MindWave headset module

The EEG electrode is placed on the Fp1 position according to the 10-20 system positioning of the electrode method [10]. Whereas the ear clip consists of grounding and the reference sensor, it is placed in the A1 position. This module has to be powered up with a AAA battery [9].

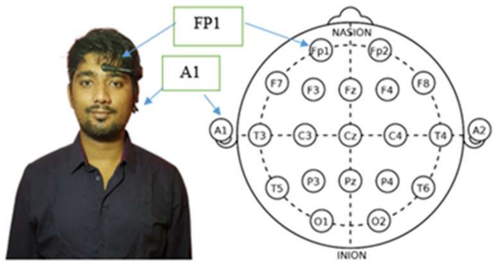

Fig. 2. Positioning Electrode According to the human head

This headset can give the output of the human's brain's attention and meditation level with the eSense meter [9]. The eSense meter gives the output of attention and meditation by calculating a wide spectrum of brain waves in frequency and time domain. It is seen that the attention level, which is used in this system, has shown more significance on the beta wave of the human brain [11].

The NeuroSky headset uses a TGAM1 module for processing brain signals. TGAM1 chip has an integrated configuration pad, which is used to change the default settings. Baud rate and data content are the two types of default settings that can be changed. A configuration pad is placed on the backside of the TGAM1 chip. Gradually B0 and B1 are used for baud rate and data content, whereas M pad is used to configure the notch filter frequency [12].

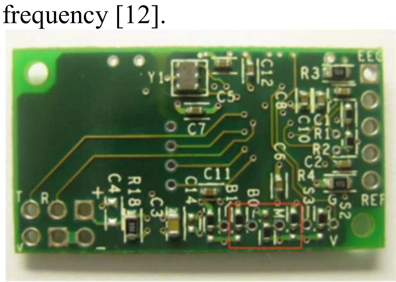

Fig. 3. Image of showing a side view of NeuroSky EEG chip TGAM1 [12]

TGAM1 chip is consists of one processor and many filters. These filters are used for filtering noise from the acquired sample signal and separate different brain wave types. When an EEG signal from the brain comes into the TGAM1 chip, it is filtered by a low pass filter for separating all the wave signals with more than 100Hz frequency [13]. Extra wave signal of frequency 50Hz or 60Hz is removed according to the M pin configuration. By this, the range of signal frequency comes between 0.3 Hz to 100 Hz [13]. This time filter would divide the sample according to different brain wave types. Finally, this signal is sampled with 512 Hz and sent to ADC with the 12-bit resolution. It is possible to get digital values for each brain wave type using this ADC [5]. For many digital values in a single brain wave, the processor has calculated power Fast Fourier Transformation. With a configuration pin, the processor gives digital FFT values for each brain wave serially [13]. The baud rate is by default set at 9600 with the expected output in this process [13]. The NeuroSky headset follows the ThinkGear Communication Protocol. It provides data values as ThinkGear Packets from a ThinkGear module to an arbitrary receiver. By using some hex code, the brain data can be extracted from this packet [12].

B. Attention level calculation

The EEG data acquired from the brain is sampled at a sampling rate of 512 Hz. A Fast Fourier Transform (FFT) technique is followed for transforming a segment with 512 sampling points to the frequency domain. Two hundred fifty-six points are overlapped with the previous segment for sliding the segment. Presuming, F(n) is the Fast Fourier Transform the result of a segment where n =1,2,3, 4……...512; then the equation of Power Spectral Density (PSD) is:

$$P(n) = \frac{F(n)F*(n)}{N} \tag{1}$$

Here, the value of N is 512 and F*(n) represents the conjugate function of F(n).

By following the EEG signal waveband distribution, the energy value of different brain waves is assumed. However, according to research [14], it is proved that α, β, δ, θ are the four main types of brain wave which is most related to human mental states [14]. The features can be defined as follows:

$$E_{\alpha} = \sum_{8}^{13} P_{freq} \tag{2}$$

$$E_{\beta} = \sum_{14}^{30} P_{freq} \tag{3}$$

$$E_{\theta} = \sum_{4}^{7} P_{freq} \tag{4}$$

$$E_{\delta} = \sum_{0.5}^{3} P_{freq} \tag{5}$$

Moreover, according to previous research, it is found that there exists an interrelation between α and β waves. The ratio between this α and β wave is used to extract and find mental attentiveness [14]. The equation for assessing the level of mental attentiveness is:

$$R = \frac{E_{\alpha}}{E_{\beta}} \tag{6}$$

Where, R indicates feature for determining whether user is attentive.

C. BlueSMiRF Module

BlueSMiRF module is followed serial communication method for sending and receiving data. In the time of sending and receiving data, this module act as a data pipeline [15]. This module has TX and RX pin. Serial data that goes into the module is received by RX pin, whereas data coming in from Bluetooth is passed out by TX pin [15]. Two steps process has to be followed for establishing data pipeline.

Fig. 4. BlueSMiRF module

Firstly, it is essential to connect something for sending and receiving header data to the Bluetooth modem. Connecting Arduino or any microcontroller with UART could be a solution for this. Baud rate is needed to be configured so that it can work at the same rate. The default baud rate is set in this module is 115200 bps [15]. By configuring the baud rate, any serial stream from 2400 to 115200bps can be passed seamlessly from this module to other targets [16]. Finally, the BlueSMiRF module is needed to establish a wireless connection with another Bluetooth device [15].

D. Block Diagram

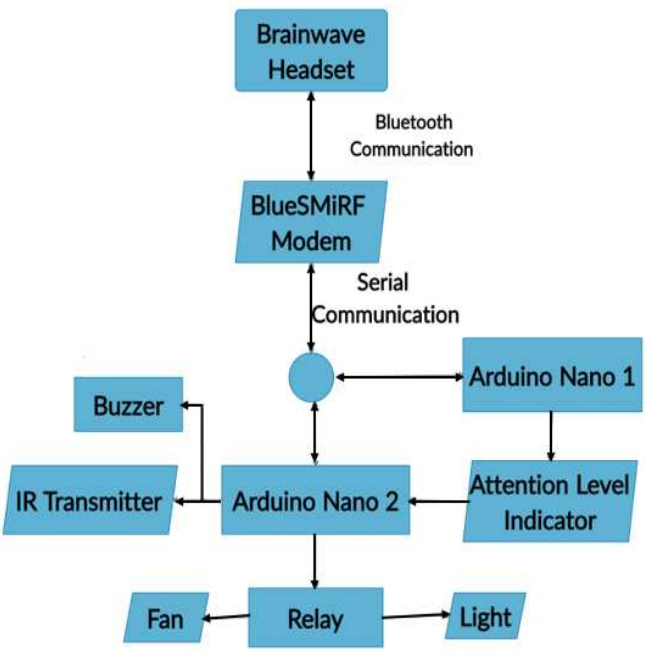

Fig. 5. Block diagram

E. Flow chart

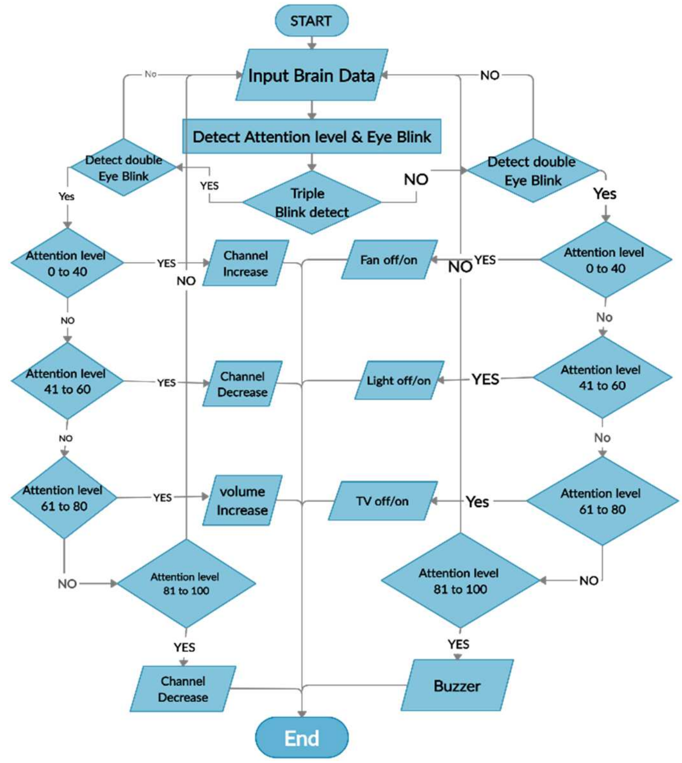

Fig. 6. Flow Chart

F. Schematic view

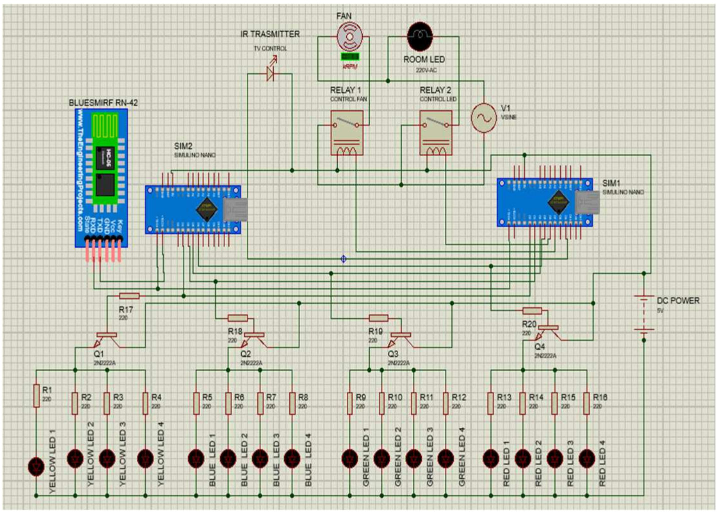

Fig. 7. Schematic view

IV. HARDWARE IMPLEMENTATION

A. Overall Hardware Implementation and working

At the time of giving the command to the main system architecture, the user is needed to wear the NeuroSky headset with proper placement. The power button of the headset is needed to be ON mode while working. Then it sends data to the main PCB via Bluetooth. BlueSMiRF module is connected with both Arduino Nano. The receiver RX pin of both Arduino is connected parallelly with the TX pin of the BlueSMiRF module. In the meantime, the RX pin of the Bluetooth module is only connected with the First Arduino

Nano TX pin. Four sets of attention level indicator LED are placed parallelly with the BJT transistor.

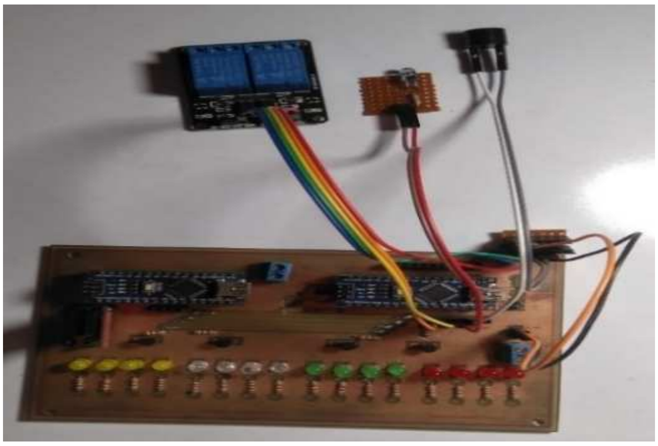

Fig. 8. Hardware View

Here, BJT transistors are used for switching purposes. All four sets of LED blinks, according to the human attention level measured by the NeuroSky headset. Each Arduino Nano is powered up with a 5V DC battery. First, Arduino Nano detects the attention level and controls attention level indicator LEDs. It also sends the attention level data to the second Arduino Nano. Second Arduino Nano receives data sent by the first Arduino Nano and detects the number of eyeblinks. According to the number of eyeblinks and attention level, this Arduino controls the Home Appliances used in this work. In the domestic load portion, the system can control light, fan, television, and buzzer. Both light and fan are controlled with relay, whereas television is controlled with an IR transmitter.

B. Algorithm

This system has two modes of control. It can interchange the modes by detecting the number of eye blinks. One control mode is the load ON/OFF mode, where the system can control the load's power. Then the other one is the television volume and channel control mode. In this mode, the system can increase or decrease volume and change the television channel. The condition for mode control is given below:

TABLE I. CONDITION FOR MODE CONTROL

Number of Eye Blink	LED Indicator	Control Mode
3	Green	Load on/off
	Blue	Television Control

If the system control mode belongs to the Load on/off portion, then it can control light, fan, television, and buzzer either OFF to ON state or vice versa. For this, the user is needed to reach a predefined level of attention, and then with a double eye blink, the control could be done. Here, a double eye blink is used for the triggering purpose. The condition for load control is given below:

TABLE II. CONDITION FOR LOAD CONTROL

Attention Level	Number of Eye Blink	LED Indicator	Types of Load control (ON/OFF)
0-40	2	YELLOW	Light
41-60		BLUE	Fan
61-80		GREEN	Television
81-100		RED	Buzzer

The second mode's algorithm and working principle are quite the same compared to the first control mode. The condition for controlling television is given below:

TABLE III. CONDITION FOR TELEVISION CONTROL

Attention Level	Number of Eye Blink	LED Indicator	Controlling Television Menu
0-40	2	YELLOW	Volume increase
41-60		BLUE	Volume Decrease
61-80		GREEN	Channel up
81-100		RED	Channel down

V. RESULT AND ANALYSIS

A. Analytical Result

This system is designed and controlled based on EEG. So, before implementing the overall system, it is imperative to know whether the used headset gives the desired output or not. The headset gives the attention value based on EEG wave, which is ranged between 0 to 100. Also, the headset could measure the level of blink strength. According to this level of blink strength, it counts the number of an eye blink. Before implanting the overall system, the output of attention and eyeblink is analyzed in MATLAB, which helps to understand the output wave shape of EEG and create an algorithm.

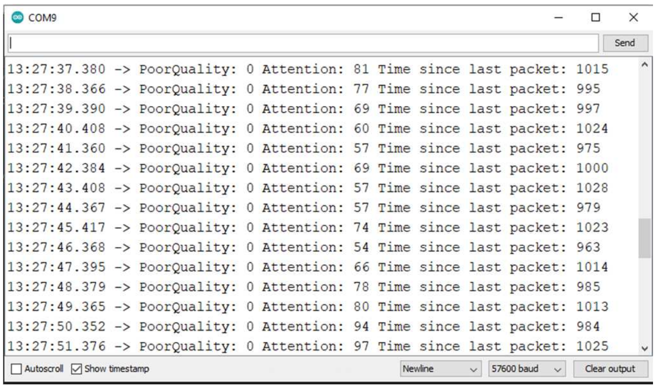

Fig. 9. Measuring Attention level

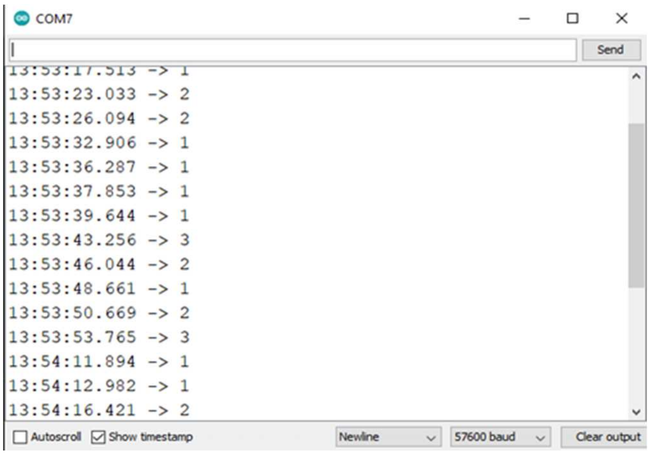

Fig. 10. Measuring number of Eyeblinks

B. Practical Testing Result

After implementing the overall system, some practical testing is done to check the overall standard of the system. This system is successfully able to control light, fan and

Television. In the controlling Television portion, the practical test is successful in increasing or decreasing volume and changing TV channels.

Fig. 11. Practical test result of controlling TV and LED Bulb

C. Overall Accuracy

A practical test is made, which is consists of four members. According to that test, an overall accuracy analysis is made. In result, it is seen that most of the time, the system is successfully able to control the Home Appliance. In number, the overall accuracy rate of the system is 90.67%. The overall accuracy of the system is given in the following table:

TABLE IV. ACCURACY ANALYSIS

USER	Total number of applied commands	Percentage of Accuracy			
		Light Control	Fan Control	TV Control	Overall Accuracy
1	60	90%	92%	90%	90.67%
2	60	94%	93%	96%	
3	60	96%	87%	89%	
4	60	88%	90%	94%	
5	60	91%	89%	90%	
6	60	92%	84%	87%	
Accuracy		91.83%	89.17%	91%	

VI. CONCLUSION

This paper represents the way to design and implement an EEG based Home Appliance control system. The main focus in designing this system is to make is very much simple in use and cost-effective in implementation. In doing this, EEG data has been acquired with the help of a non-invasive brain wave acquisition headset. EEG data is used to create the control range of different load, whereas Eye Blinks is used for triggering. The main focus of this paper is to use the brain signal to control different types of domestic home appliance. This concept reduces the amount of physical movement to control those Home Appliances. This system eventually helps people who are physically disabled or reluctant to do any physical movement in controlling the Home Appliance.

Currently, this paper represents the course of action to control a light, television and fan. However, in future, this system has the capability of upgrading the considerable number of a load. As this system is designed mainly focusing on physically disable people so it might be pervasive that they are badly in need of the help of others in some cases.

REFERENCES

[1] WORLDBANK, “DISABILITY INCLUSION”, May 15, 2020, Accessed on: July 10, 2020. [Online]. Available: https://www.worldbank.org/en/topic/disability

[2] Chaudhary, U.; Birbaumer, N.; Ramos-Murguialday, A. Brain–computer interfaces for communication andrehabilitation.Nat. Rev. Neurol.2016,12, 513–525

[3] K. Cherry, “Comparing the Amount of Neurons in Human and Different Animal Brains,”*Verywell Mind*. Accessed on: July 15, 2020. [Online]. Available: https://www.verywellmind.com/how-many-neurons-are-in-the-brain-2794889.

[4] What are Brainwaves?,” *What are Brainwaves ? Types of Brain waves | EEG sensor and brain wave – UK*. Accessed on: December 3, 2020.[Online]. Available: https://brainworksneurotherapy.com/what-are-brainwaves.

[5] A. A. Ghodake and S. D. Shelke, "Brain controlled home automation system," 2016 10th International Conference on Intelligent Systems and Control (ISCO), Coimbatore, 2016, pp. 1-4, doi: 10.1109/ISCO.2016.7727050.

[6] Bhat, Deeksha Seetharama, “Assessing Performance of Detectors of High Frequency Oscillations in EEG Signals,” Ph.D. dissertation, University of Texas at El Paso, 2018.

[7] N. bt Aripin and M. B. Othman, "Voice control of home appliances using Android," *2014 Electrical Power, Electronics, Communicatons, Control and Informatics Seminar (EECCIS),* Malang, 2014, pp. 142-146, doi: 10.1109/EECCIS.2014.7003735.

[8] S. Dey, A. Roy and S. Das, "Home automation using Internet of Thing," *2016 IEEE 7th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, New York, NY, 2016, pp. 1-6, doi: 10.1109/UEMCON.2016.7777826.

[9] NeuroSky, “NeuroSky Store, NeuroSky Mindwave Mobile 2” Accessed on: September 21, 2020. [Online]. Available: https://store.neurosky.com/pages/mindwave

[10] “Neuro Science for Kids, 10-20 system of electrode Placements” Retrieved From: https://faculty.washington.edu/chudler/1020.html

[11] NeuroSky, "What is eSense," NeuroSky, September 21, 2020. [Online]. Available: NeuroSky http://support.neurosky.com/kb/science/what-is-esense/ [Accessed September 21, 2020]

[12] NeuroSky, “TGAM1 Spec Sheet” March 24, 2010, Accessed on: Sept.16, 2020. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Biometric/tgam1.pdf

[13] “Understanding NeuroSky EEG Chip in Detail” Accessed on: September 21, 2020. [Online]. Available: https://www.engineersgarage.com/tutorials/understanding-neurosky-eeg-chip-in-detail-part-2-13/

[14] Liu, N.H., Chiang, C.Y. and Chu, H.C., 2013. Recognizing the degree of human attention using EEG signals from mobile sensors. Sensors, 13(8), pp.10273-10286

[15] Using the BlueSMiRF. Accessed on: September 21, 2020. [Online]. Available: https://learn.sparkfun.com/tutorials/using-the-bluesmirf/firmware-overview.

[16] “SparkFun Bluetooth Modem - BlueSMiRF Silver,” WRL-12577 - SparkFun Electronics. [Online]. Available: https://www.sparkfun.com/products/12577. [Accessed: 05-Dec-2020].