EEG-Based Brain Controlled Robo and Home Appliances

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Abstract - *Brain Computer Interface (BCI) systems are the tools which are proposed to help the damaged people who are impotent of making a motor response to interface with a computer using brain signal. The aim of BCI is to translate brain activity into digital form which performs as a command for a computer. The BCI application can be used in different areas like Education, Industrial, Gaming and Medical areas. In my project, EEG-based Brain controlled Robotic, and Home automation using IOT has been developed using BCI with the help of NeuroSky technology. eSense is a NeuroSky's quick fix algorithm for distinguishing mental states. The ThinkGear technology in NeuroSky mindwave headset fetches out the user brainwave signal and removes the muscle movement and atmosphere noise. For the remaining signals, the eSense algorithm is then appealed, which results in the elucidated eSense meter values. The fetched brain signals are transmitted to the Microcontroller via HC-05 Bluetooth module. The robotic module designed consists of Arduino Microprocessor coupled with DC motor to perform the control. The attention level was used to monitor the direction of the robotic and meditation level was used to monitor the home appliances using IOT. The wireless BCI system could allow the paralyzed people to control their robotic and home appliances without any difficulty, provided it is more increased, portable and wearable.*

Keywords — *Brain Computer Interface, EEG, eSense Technique, Robotic, home Appliances.*

I. INTRODUCTION

Now a day, humans have fantasized to communicate and interact with machines through the thoughts and also create devices that work with human's mind and thoughts. The human mind imagination is captured in the form of modern science fiction stories and ancient myths. However, cognitive neuroscience and brain imaging technologies have recently started to provide people with the ability to interface with the human brain. Using sensors some of the physical activity that occurs within the brain that corresponds with forms of thought can be monitored.

For the needs of people in growing societal recognition on, researchers have used this technology to build brain computer interfaces (BCIs), communication systems, i.e., a computer system that does not depend on peripheral muscles and nerves of the brains.

Brain–Computer Interface (BCI) is used to build a direct control channel between user's brain, i.e., user's intension and computer system. Such a system can help two kinds of people, first people who have damage in their physical system to recover their activities with a wheelchair, or control over a neuroprosthesis or a robot and so on. Second, for healthy people, it could be an additional man–machine interface, which is able to increase the productivity and the efficiency in high-throughput tasks.

Among different techniques for the non-invasive measurement of electrophysiological signals of brain oscillations, the electroencephalography (EEG) is commercially used and has excellent results, which enables real time interaction through Brain Computer Interface (BCI) [7].

Electroencephalography (EEG) refers to an electrophysiological monitoring method which will record the electrical activity which is occurring at the surface of the brain using electrodes/sensors placing on the scalp of the brain. EEG measures electrical signals from the brain in voltage fluctuations currently occurring within the neurons of the brain. This action, in turn, will appear on the screen of the computer which in turn connected to electrodes implanted in the brain as waveforms of varying amplitude and frequency measured in voltage or as digital values.

EEG waveforms are categorized in accordance to their amplitude, shape, frequency as well as the site on the scalp at which electrical signals are recorded. The most intimate grouping uses EEG waveform frequency like alpha, beta, theta, delta, spindle, etc. The most frequently used approach to diagnose epilepsy and stoke is EEG, which causes irregularity in EEG readings. It is also used to diagnose brain death, sleep disorders, coma, muscle injury and encephalopathies. EEG used to be a primary method of diagnosis for tumor's, epilepsy, stroke and other focal brain disorders.

A. Problem Statement

Now a day's stroke, epilepsy, brain injury, back bone injury and muscle injury are the leading causes of disability affecting over a million individuals. About 800,000 people have reported severe problems with hand function, muscle damage, and conventional physical therapy produces significant improvement after 3 months of post injury. Loss of hand function causes a sharp decrease in life quality for affected persons. Accordingly, permanent disabilities result in a typical cost between $90k and $3M per patient, including inpatient rehabilitation, care, and so on. The majority of EEG therapies have patients actively directing their hand, limb, which is not an option in cases of severe paralysis of many individuals. While BCIs promise new hope for treatment, to solve the existing problem. In addition, BCI's method cannot be applied in cases of brain injury since the classical motor signals in cortex contralateral to the target hands; limb needed would be gone with the many injuries.

B. Motivation

Emotions and feelings are unconscious and hard to describe generally. The research of EEG has identified several regions that are sensitive to feelings and emotional stimulations; these feelings are typically located deep in the brain and hard to measure from with low-density signals. A new but emergent field for EEG is BCI, i.e., brain computer interfaces. Now a day we know in more detail which brain areas are active when we recognize stimuli, when prepare and execute movements of the body or learn and memorize things. This gives rise to very robust EEG applications to direct devices using brain activity. For instance, this can help paralyzed patients to move a cursor on a screen or to address their wheelchairs, BCI technology is also used for the purpose of the military where soldiers are permitted to lift, move, and carry bulky items only based on brain activity and also provided them with EEG cap and an exoskeleton. BCI technology is also been used to control the home appliances using IOT.

C. Applications

- Provide environment control, communication, and movement restoration for people with disabilities.
- Provide disabled individuals with enhanced control of devices such as assistance robots, wheelchairs, or vehicles.
- Provide additional passage of control in computer games for people who have damage in their peripheral pathway.
- Monitor consciousness in aircraft pilots, or long-distance drivers, send out message and warning for aircraft pilots.
- Provide disabled people with control of robots that function in dangerous or inhospitable situations for example in extreme cold or heat or underwater.
- Monitor different stages of Bionics/Cybernetics, Sleep, Dream Capture, Memory upload or download, etc.
- Provide enhanced control of home appliances using IOT.

II. RELATED WORKS

The Brain-Computer Interface (BCIs) system serves the disabled people. The various brain-computer system and applications that have been developed with different time span and a brief description of the work is discussed in this section. The common spatial patterns (CSPs) are the most widely used algorithm for the EEG Classification by Stationary Matrix Logistic Regression in Brain–Computer Interface [1]. The CSP aim is to present the discriminative spatial projection with the belt power characterization of signals. There are two significant drawbacks for the CSP-based method. Initially, the classification algorithm LDA and the feature extraction algorithm CSP modify different detached functions. Second, the intrinsic nonstationarity of the EEG signals recording in a single session tends to worsen the classification performance with the primary CSP-based method.

The divergence-based framework for common spatial patterns algorithms [2]. The divergence-based framework just allows catching different unchangeability and employing details from other substances. Hence, it combines the currently suggested many of CSP alternatives in a principled manner. As well as, it permits scheming novel spatial filtering algorithms by including usual schemes into the accumulation process or appealing different severances.

A Kullback–Leibler (KL) CSP is favored, in which the linear spatial filtering algorithm is used to withdraw characteristics that are robust and inflexible. In opposite, the recommended KLCSP algorithm simultaneously maximizes the variances between the class means and it also minimizes the within-class differences which are unhurried by a loss function [3]. Bayesian learning for spatial filtering in Brain–Computer Interface based electroencephalography (EEG). However, there is no established hypothesis for spatial filtering that directly links to Bayes classification error. In order to report this problem for spatial filtering, a

Bayesian analysis theory in correlation to Bayes error is proposed [4]. The stationary standard spatial patters for brain-computer interfacing. This method is not only appropriate to Brain signals using EEG but also to the censorious modeling of the innovative standard beyond BCI [5]. . In iterative spatio-spectral patterns learning (ISSPL), to achieve efficient performance the spectral filters and classifier are simultaneously parameterized for an extension. In ISSPL, a rigorous derivation and theoretical analysis are complicated [6].

A. Advantages of Proposed System

Benefits of the EEG classification in BCI systems are mentioned below:

- Economical, Portable, low maintenance cost.

- Enable broken people to control prosthetic limbs with their mind.
- Allowing the deaf person to hear, by transmitting sensory data to their mind.
- Permit gamers (especially broken people) to control video games with their minds.
- Enable injured people to control a wheelchair, robotic and so on.
- Allows a person to monitor the home appliances using IOT.
- Allows a dumb person to have their line of thinking displayed and spoken by a computer.

III. SYSTEM REQUIREMENTS

A. Hardware Requirements

- Arduino Microcontroller
- EEG Sensor
- HC-05 Bluetooth Module
- USB Cable for Arduino
- Breadboard
- Jumper wires
- Monitor
- Robotic chassis
- Wheels
- Battery
- DC motors
- Relay
- Light

B. Software Requirements

- Embedded C
- Arduino 1.8.1
- Flash magic burner software

IV. PROPOSED METHODOLOGY

The proposed Single-Trail EEG Classification in BCI consists of two modules:

A. Signal Acquisition

For the accession system, the most frequently used recording method is EEG. The EEG method uses electrodes/sensor which is an appeal on the scalp; there is the main advantage of using this approach that is the portability of the recording system. Further methods required bulky instrumentation which is costly or is very expensive and those are invasive.

The different phases of this module are:

Brainwaves: In this system, the Mindwave Mobile headset by NeuroSky is utilized to read the EEG signals, shown in Fig. 1. The eSence algorithm by NeuroSky's exercises the EEG signals and wirelessly transmits the calculated attention and meditation values through Bluetooth to a master device i.e. HC 05 Bluetooth module at the rate of 1Hz.

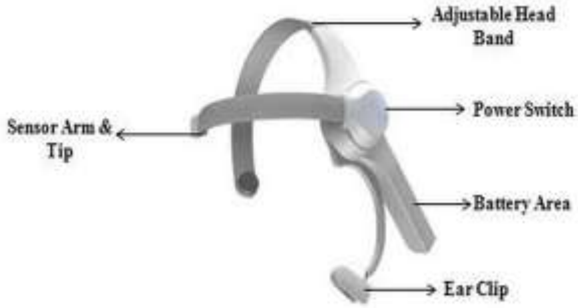
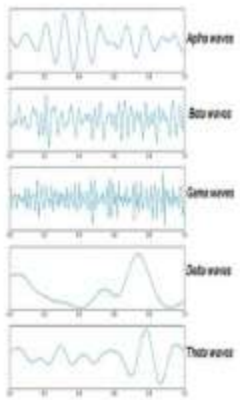


Fig. 1: NeuroSky Wireless EEG headset

The patterns and frequencies of electrical signals can be measured by placing a sensor on the scalp. In headset product, the MindTools line contains NeuroSky ThinkGear technology which meters the electrical signals and exercises them into digital signals; these electrical signals are often referred to as brainwaves. The ThinkGear equipment then makes those measurements and signals obtainable to games and applications. The Table I inferior to present with a general synopsis of some of the commonly-recognized frequencies that tends to be generated by different types of activity in the brain.

Table I. EEG rhythmic activity frequency bands



TYPE	FREQUENCY	MENTAL STATES
Delta	0.1Hz to 3Hz	Deep, dreamless sleep, non-Rem sleep, unconscious
Theta	4Hz to 7Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8Hz to 12Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12Hz to 15Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16Hz to 20Hz	Thinking, aware of self & surroundings
High Beta	21Hz to 30Hz	Alertness, agitation
Gamma	30Hz to 100Hz	Motor functions, high mental activity

ThinkGear: ThinkGear is the equipment which is the contemporary interior of every NeuroSky product that allows a device to integrate with the user's brainwaves. It consists of the sensor which touches the forehead of the user, the reference and junction points presented in the ear clip, and the on-board chip that operates all of the data. Both the dominant brainwaves and the eSense Meters (Attention and Meditation) are calculated on the ThinkGear chip.

eSense: eSense is a NeuroSky's quick fix algorithm for distinguishing mental states. To compute eSense, the NeuroSky ThinkGear technology fleshes out the raw brainwave signal and removes the atmosphere noise and muscle movement. The eSense algorithm is then appealed to the remaining signal, resulting in the elucidated eSense meter values.

eSense Meter: Technical Description: For each different type of eSense, i.e., the Attention and Meditation meter value are described on eSense respective scale of 1 to 100.

A value across 40 to 60 at any given moment in time is considered “neutral” and is similar in notion to “baselines. A value across 60 to 80 is considered “slightly elevated”, and may be interpreted as levels of eSense values may be higher than normal for a given person. Values across 80 to 100 are considered “elevated”, denoting they are strongly expressive of heightened levels of that eSense.

Similarly, on the other end, a value across 20 to 40 indicates “reduced” levels of the eSense, while a value across 1 to 20 indicates “strongly lowered” levels of the eSense.

Attention eSense: The eSense Attention meter specifies the strength of a user's level of mental “attention” or “focus”, which occurs during extreme concentration and directed (but stable) mental activity. The meter value ranges from 0 to 100. Lack of concentration, wandering thoughts, Distractions, or anxiety may decrease the Attention meter level.

Meditation eSense: The eSense Meditation meter specifies the user’s level of mental “relaxation” or “calmness”. The value ranges from 0 to 100. The account that Meditation is a meter of a person's mental states, not physical states so just relaxing of all body muscles may not quickly result in an enhanced Meditation level. Nevertheless, for most people in most everyday situations, relaxing the body frequently helps the mind to relax as well. Meditation is associated to decrease activity by the active mental processes in the brain. It has been an observed that closing the eyes is often an effective method for increasing the Meditation meter level. Distractions, anxiety, sensory stimuli and wandering thoughts may lower the Meditation meter levels.

HC-05 Bluetooth: 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. This module is shown in the Fig. 2.

Fig. 2: HC-05 Bluetooth

Arduino: The Arduino is a microcontroller board with open-source. It is configured by writing software to it, incorporating an ARM processor. It has 14 digital inputs or output pins, a 16 MHz quartz crystal, a USB connection, 6 analog inputs, a reset button, an ICSP header and a power jack. It holds everything required supporting the microcontroller, and it directly connects to a computer with a USB cable or battery to get started or controls with an AC-to-DC adapter. Arduino boards are allowed to read inputs, and it is also used to twitter message, activating a motor, turn it into an output, turning on a LED, figure on a button and light on a sensor. Arduino microcontroller is shown in the Fig. 3.

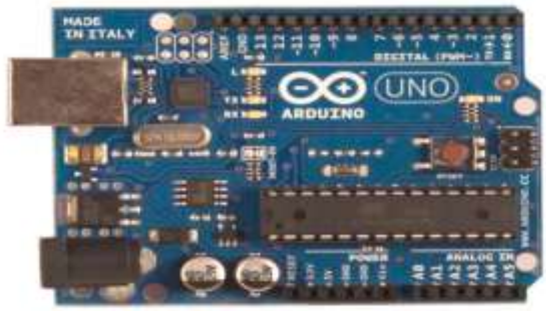


Fig. 3: Arduino Microcontroller

In this project, the Arduino microcontroller is worned to gather and examine the electrical brain signals from the sensor to be used in actual-time or stored for future analysis. Configure the HC-05 module to the Arduino microcontroller as per the below Fig. 4.

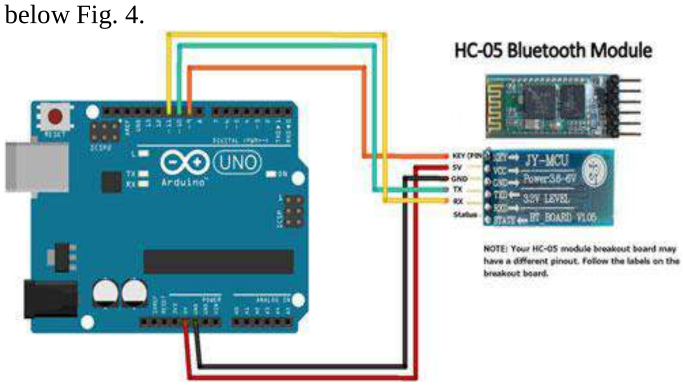


Fig. 4: Connecting HC-05 Module to Arduino

On the HC-05 Bluetooth module press and hold the push button for few seconds while powering on the Arduino. Once both the devices are powered on free the knob. On the HC-05 module, the LED should blink at low toggle (blink slowly) specifying that the instrument is in Data Mode if it blinks at large toggle (flash faster) then power down the device and try again.

B. BCI Application

The BCI Application which is used in the project is Robotic Chassis and for controlling the home appliances using IOT. The system consists of an Arduino microcontroller for controlling the movement and direction of the Robotic Chassis and for controlling the home appliances with respect to the command received from the signal processing unit. Mindwave mobile handset output i.e. attentions eSense meter values are given as input to robotic chassis module which consists of Dc Motors when attention value reaches above 70 then the robotic will moves in a Forward direction to ten feet and will come back to the starting point. Likewise, if attention value reaches below 30, then the buzzer will turn on indicating that attention value is little. Meditations meter values are used to control the home appliances using IOT, if value reaches above 70 then automatically lights will turn off, and fan will turn on. Similarly, if value reaches below 30 then automatically lights will turn on, and fan will turn off. Using the url which generated anyone can also see the status of the home appliances and they can also turn on/off the home appliances using the internet.

V. SYSTEM BLOCK DIAGRAM

Brain–Computer Interface (BCI) is used to build a direct control channel between user's intentions that is human brain and computer. Two different applications are used to demonstrate the project. One is Robotic Arm, and another is controlling the home appliances using IOT. Such a system can help two kinds of people, first people who have damage in their physical system to recover their activities with a wheelchair, or control over a neuroprosthesis or a robot and so on. Second, for healthy people, it could be an additional man–machine interface, which is able to increase the productivity and the efficiency in high-throughput tasks.

The signals from the brain are captured using EEG sensor i.e. by Mindwave mobile handset which can be seen as digital values on the PC and then it is dumped into Arduino microcontroller. The microcontroller in turn connected to robotic chassis and the home appliances. Attention values are used to operate the robotic frame, and meditation values are used to control home appliances. The block diagram Fig. 5 shows all the connections and the activities:

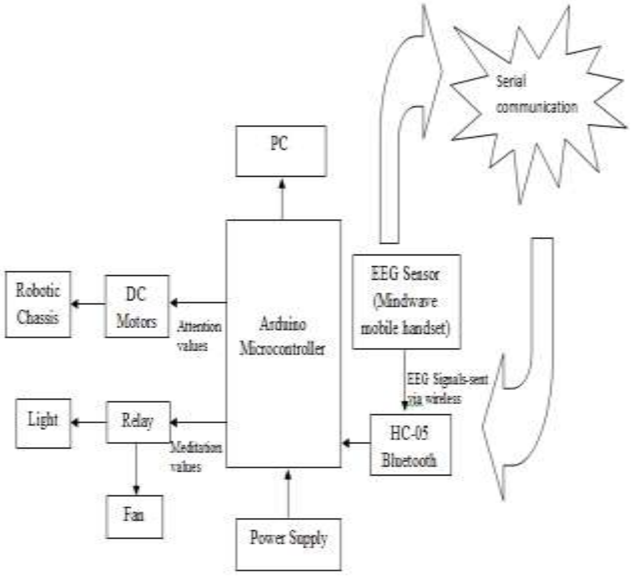


Fig. 5: System Block Diagram

VI. DESIGN FLOW

A flowchart is concerned with a graphic representation of a logic sequence, manufacturing process or work, similar formalized structure, or organization chart. The cause of a flow chart is to furnish people with a common reference point or language when trading with a project.

The below flow diagram Fig. 6 shows how home appliances is controlled over the internet using meditation signals from the human brain. It works as follow; the first step is to initialize the Neurosky mobile handset and then capture the EEG meditation signals. The signal values range from 0 to 100. Initially, medit_count will be maintained, if meditation signals values are greater than 70 then the count will become zero, if values become greater than 70 simultaneously for three times then the count will become 2, then the home appliances i.e. lights will turn off, and fan will turn on automatically. If not repeat the procedure, capture the meditations signals simultaneously for three times. Initially, medit_count will be maintained, if meditation signals are below 30 then the count will become zero if values become below 30 simultaneously for three times then count will become 2, then the home appliances i.e. lights will turn on, and fan will turn off automatically. The home appliances can also be controlled by anyone by opening a URL which is generated while executing the program and the status of the machines can also be seen by anyone by opening the URL.

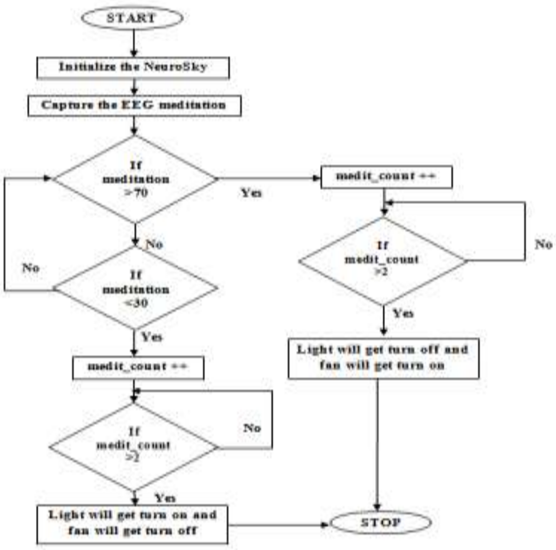


Fig 6: The design flow of brain controlled home appliances.

The below flow diagram Fig. 7 shows how robotic is controlled using attention signals from the human brain. It works as follow; the first step is to initialize the Neurosky mobile handset and then capture the EEG attention signals. The signal values range from 0 to 100. Initially, atten_count will be maintained, if attention signals values are greater than 70 then the count will become zero if values become greater than 70 simultaneously for three times then count will become 2, then the robotic will starts moving in the forward direction for ten feet's and will come back to starting point. If not repeat the procedure, capture the attention signals simultaneously for three times. Initially, atten_count will be maintained, if attention signals are below 30 then the count will become zero if values become below 30 simultaneously for three times then count will become 2, then the buzzer will turn on.

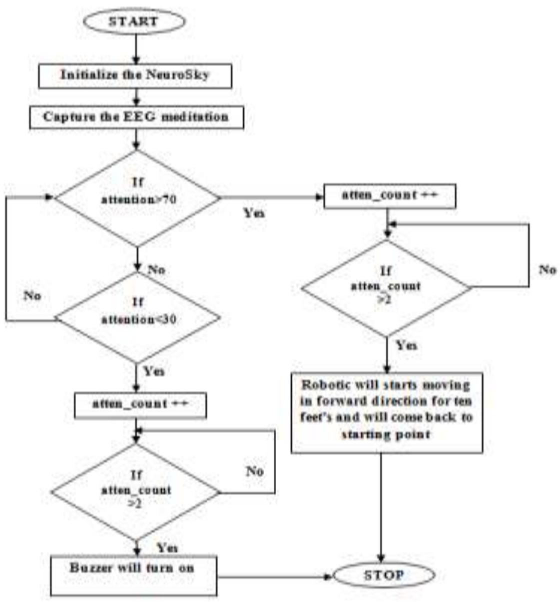


Fig. 7: The design flow of brain controlled Robotic

VII. IMPLEMENTATION

Algorithm for the implemented modules

A. *Signal Acquisition module*

eSense algorithm eSense is a NeuroSky's quick fix algorithm for distinguishing mental states. To compute eSense, the NeuroSky ThinkGear technology fleshes out the raw brainwave signal and removes the atmosphere noise and muscle movement. The eSense algorithm is then appealed to the remaining signal, resulting in the elucidated eSense meter values.

Algorithm 1

Input: Brain signals.
Output: eSense meter values.
Step1: Microprocessor Setup
    Begin Serialization at Baudrate at 57600
Step2: print "MIND wave programming."
Step3: while serial available do
Step4: Read serial data and echo the same byte out the USB serial:
Step5: 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
Step6: if user is not wearing the device do:
    Print poorQuality = 200; attention = 0; meditation = 0;
Step7: if user is wearing the device do parse the payload for poorQuality, attention and meditation.

B. *Arduino*

The Arduino is a microcontroller board with open-source. It is configured by writing software to it, incorporating an ARM processor. It has 14 digital inputs or output pins, a 16 MHz quartz crystal, a USB connection, 6 analog inputs, a reset button, an ICSP header and a power jack. It holds everything required supporting the microcontroller, and it directly connects to a computer with a USB cable or battery to get started or controls with an AC-to-DC adapter. Arduino boards are allowed to read inputs, and it is also used to twitter message, activating a motor, turn it into an output, turning on a LED, figure on a button and light on a sensor. Here, the Arduino microcontroller is used to congregate and examine the data from the headset which can be in real-time applications or stored for future analysis.

Algorithm 2:
Step1: BTSerial RX pin is 0, TX pin is 1
Step2: pinMode 9 as output pin
Step3: Begin Serialization at 57600
Step4: Keep reading from HC-05 and send to
Arduino Serial Monitor
if Serialization is available do
Serial.write(BTSerial.read())
Step5: Keep reading from Arduino Serial Monitor
and send to HC-05
if Serialization is available do
BTSerial.write(Serial.read())

C. HC-05 Bluetooth

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 baudrate 57600 and type the following commands sequentially.

1. AT+NAME=”PANTECH”
2. AT+UART=”57600,0,0”
3. AT+ROLE=”1”
4. AT+PSWD=”1234”
5. AT+CMODE=”0”
6. AT+BIND=”XXXX,YY,ZZZZZZ” (Mindwave Unique Number)
7. AT+IAC=”9E8B33”
8. AT+CLASS=”0”
9. AT+INQM=”1,9,48”

Then 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 Mindwave Mobile headset once both devices are powered on.

D. BCI Application-Robotic Chassis

A DC motor is part of a class of rotational electrical machines that directly converts electrical energy into mechanical energy. The nearly all common types depend on the forces produced by magnetic fields. All types of DC motors have some interior machine to regularly adjust the direction of current flow in the motor which is either electronic or electromechanical. A DC motor's speed can be managed by using either by changing the strength of the current in its field windings or a variable supply voltage or. DC motors are used in various appliances, toys, robotics, and tools. DC motor is showed in Fig. 8.

Fig. 8: DC motor

Algorithm 3:

Input: eSense meter values
Output: Robotic chassis will start moving forward, reverse, and stop.
Step1: setup pinMode 8, 9, 10, 11 as output
Step2: To move robo in Forward motion:
digitalWrite(8, HIGH); (9, LOW); (10, HIGH); (11, LOW);
Step3: To move robo in Reverse motion:
digitalWrite(9, HIGH); (8, LOW); (11, HIGH); (10, LOW);
Step4: To stop the robo:
digitalWrite(8, LOW); (9, LOW); (10, LOW); (11, LOW);

VIII. RESULTS

Once the user is wearing the headset and does the task, the high values of attention and meditation activity of brain start ranging from 0 to 100 which is shown in Fig. 9 and 10.

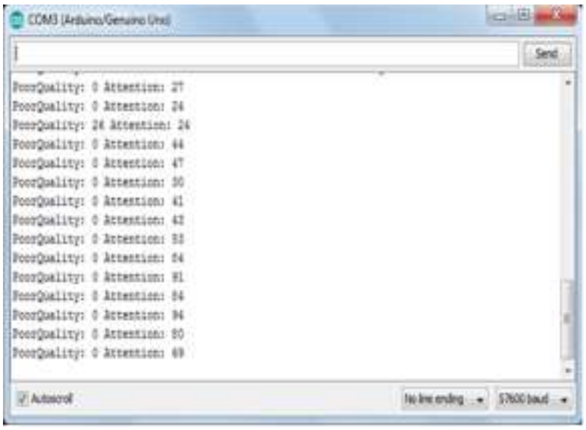


Fig 9: Elevated values of attention activity of Brain

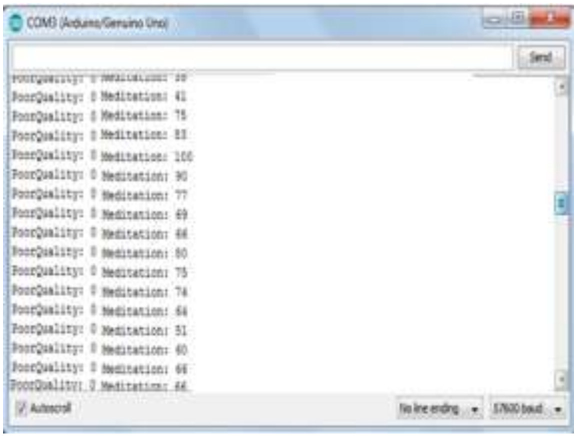


Fig. 10: Elevated values of meditation activity of brain

The overall model with arduino microcontroller, LCD display, power supply, relay, light, jumper wires and robotic chassis looks like as shown in the Fig. 11.

Fig. 11: Overall Model

Once the attention values reach above 70 simultaneously for 3 times then the following Fig. 12 robotic chassis starts moving in forwarding direction for 10 feet's and will come back to starting point.

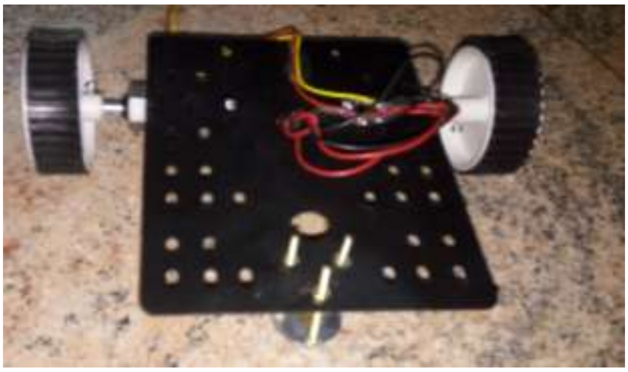


Fig. 12: Robotic chassis

Once the meditation values reach above 70 simultaneously for 3 times then the home appliances i.e. light will automatically turn on, and fan will turn off. Likewise, when meditation benefits reach below 30 then the light will turn on, and fan will turn off. The following Fig. 13 shows the demo.

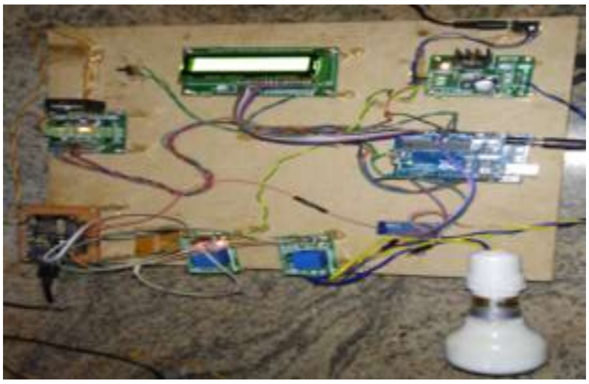


Fig. 13: Controlling Home appliances

The user can see the current status of the devices and also operate the home appliances from anywhere via the internet by using a URL which is generated when executing a program. The home page is shown in the Fig. 14.

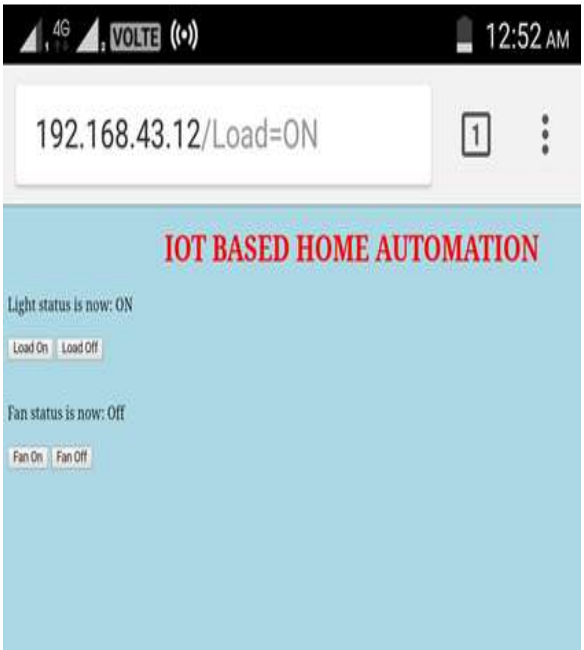


Fig. 14: IOT based home page

IX. CONCLUSION AND FUTURE WORK

An EEG-based Brain-controlled robotic and home appliance was proposed for disabled people and senior's people to lead their daily life without any arduousness. Two applications were developed. The electrical signals of attention were used for making a robo to move in forwarding direction for ten feet's and coming back to a starting point, and meditation signals were used for controlling the home appliances. Based on various metrics the performance was analysed. The prototype model of

EEG-based controlling robotic and home appliances has been developed with the help of NeuroSky technology. The eSense technique was implemented in signal processing; the robo and home appliances were controlled by Arduino Microcontroller. This system can help the people do their work without any human interrelation and also enrich their life standard. Though the BCI system field is in its early development, but it requires improvement on the robotic to be more user-friendly. The robotic shall be further upgraded by removing noise level and duplicates precisely in signal processing and thus focus on additional improvement of the detection of irregular attention and meditation so that, the robotic and home appliances can be controlled accurately without any contradiction.

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