VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JNANA SANGAMA, BELAGAVI-590014

Project report

on

"EEG BASED CONTROL OF ROBOTIC ARM"

Submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

For the academic year

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By

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is certified that the project work entitled **"EEG BASED CONTROL OF ROBOTIC ARM"** carried out by **Dileep Kumar B (1TJ18EC013) , Harsha M M (1TJ18EC016), Sandeep B (1TJ18EC035) , Varun D N (1TJ18EC040)** are bonafide student of **T John Institute of Technology** in partial fulfilment for seventh semester of **Bachelor of Engineering** in **Electronics and Communication Engineering** of **Visvesvaraya Technological University, Belagavi** during the year **2021-2022**. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited . The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

DECLARATION

We , hereby declare that the project entitled **"EEG BASED CONTROL OF ROBOTIC ARM"** submitted to Visvesvaraya Technological University , Belagavi , is carried out at the department of Electronics and Communication Engineering , T John Institute of Technology , Bangalore under the guidance of **Mrs. Nisha Joy** , Assistant Professor. This reporthas not been submitted for the award of any Diploma of this or any other University.

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Abstract

Brain-machine interfaces (BMIs) can be used to decode brain activity into commands to control external devices . This project shows electroencephalograph (EEG) controlled robotic arm based on Brain-computer interfaces (BCI). BCIs are systems that enable bypassing conventional methods of communication (i.e. muscles and thoughts) and provide direct communication and control between the human brain and physical devices using the power of the human brain. The main goal of the project work is to develop a robotic arm that can assist the disabled people in their daily life and by it make their work independent on others .

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Chapter 1

1.Introduction

BRAIN-MACHINE interface (BMI) technology is a promising tool for the recognition of user intention and for communicating with external devices.Noninvasive BMIs aim to translate human thoughts, decoded by brain activity into control signals, for external applications without brain implant surgery.

These interfaces typically decode the cortical correlates of movement parameters such as velocity/position of limb movements or muscular activity to generate control sequences over the past decades, BMIs have been developed to control devices such as wheelchairs and robotic arms not only facilitating the recovery of movement functions for spinal cord injury (SCI) and amyotrophic lateral sclerosis (ALS) patients, but also supporting the abilities of healthy people.

The robotic arm could provide alternative upper extremity function to both healthy people and motor-disabled patients, allowing them to perform high-level tasks, such as drinking water or moving objects.

Some BMI groups have investigated scalp electroencephalogram (EEG)-based robotic arm control systems using various BMI paradigms, such as steady-state visual evoked potentials , P300 potentials, error-related potentials, motor imagery, and shared control.

To emulate the natural control of a brain-to-robot arm, motor imagery is an important topic that reflects the thought of users about moving specific body parts without any external stimuli.

1.1 Objective of the Proposed Project

- The main objective is to enable the free movement of a robotic arm as an assistive device, by sensing a patient's brain activity in real time
- Here we use our eye movements for the control of our robotic arm
- Electrooculography (EOG) measures voltage fluctuations resulted in from eye movements .
- EOG can be used to track the eye-gaze directions (like an eye tracker) , it also recognize information of eyelid movements such as blinks and winks .

1.2 Problem Statement

- Paralyzed people lost their mobility of the whole body or part of body so they are unable to carry out most of the daily activity
- They rely on external devices to regain their mobility with limited movement only
- Some of them cannot use the external devices because they are unable to move any part of body
- However, they still can think about movement and the proposed mechanism can make the thinking into real movement

Chapter 2

2.Literature Survey

[1] "Restoring Activities of Daily Living Using an EEG/EOG-Controlled Semiautonomous and Mobile Whole-Arm Exoskeleton in Chronic Stroke"
Marius Nann, Francesca Cordella, Emilio Trigili – 2021

A novel hybrid electroencephalography/electrooculography (EEG/EOG)-based brain/neural control paradigms were developed for guiding a whole-arm exoskeleton. It was unclear, however, whether hemiplegic stroke survivors are able to reliably use such brain/neural-controlled device. Here,they tested feasibility, safety, and user-friendliness of EEG/EOG-based brain/neural robotic control across five hemiplegic stroke survivors engaging in a drinking task that consisted of several subtasks (e.g., reaching, grasping, manipulating, and drinking). Reliability was assumed when at least 75% of subtasks were initialized within 3 s. Fluent control was assumed if average "time to initialize" each subtask ranged below 3 s. System's safety and user-friendliness were rated using Likert-scales. All chronic stroke patients were able to operate the system reliably and fluently. No undesired side effects were reported. Four participants rated the system as very user-friendly. These results show that chronic stroke survivors are capable of using an EEG/EOG-controlled semiautonomous whole-arm exoskeleton restoring ADLs.

[2] "Real-Time EEG–EMG Human–Machine Interface-Based Control System for a Lower-Limb Exoskeleton"
Sergey A. Lobov , Nikita A. Grigorev , Andrey O.Savosenkov – 2020

This project presents a rehabilitation technique based on a lower-limb exoskeleton integrated with a human-machine interface (HMI). HMI is used to record and process multimodal signals collected using a foot motor imagery (MI)-based brain-machine interface (BMI) and multichannel electromyographic (EMG) signals recorded from leg muscles. Current solutions of HMI-equipped rehabilitation assistive technologies tested under laboratory conditions demonstrated a great deal of success, but faced several difficulties caused by the limited accuracy of detecting MI electroencephalography (EEG) and the reliability of online control when executing a movement by patients dressed in an exoskeleton. In the case of lower-limb representation, there is still the problem of reliably distinguishing leg movement intentions and differentiating them in BMI systems

[3] "A Bayesian Shared Control Approach for Wheelchair Robot With Brain Machine Interface"
Xiaoyan Deng, Zhu Liangiang Yu , Canguang Lin – 2020

In this a novel shared controller based on Bayesian approach is proposed for intelligently combining robot automatic control and brain-actuated control, which takes into account the uncertainty of robot perception, action and human control. Based on maximum a posteriori probability (MAP), this method establishes the probabilistic models of human and robot control commands to realize the optimal control of a brain-actuated shared control system. Application on an intelligent Bayesian shared control system based on steady-state visual evoked potential (SSVEP)-based brain machine interface (BMI) is presented for all-time continuous wheelchair navigation task. Moreover, to obtain more accurate brain control commands for shared controller and adapt the proposed system to the uncertainty of electroencephalogram (EEG), a hierarchical brain control mechanism with feedback rule is designed.

[4] "Brain-Controlled Robotic Arm System Based on Multi-Directional CNN-BiLSTM Network Using EEG Signals"
Ji-hoon Jeong, Kyung-HwanShim , Dong-Joo Kim – 2020

In this paper they had presented the decoding of intuitive upper extremity imagery for multi-directional arm reaching tasks in three-dimensional (3D) environments. We designed and implemented an experimental environment in which electroencephalogram (EEG) signals can be acquired for movement execution and imagery. Fifteen subjects participated in our experiments. We proposed a multi-directional convolution neural network-bidirectional long short-term memory network (MDCBN)-based deep learning framework. The decoding performances for six directions in 3D space were measured by the correlation coefficient (CC) and the normalized root mean square error (NRMSE) between predicted and baseline velocity profiles. The grand-averaged CCs of multi-direction were 0.47 and 0.45 for the execution and imagery sessions, respectively, across all subjects. The NRMSE values were below 0.2 for both sessions. Furthermore, in this study, the proposed MDCBN was evaluated by two online experiments for real-time robotic arm control, and the grand-averaged success rates were approximately 0.60 (±0.14) and 0.43 (±0.09), respectively. Hence, we demonstrate the feasibility of intuitive robotic arm control based on EEG signals for real-world environments.

[5] "Modelling of Human Operator Behaviour for Brain-Actuated mobile Robots Steering"
Hongqi Li, Luzheng Bi , Haonan Shi – 2020

In this paper, we propose an operator brain-controlled steering model consisting of an operator decision model based on the queuing network (QN) cognitive architecture and a brain-machine interface (BMI) performance model. The QN-based operator decision model can mimic the human decision process with the individual operator differences considered. The new BMI performance model is built to represent the varied accuracy of BMI during brain-controlled direction operations. Furthermore, the model is simulated and validated against the results of human operator-in-the-loop experiments.

[6] "Brain–Robot Interface-Based Navigation Control of a Mobile Robot in Corridor Environments"
Yiliang Liu , Zhijun Li , Tong Zhang Suna Zhao – 2020

This paper proposes a brain-robot interface (BRI)-based control strategy in combination with the simultaneous localization and mapping (SLAM) to achieve the navigation and control of a mobile robot in uncertain environments. The BRI is based on steady state visually evoked potentials, utilizing the multivariate synchronization index classification algorithm to analyze the human electroencephalograph (EEG) signals in such a manner that human intentions can be recognized and motion commands can be produced for the brain controlled robot. The entire system is semi-autonomous since the navigation of mobile robot is commanded by the BRI, and the low-level motion of the mobile robot is autonomous with a designed kinematic controller. By utilizing vanishing points and door plates as the environmental features, a global metric map of the environment has been built by a sequential SLAM algorithm. The main contribution of this paper is the combination of an artificial potential field (APF) and the brain signals, which builds up the relationship between the strength of EEG signals and the intensity of the potential field. Through the proposed EEG-APF method, motion commands that would plan an obstacle-free trajectory in un-structured environments, can be obtained. The entire system has been tested with eight volunteer subjects, and all subjects are able to successfully fulfill manipulating mobile robot in the experiments.

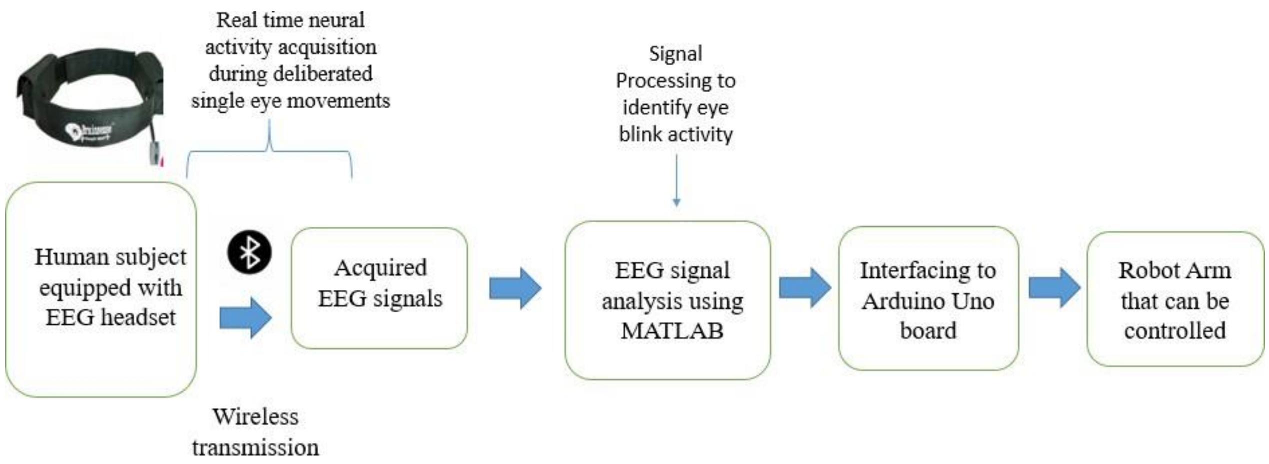
[7] "A Novel EOG/EEG Hybrid Human-Machine Interface Adopting Eye Movements and ERPs: Application to Robot Control"
Jiaxin Ma , Yu Zhang , Andrzej Cichocki , Fumitoshi Matsuno – 2015

In this study a novel human-machine interface (HMI) based on both electrooculography (EOG) and electroencephalography (EEG). This hybrid interface works in two modes: an EOG mode recognizes eye movements such as blinks, and an EEG mode detects event related potentials (ERPs) like P300. While both eye movements and ERPs have been separately used for implementing assistive interfaces, which help patients with motor disabilities in performing daily tasks, the proposed hybrid interface integrates them together. In this way, both the eye movements and ERPs complement each other. Therefore, it can provide a better efficiency and a wider scope of application. In this study, we design a threshold algorithm that can recognize four kinds of eye movements including blink, wink, gaze, and frown. In addition, an oddball paradigm with stimuli of inverted faces is used to evoke multiple ERP components including P300, N170, and VPP. To verify the effectiveness of the proposed system, two different online experiments are carried out. One is to control a multifunctional humanoid robot, and the other is to control four mobile robots. In both experiments, the subjects can complete tasks effectively by using the proposed interface, whereas the best completion time is relatively short and very close to the one operated by hand.

Chapter 3

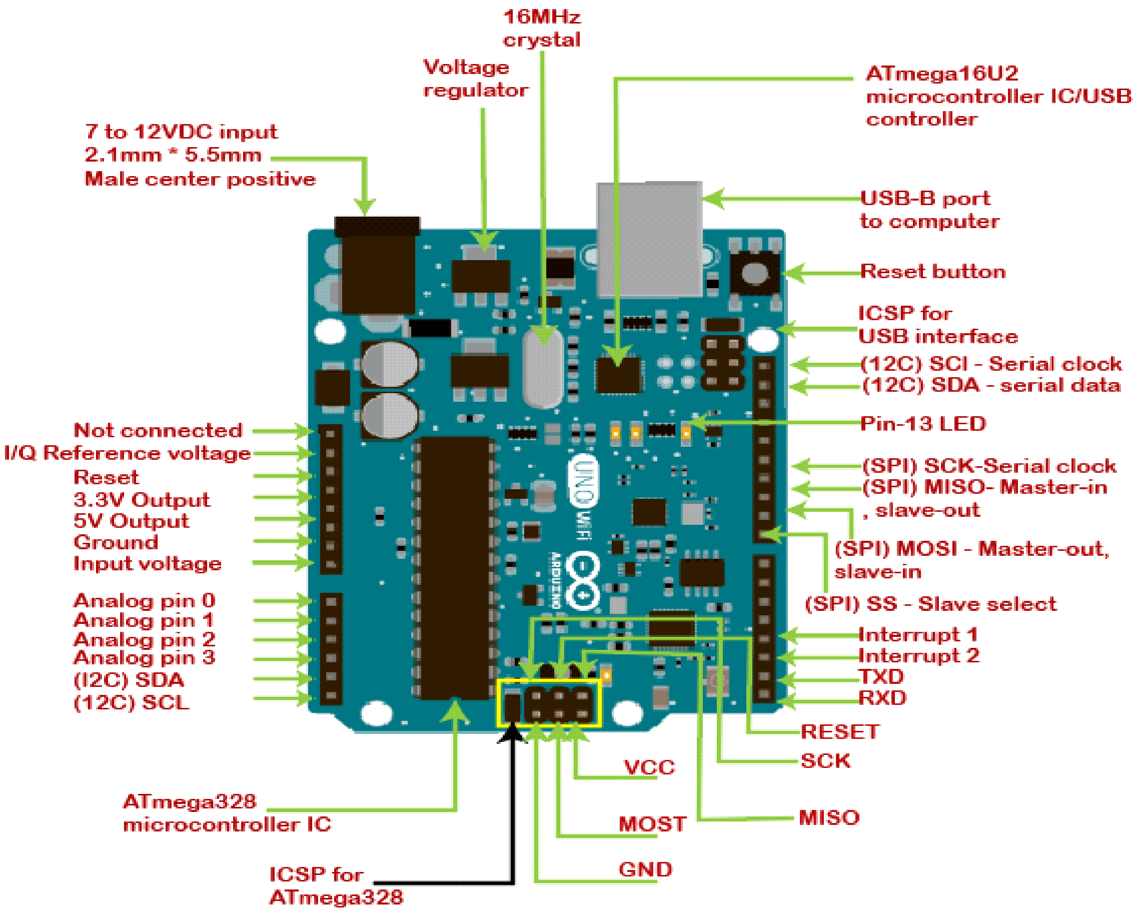
3.Proposed System

3.1 Block Diagram



3.2 Components Required

Arduino Uno



The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

setup( ): A function present in every Arduino sketch. Run once before the loop( ) function. Often used to set pinmode to input or output. The setup( ) function looks like:

```
void setup( ){
        //code goes here
        }
```

loop( ): A function present in every single Arduino sketch. This code happens over and over again. The loop( ) is where (almost) everything happens. The one exception to this is setup( ) and variable declaration. ModKit uses another type of loop called “forever( )” which executes over Serial. The loop( ) function looks like:

```
void loop( ) {
        //code goes here
        }
```

input: A pin mode that intakes information.
output: A pin mode that sends information.
HIGH: Electrical signal present (5V for Uno). Also ON or True in boolean logic.
LOW: No electrical signal present (0V). Also OFF or False in boolean logic.
digitalRead: Get a HIGH or LOW reading from a pin already declared as an input.
digitalWrite: Assign a HIGH or LOW value to a pin already declared as an output.
analogRead: Get a value between or including 0 (LOW) and 1023 (HIGH). This allows you to get readings from analog sensors or interfaces that have more than two states.
analogWrite: Assign a value between or including 0 (LOW) and 255 (HIGH). This allows you to set output to a PWM value instead of just HIGH or LOW.
PWM: Stands for Pulse-Width Modulation, a method of emulating an analog signal through a digital pin. A value between or including 0 and 255. Used with **analogWrite.**

These boards below use the same micro-controller, just in a different package. The Lilypad is designed for use with conductive thread instead of wire and the Arduino Mini is simply a smaller package without the USB, Barrel Jack and Power Outs.

It depends on what you want to do with it really. There are two different purposes outlined above for the voltage divider, we will go over both.

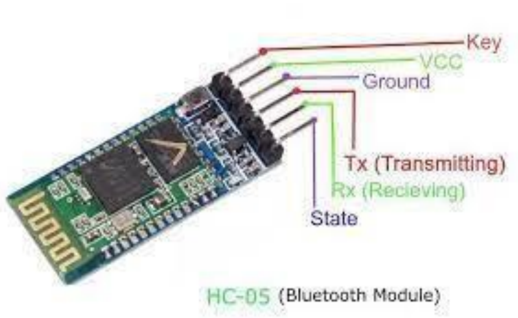
If you wish to use the voltage divider as a sensor reading device first you need to know the maximum voltage allowed by the analog inputs you are using to read the signal. On an Arduino this is 5V. So, already we know the maximum value we need for Vout. The Vin is simply the amount of voltage already present on the circuit before it reaches the first resistor. You should be able to find the maximum voltage your sensor outputs by looking on the Datasheet; this is the maximum amount of voltage your sensor will let through given the voltage in of your circuit. Now we have exactly one variable left, the value of the second resistor. Solve for R2 and you will have all the components of your voltage divider figured out! We solve for R1's highest value because a smaller resistor will simply give us a smaller signal which will be readable by our analog inputs.

Powering an analog Reference is exactly the same as reading a sensor except you have to calculate for the Voltage Out value you want to use as the analog Reference.

All of the electrical signals that the Arduino works with are either Analog or Digital. It is extremely important to understand the difference between these two types of signal and how to manipulate the information these signals represent

HC-05 Bluetooth Module

1.**Key/EN:** It is used to bring Bluetooth module in AT commands mode. If Key/EN pinis set to high, then this module will work in command mode. Otherwise by default it isin data mode. The default baud rate of HC-05 in command mode is 38400bps and 9600in data mode.
HC-05 module has two modes,
Data mode: Exchange of data between devices.
Command mode: It uses AT commands which are used to change setting of HC-05. To send these commands to module serial (USART) port is used.
VCC: Connect 5 V or 3.3 V to this Pin.
GND: Ground Pin of module.
TXD: Transmit Serial data (wirelessly received data by Bluetooth moduletransmitted out serially on TXD pin)
RXD: Receive data serially (received data will be transmitted wirelessly by Bluetooth module).
State: It tells whether module is connected or not.



HC-05 is a Bluetooth module which is designed for wireless communication. This module can be used in a master or slave configuration.

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.
Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband
Through which one can build wireless Personal Area Network (PAN). It uses frequency-hopping spread spectrum (FHSS) radio technology to send data over air.
It uses serial communication to communicate with devices. It communicates with microcontroller using serial port (USART).

HC-05 module Information

- HC-05 has red LED which indicates connection status, whether the Bluetooth is connected or not. Before connecting to HC-05 module this red LED blinks continuously in a periodic manner. When it gets connected to any other Bluetooth device, its blinking slows down to two seconds.

- This module works on 3.3 V. We can connect 5V supply voltage as well since the module has on board 5 to 3.3 V regulator.
- As HC-05 Bluetooth module has 3.3 V level for RX/TX and microcontroller can detect 3.3 V level, so, no need to shift transmit level of HC-05 module. But we need to shift the transmit voltage level from microcontroller to RX of HC-05 module.

Bluetooth communication between Devices

- E.g. Send data from Smartphone terminal to HC-05 Bluetooth module and see this data on PC serial terminal and vice versa.

To communicate smartphone with HC-05 Bluetooth module, smartphone requires Bluetooth terminal application for transmitting and receiving data. You can find Bluetooth terminal applications for android and windows in respective app. store

So, when we want to communicate through smartphone with HC-05 Bluetooth module, connect this HC-05 module to the PC via serial to USB converter.

Before establishing communication between two Bluetooth devices, 1st we need to pair HC-05 module to smartphone for communication.

HC-05 Default Settings

- Default Bluetooth Name: “HC-05”
- Default Password: 1234 or 0000
- Default Communication: Slave
- Default Mode: Data Mode
- Data Mode Baud Rate: 9600, 8, N, 1
- Command Mode Baud Rate: 38400, 8, N, 1
- Default firmware: LINVOR

EEG Controller (Brain sense)

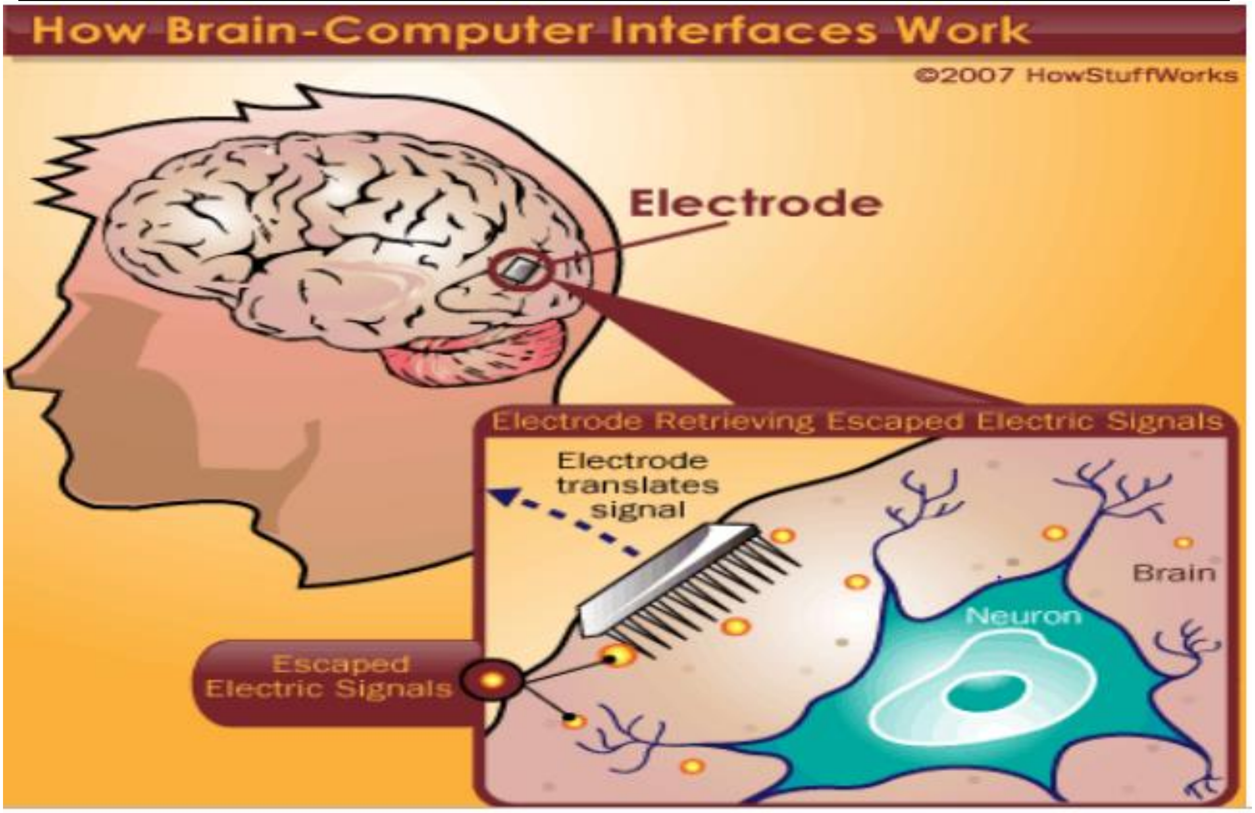
Brainsense is a Brain Computer Interface (BCI) device for Student, Researchers and Wellness Community.A sleek, single-channel, wireless headset that monitors our Brain Activity and translates EEG into meaningful data that we can understand.

Systems capable of understanding the different facets of human communication and interaction with computers are among trends in Human-Computer Interfaces (HCI). An HCI which is built on the guiding principle (GP): “think and make it happen without any physical effort” is called a brain-computer interface (BCI). Indeed, the “think” part of the GP involves the human brain, "make it happen" implies that an executor is needed (here the executor is a computer) and "without any physical effort" means that a direct interface between the human brain and the computer is required. To make the computer interpret what the brain intends to communicate necessitates monitoring of the brain activity.

TYPES OF BCIs

INVASIVE BCI

Invasive BCI research has targeted repairing damaged sight and providing new functionality to paralysed people. Invasive BCIs are implanted directly into the grey matter of the brain during neurosurgery. Using chips implanted against the brain that have hundreds of pins less than the width of a human hair protruding from them and penetrating the cerebral cortex, scientists are able to read the firings of hundreds of neurons in the brain. The language of the neural firings is then sent to a computer translator that uses special algorithms to decode the neural language into computer language. This is then sent to another computer that receives the translated information and tells the machine what to do. As they rest in the grey matter, invasive devices produce the highest quality signals of BCI devices but are prone to scar-tissue build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain.

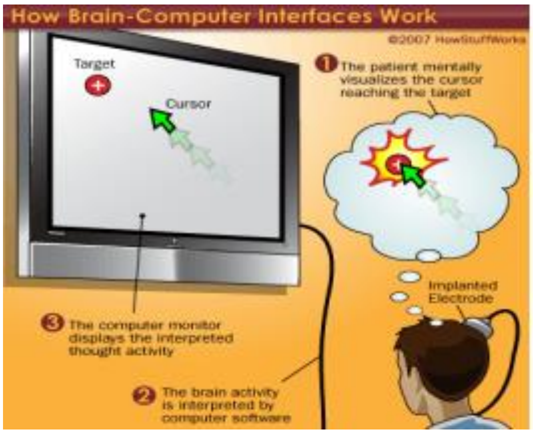


NON-INVASIVE BCI

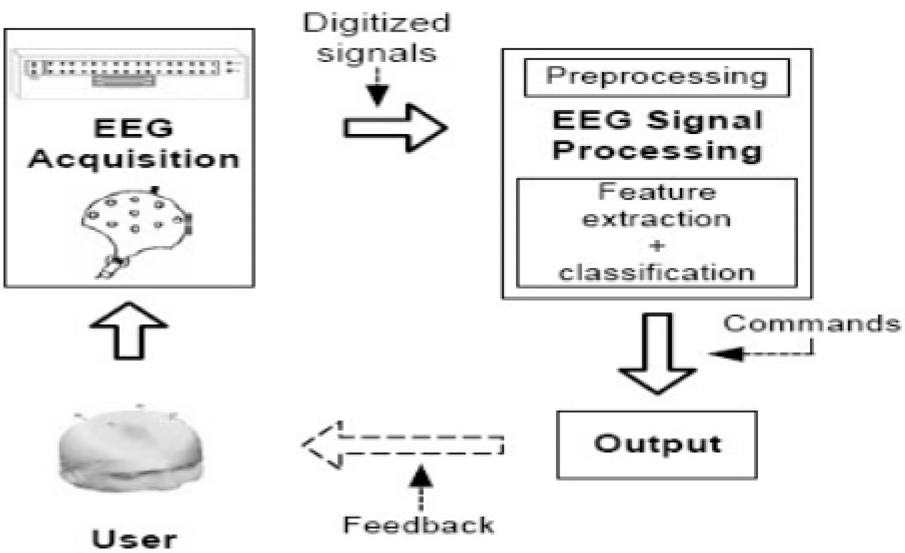
The easiest and least invasive method is a set of electrodes,this device known as an electroencephalograph (EEG) -- attached to the scalp. The electrodes can read brain signals. Regardless of the location of the electrodes, the basic mechanism is the same: The electrodes measure minute differences in the voltage between neurons. The signal is then amplified and filtered. In current BCI systems, it is then interpreted by a computer program, which displayed the signals via pens that automatically wrote out the patterns on a continuous sheet of paper. Even though the skull blocks a lot of the electrical signal, and it distorts what does get through it is more accepted than the other types because of their respective disadvantages.

ELECTROENCEPHALOGRAM BASED BCI

Electroencephalography (EEG) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain.



How BCI works Among the possible choices the scalp recorded electroencephalogram (EEG) appears to be an adequate alternative because of its good time resolution and relative simplicity. Furthermore, there is clear evidence that observable changes in EEG result from performing given mental activities. The BCI system is subdivided into three subsystems, namely EEG acquisition, EEG signal processing and output generation.



Software Required

1.Arduino IDE

The Arduino Integrated Development Environment is a cross-platform application that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards.

2.Matlab

MATLAB is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages

3.4 Arduino Program

```
#include<SoftwareSerial.h>
SoftwareSerial bci(3,4);
#define BAUDRATE 57600
#define LED 13

byte payloadData[32] = {0};
byte Attention[5]={0};
byte checksum=0;
byte generatedchecksum=0;
int  Plength,Temp;
int  Att_Avg=0,On_Flag=1,Off_Flag=0;
int  k=0;
signed int  j=0;


void setup()
{
  Serial.begin(9600);
  bci.begin(BAUDRATE);          // USB
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(6,OUTPUT);
}

byte ReadOneByte()          // One Byte Read Function
{
  int ByteRead;
  while(!bci.available());
  ByteRead = bci.read();
//  Serial.println(ByteRead);
  return ByteRead;
}

void loop()                  // Main Function
{
  digitalWrite(6,HIGH);
  while (1)
  {
    if(ReadOneByte() == 170)        // AA 1 st Sync data
    {
      if(ReadOneByte() == 170)      // AA 2 st Sync data
      {
//        Serial.println("IN");
        Plength = ReadOneByte();
        if(Plength == 32)   // Big Packet
        {
```

```
//          Serial.println("IN1");
        generatedchecksum = 0;
        for(int i = 0; i < Plength; i++)
        {
          payloadData[i]     = ReadOneByte();      //Read payload into memory
          generatedchecksum  += payloadData[i] ;
        }
        generatedchecksum = 255 - generatedchecksum;
        checksum  = ReadOneByte();

        if(checksum == generatedchecksum)        // Varify Checksum
        {
          if (payloadData[28]==4)
          {
            if (j<4)
             {
               Attention [k] = payloadData[29];
               Temp += Attention [k];
               j++;
             }
             else
             {
               Att_Avg = Temp/4;
//               Serial.print("avg att:");
               Serial.println(Att_Avg);
               if (Att_Avg>=40)
               {
                 if(On_Flag==1)
                 {
                Serial.println('A');
                   On_Flag=0;
                   Off_Flag=1;
                 }
                 else if(Off_Flag==1)
                 {
//                   Serial.println('B');
                   On_Flag=1;
                   Off_Flag=0;
                 }
               }
               else
               {
                Serial.println('B');
               }
               j=0;
               Temp=0;
             }
//             Serial.print("att:");
//             Serial.println(Temp);
             delay(1000);
          }
         }
```

```
        }
      }
    }
  }
}
```

3.5Advantages

- It is a measure of Brain function
- Provides direct rather than indirect evidence of epileptic abnormality
- Low cost
- Low morbidity
- Portable
- Can be operated on free will of the user

3.6Applications

- Human Computer Interfaces (BCI)
- Pharmacology
- Intensive care
- Acts as an bionic arm for amputee
- Medical rehabilitation
- Education and study

Chapter 4

4.Conclusion

- In this project, we present a brain-controlled robotic arm system.
- It enables people to communicate and control robotic arm with the use of brain signals
- Numerous future applications
- It is helpful for Arm amputated people

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