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BMS Institute of Technology and Management

(An Autonomous Institution, Affiliated to VTU Belagavi)
Avalahalli, Yelahanka, Bengaluru – 560 119

Student Project Review and Assessment Committee

Synopsis

Batch No: 13 **Date:**

Subject Name & Code: Major Project Phase-I, BEEP606 (VI Semester)

Area of Specialization:

Guide: Dr. Prashant A Athavale

Project Title: Characterizing the Brain Waves associated with controlled hand movement.

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Project Category	

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Abstract:

Understanding brain waves associated with controlled hand movement is crucial for advancements in brain-computer interfaces (BCIs) and neurorehabilitation. This study focuses on characterizing the brainwave patterns linked to intentional hand movements by analyzing electroencephalogram (EEG) signals. EEG provides a non-invasive method to detect and recognize neural activity related to motor actions.

We employ signal processing and machine learning techniques to extract and analyze features from EEG data recorded during controlled hand movements. Key frequency bands such as Alpha (8–13 Hz) and Beta (14–30 Hz), which play a significant role in motor control, are examined. Time-frequency analysis methods, including wavelet transforms and power spectral density estimation, are used to identify characteristic patterns associated with different hand movements. Additionally, spatial filtering techniques like common spatial patterns (CSP) enhance signal discrimination.

To demonstrate real-time applications, we integrate a system that visualizes EEG signals on a monitor while the subject moves a cursor from point A to point B using controlled hand movements. This setup provides immediate feedback on the neural activity associated with motor execution, aiding in performance evaluation and improving BCI responsiveness.

Machine learning models, including deep learning approaches, are trained to classify hand movements based on extracted features. Performance is evaluated using metrics such as accuracy, precision, and recall. The results provide insights into the distinct neural signatures of hand movements, contributing to the development of more efficient BCIs for assistive technologies, prosthetics, and rehabilitation systems.

By characterizing brain waves associated with hand movement and integrating real-time visualization, this research enhances our understanding of motor control mechanisms and facilitates practical neuroadaptive applications.

Introduction:

Anatomy of Brain:

The human brain is divided into two hemispheres, each controlling the opposite side of the body, and consists of four main lobes: the frontal, parietal, temporal, and occipital lobes. The cerebellum, located at the back of the brain, plays a key role in balance and movement coordination. Among these regions, the frontal and parietal lobes are most crucial for voluntary hand movements. The primary motor cortex (M1) in the frontal lobe is responsible for generating neural signals that direct muscle movement, while the premotor cortex and supplementary motor area (SMA) assist in movement planning and coordination. The somatosensory cortex, located in the parietal lobe, processes sensory feedback from the hand, helping refine movement control.

Beyond the cortex, deeper structures like the basal ganglia regulate movement initiation and suppression, ensuring smooth execution, while the cerebellum fine-tunes precision and coordination. These regions communicate via neural pathways such as the corticospinal tract, which transmits motor commands from the brain to the hand muscles. EEG primarily detects electrical activity from the cortex, making the motor and sensory cortices the main sources of brainwave signals associated with hand movement. By analyzing these signals, we can better understand and model brain activity related to voluntary motor control, which is essential for applications in brain-computer interfaces (BCIs) and neurorehabilitation.

Brain Waves:

Brain waves are patterns of electrical activity in the brain, generated by neurons as they communicate. They are categorized into different frequency bands, each associated with specific brain functions. Delta waves (0.5–4 Hz) are the slowest and linked to deep sleep, while theta waves (4–8 Hz) are connected to relaxation and light sleep. Alpha waves (8–12 Hz) occur when the brain is calm but alert, often seen when a person is resting. Beta waves (13–30 Hz) are associated with active thinking, problem-solving, and movement control, making them crucial for motor function. Gamma waves (30–100 Hz) are the fastest and are linked to higher cognitive processes like perception and consciousness. In the context of hand movements, the mu rhythm (8–12 Hz), a type of alpha wave, and beta waves play a significant role. Mu waves are typically present when a person is at rest but decrease when they prepare for or perform a movement. Beta waves increase during active movement and motor planning. EEG captures these brainwave patterns, allowing researchers to analyze motor-related activity and develop applications like brain-computer interfaces (BCIs) for movement control.

Signal Acquisition Currently Used:

Signal acquisition methods for brain activity measurement primarily focus on capturing electrical signals generated by neurons. The most widely used technique is electroencephalography (EEG), which records brain waves non-invasively using electrodes placed on the scalp. EEG is popular due to its high temporal resolution, portability, and affordability. It captures signals from the motor and sensory cortices, making it ideal for detecting brain activity related to hand movements. However, EEG has limitations, such as susceptibility to noise and lower spatial resolution. Other non-invasive methods include magnetoencephalography (MEG), which records magnetic fields produced by neural activity, offering better spatial accuracy but at a much higher cost. Functional near-infrared spectroscopy (fNIRS) is another non-invasive technique that measures changes in blood oxygenation, indirectly reflecting brain activity but with lower temporal precision compared to EEG.

For more precise and direct brain activity recording, invasive methods like electrocorticography (ECoG) and local field potentials (LFPs) are used. ECoG involves placing electrodes directly on the brain's surface, providing higher signal clarity and spatial resolution than EEG, but requiring surgical implantation. LFPs, recorded using microelectrodes implanted deep within the brain, capture neural activity at a very fine level and are commonly used in research on movement control and brain-computer interfaces (BCIs). While invasive techniques provide more accurate data, they pose risks such as infection and long-term stability concerns. Depending on the application, researchers choose between non-invasive EEG for real-time applications and invasive methods for high-precision studies in clinical and experimental settings.

Motivation:

The human brain has the incredible ability to control movements, but some people lose this ability due to conditions like paralysis, stroke, or nerve damage. A Brain-Computer Interface (BCI) can help by allowing people to control devices using only their brain signals, without needing physical movement. This technology can improve the lives of those with disabilities by helping them perform daily tasks, operate prosthetic limbs, or control wheelchairs using their thoughts. To achieve this, we need to develop a model that can accurately understand and recognize brain waves linked to hand movements.

In this project, we will study EEG signals, which are brain waves recorded from the scalp, to detect and recognize patterns related to hand movements. We will also display these signals in real-time on a screen while the user moves a cursor from one point to another using brain activity. This will help us understand how the brain controls movement and improve the accuracy of BCIs. By using signal processing and machine learning, we can build a system that learns to recognize movement-related brain signals more effectively.

Additionally, showing brain activity in real-time will make BCIs easier to use and more interactive. This will help users adjust their thoughts for better control over devices. By combining brain signal monitoring with advanced computer models, we aim to create a more reliable and practical BCI system. This technology can be useful not only for medical purposes but also for fields like gaming, robotics, and virtual reality. Our goal is to make brain-controlled systems smarter, more efficient, and accessible to those who need them.

Objectives:

- Record the brain signals associated with the hand movement.
- Refine the method to acquire suitable signals.
- Detect signature pattern in the recorded signals associated with cursor displacement.
- Study on mouse or touchpad movement efficacy.

Methodology:

The methodology for this project involves the acquisition, processing, and analysis of EEG signals to identify patterns associated with cursor movement. The following steps outline the process:

1. **Data Acquisition**:
   EEG signals are recorded using the Ultracortex "Mark IV" EEG Headset while individuals of different age groups perform the task of moving a cursor from Point A to Point B through various paths. This ensures the collection of diverse neural responses related to hand movement.
2. **Preprocessing and Noise Reduction**:
   The acquired EEG signals undergo preprocessing to remove artifacts and noise. Standard filtering techniques are applied to enhance signal clarity and eliminate interference.
3. **Feature Extraction and Analysis**:
   Various signal processing techniques, such as Wavelet Transform, are employed to extract relevant features from the EEG signals. These features are analyzed to identify common patterns in brain activity corresponding to cursor movement.
4. **Data Comparison and Pattern Recognition**:
   The extracted features are compared across different age groups to detect similarities and variations in brain activity during cursor displacement. Statistical and machine learning techniques may be used to recognize significant patterns.
5. **Implementation and Validation**:
   The entire processing and analysis workflow is implemented using MATLAB, which provides robust tools for signal analysis and visualization. The results obtained will be validated by comparing them with existing research findings to ensure accuracy and reliability.

This structured approach enables a comprehensive understanding of EEG-based hand movement patterns and contributes to advancements in brain-computer interface (BCI) research.

Materials required:

- OpenBCIgui software
- Matlab software
- Ultracortex “Mark IV” EEG Headset
- LED display
- Mouse/Touchpad

References:

- **https://docs.openbci.com/**
- EEG SIGNAL PROCESSNG by Saeid Sanei and J.A. Chambers.
- https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Synopsis for the Project, Phase-I (BEEP606)

"Characterizing The Brain Waves Associated With Controlled Hand Movement"

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2025-2026