Cerebro

A mind controlled prosthetic arm

Amritha Aradhana Bharath Pooja
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***Abstract*—Motor imagery based approach on controlling a 3-Degree of freedom arm with haptic feedback integration**

***Index Terms*—Motor Imagery, Haptics, Robotic Manipulator**

I. INTRODUCTION

The project proposes an approach towards EEG-driven position control of a robot arm by utilizing motor imagery, P300 waveform and Visually evoked Potential to align the robot arm with desired target position.
The user produces motor imagery signals to control the motion of the arm. The P300 waveforms gives us sufficient data to detect whether we are performing any motion or even imagining doing so. This becomes even more accurate with C3, C4, PZ, FZ signals coming into picture. Taking these signals as features gives us appropriate information on the motion imagined by the user. This information can be used to control different parameters that are necessary for controlling the arm.

This Project has a lot of Applications. This will facilitate the living of individuals with upper extremity impairment. The Brain-computer interface can act as a medium for them to use robotic arm for the activities of their daily life. Haptic feedback will give them the sense of touch. This can be achieved by giving neuro-feed back to the brain. The haptic feedback can be very helpful when it comes to invasive surgery using robotic arms.

II. SCOPE OF RESEARCH

The project involves 4 major steps: Signal acquisition, Classification, Inverse Kinematics and haptic feedback. EEG signals are tapped from the scalp using electrodes. A good electrical contact is necessary with impedance lesser than 5kOhms. Signal obtained from the electrodes has to be filtered out of noises and amplified to sufficient amount necessary for processing. The above process can be achieved easily by using Ganglion board. Processed data is fed into Recurrent neural network for classification. The data processed by the ganglion can be sent to the microcontroller serially and this is used to control the robotic arm. A 4 DOF robotic arm is modelled with 2 DOF in shoulder, 1 DOF in elbow and grip being the 4th using Denavit-Hartenberg convention. Haptic feedback is achieved by using force and flex sensors in the robotic arm and by using PDMS haptic balloons. The main application of this project will be to help people with paralysis and other rehabilitative activities. This project can also be used in the field of robotic surgery where a surgery can be conducted by a remote doctor.
A variety of machine learning/deep learning techniques can be experimented for motor imagery classification. We compare all the algorithms and evaluate their results. A comparative analysis can be made to ensure the accuracy of the model. A different method can be tried out instead of the control law specified in this abstract to attain a comparatively better performance.

III. RESEARCH METHODOLOGY

A. Designing the arm

A 3 DOF arm is designed with 2 degrees of freedom at the world-arm joint and 1 degree of freedom at arm-forearm joint. A humanoid hand is in turn connected to the free end of the forearm. The CAD specifications will take into account the quality and cost required for 3D printing the arm. The arm movements are actuated with high torque servos of appropriate specifications.

B. Trajectory tracking

For a given set of coordinate points, the end effector of the arm has to track the points with minimal error possible. Appropriate controller is designed such that the end effector tracks with high accuracy. Since we have limited number of commands from motor imagery, the trajectory to a particular point is followed by a predefined set of rules. This means, the end effector will have to move only in parallel to the axes. If the goal is to reach (2,3) from (1,2), the end effector will reach (1,3) first before reaching (2,3).

C. Electrode Placements

The signals we will be needing for motor imagery are C3, C4, PZ, FZ region. These regions are present in the central region of our head. EEG electrodes are placed in the respective positions along with the reference electrode which is placed over any of the ear lobe. The reference electrode is given as The reference electrode is given to shorted negative terminals of the channels, while the other four electrodes are given to positive terminal of the respective channels.

D. EEG signal Acquisition

ADS1299 is a device by Texas Instruments. It has 8 channels, that is, 8 differential amplifiers. The negative terminal of the amplifiers can be shorted and reference voltage is applied, which will be the same across all negative terminals. The common mode noise is significantly reduced

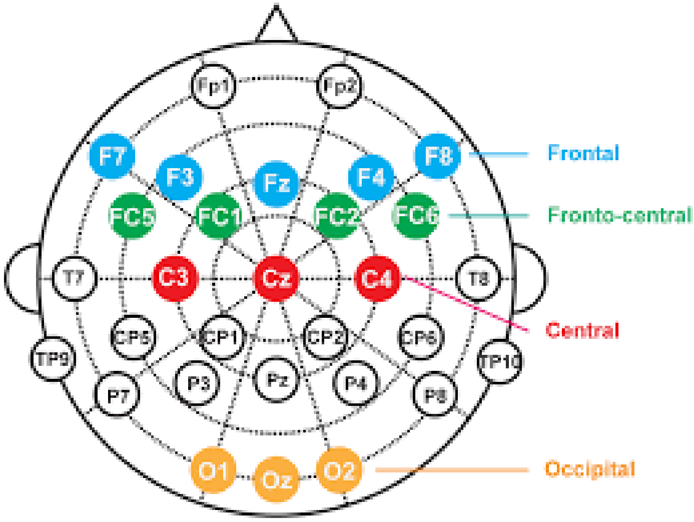

Fig. 1. Electrode placement.

on giving input signals through the differential amplifier. The dc noise is reduced by adding a High pass filter with sufficient cutoff voltage. The 50hz live-line voltage interference can be reduced in a similar way by adding a low pass filter with a cutoff frequency of 40hz. A better way to reduce 50hz noise is to implement second order butter worth filter ,the roll off doubles up reducing the noise even more.

The output signal from ADS1299 is sent to Arduino using serial Peripheral interface.This is further transferred to PC serially. Python receives the serial data and feeds the data to classification algorithm.

E. Motor Imagery Data Classification

The data is saved in a data buffer of length 5 seconds. The number of samples will be the baudrate * 5. This data is fed either to SVM Classifier or CNN or RNN. The model is chosen based on the validation accuracy. SVM is currently the popular algorithm used for EEG signal classification. The classic, one vs rest classification can be used to classify the signals from one another. But using Recurrent Neural Networks may improve the accuracy significantly since EEG signal is a time series. The data is fed into Recurrent neural networks with applicable hyper parameters to get the final output.

F. Integration of sensors and actuators

We have to process data from a variety of sensors and actuators. ROS makes it easier to process and transmit data from these sensors and actuators. A node is created to give out the control commands. Once we receive the classification output from motor imagery node, we get a set of control commands, this is further converted to servo angles data and sent to the servo actuators. A gazebo simulation is to be developed before implementing it in the actual arm.

G. Haptic feedback

The haptic feedback system is to make the user feel the pressure/force experienced by the robotic arm(eg. in case of a robotic surgery). A tactile pneumatic actuator that will input into the sensory system by stimulating the SA mechanoreceptors on the fingers is going to be developed. The inflation of hemispherical balloons increases the force on the skin, creates skin deformation and optimally stimulates both SAI and SAII mechanoreceptors. The elastic balloon modules have the ability to conform to the shape of the fingers allowing uniform distribution of force. The force sensors, kept at different positions in the robotic system converts the mechanical force it experiences to electrical signals. These signals will be processed by Arduino MEGA / DUE. The Arduino will control the individual air pumps for different haptic balloons(either a pressure of 0 psi or 15 psi), based on the signal from different force sensors. This will enable the user to have a good haptic feedback. Each finger in the glove will have 2 haptic balloons and hence a total of 10 haptic balloons for the system.

Procedure for making the microfluidic chip

1. Silanisation of Wafer:

- Silanise your silicon wafer under vacuum for 50-60 min under 720 torr, using chlorotrimethoxysilane.
- Prepare an aluminium boat by cutting two square pieces of aluminium foil and placing them at 45 to each other. Keep this on a circular surface with some depth and mold the aluminium foil accordingly. Make sure that the boats base is wrinkle-free.
- Remove the wafer from the silaniser and place it in an aluminium boat. The aluminium boat acts like a holder for the wafer. Make sure that the wafer is neatly placed at the bottom of the boat and its edges are sealed with no gaps.

2. Making PDMS(Polydimethylsiloxane):

- Place a plastic beaker on the weighing scale, clean it with compressed air before use.
- Pour the PDMS and the curing agent in 10:1 ratio(mostly 40g and 4g respectively)
- Using glass rod stir the mixture vigourously till you see small bubbles forming and the mixture turning white.
- Pour this mixture over your wafer and degas in vacuum for 1h.
- Keep it in the oven at 65C overnight

3. Cutting, Punching and Washing

- Remove the PDMS mould from the afer by carefully peeling off
- Cut out the chips using scalpel from the mould without touching the design
- Punch access holes using 1.5mm biopsy punch

- Wash the chips with soap, DI water, IPA(Iso proply alcohol), acetone and ethanol.
- Dry it using compressed air gun
- Keep it in the oven at 65C for 1 h.
- Make a repeat of process 1-10 using (10g,1g) PDMS and curing agent respectively

4. Plasma Bonding

- Clean the chip and the membrane with compressed air
- Keep them into the Plasma Bonding machine for 3 min(2 min pump, 1min air plasma)
- Remove them and press them firmly so that they bond with each other
- Leave them on the hot plate at 90C for one hour
- Place them in the oven overnight at 65C
- Insert tubing into the holes punched in the chip
- Pass air through the holes
- If the membrane does not rise up
- Gently peel the middle part of the membrane bonded to the chip, be careful to not remove bonding in the edges.
- Attach the tubing to the side of the chip (not through the holes) just below the part where you peeled off.
- Your haptic feedback device is ready to use

TIMELINE

August : Arm design, Trajectory tracking, simulation

September : motor imagery classification, Development of the actuation for haptic feedback

October : Testing of the haptic feedback system, EEG signal acquisition from scalp

December: Arm Assembly/3D print, Complete design of flex sensors and force sensors with robotic hand

January : Interface all the modules

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