Christian-Albrechts-Universität zu Kiel

Technische Fakultät

Pattern Recognition Techniques in Brain Computer Interface (BCI)

Souvick Chakraborty

Master‘s Student,
Christian-Albrechts-Universität zu Kiel
Institute of Electrical and Information Engineering

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

Contents

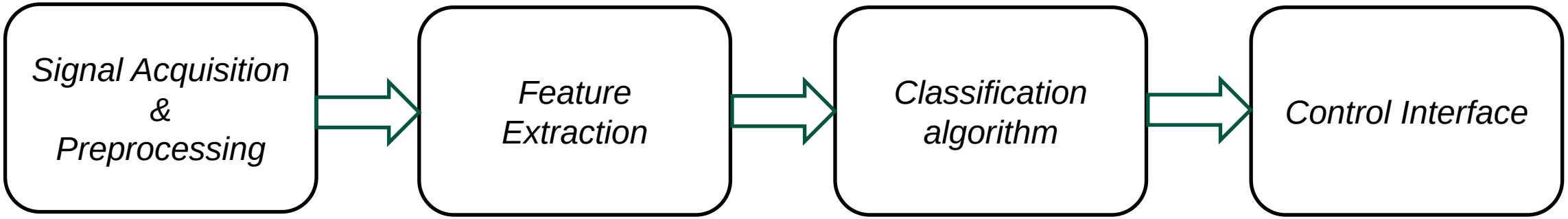
- *Introduction*
- *Signal Acquisition and Preprocessing*
- *Feature Extraction*
- *Classification Algorithm*
- *Conclusion*

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

- **Definition:**

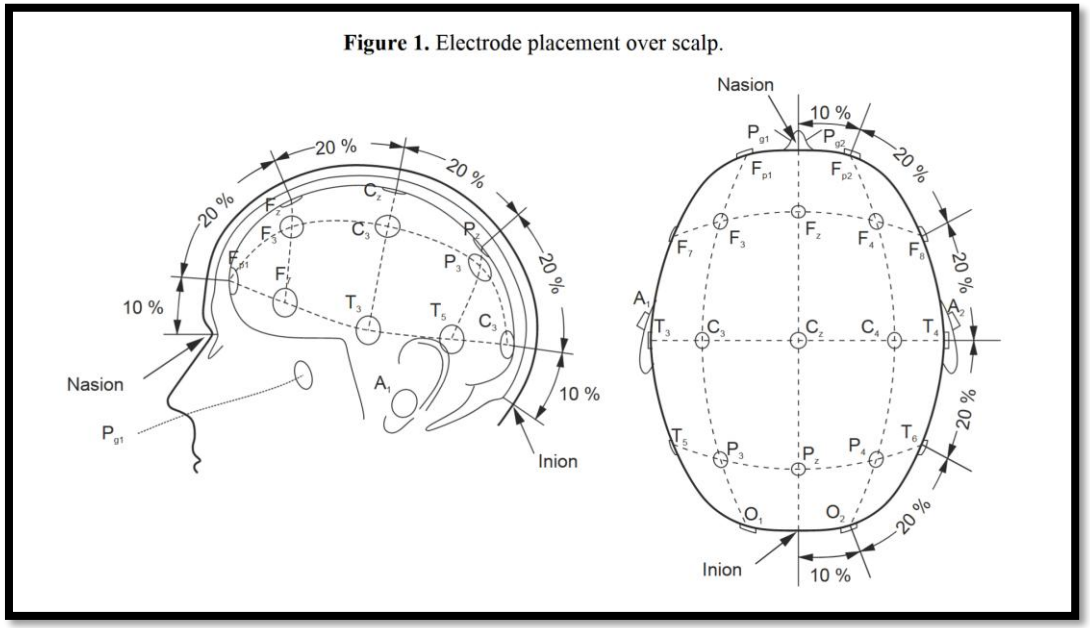
  BCI is a system that records central nervous system (CNS) activity and translates it into artificial outputs that replace, restore, enhance, or improve natural CNS outputs.

- It can recognize a certain set of patterns in brain signals in five consecutive stages:

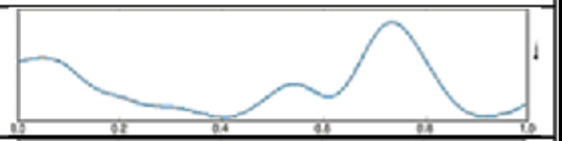
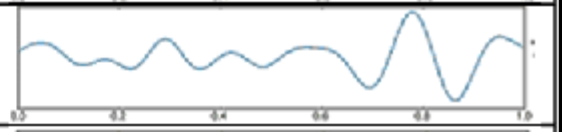
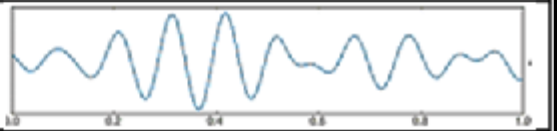
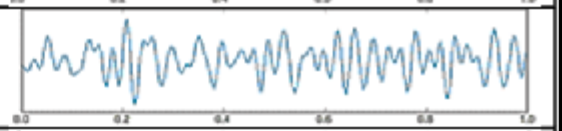
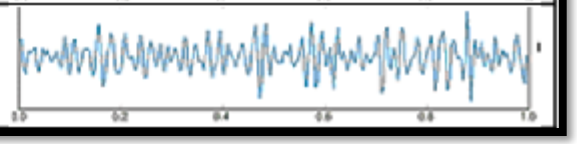


❑ Signal Acquisition and Preprocessing:

1. BCIs measure electrophysiological (e.g., EEG) or hemodynamic activity
2. Electrophysiological activity refers to the electrical activity produced by neurons.
3. Hemodynamic activity is related to metabolic processes
4. EEG signals are non-stationary; statistical properties (*like mean, variance, or frequency content*) change over time



❑ Brain Signals:

Waves	Frequency bands (Hz)	Behaviour Trait	Signal Waveform
Delta	0.3 – 4	Deep sleep	
Theta	4 – 8	Deep Meditation	
Alpha	8 – 13	Eyes closed, awake	
Beta	13 – 30	Eyes opened, thinking	
Gamma	30 and above	Unifying consciousness	

Feature Extractions

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

❑ Short Time Fourier Transform:

1. EEG signal (Time domain Signal) is divided into smaller time-domain frames (e.g., 128-point segments) with 50% overlap

2. A window function (e.g., Hamming window) is applied to each segment to reduce edge effects and spectral leakage

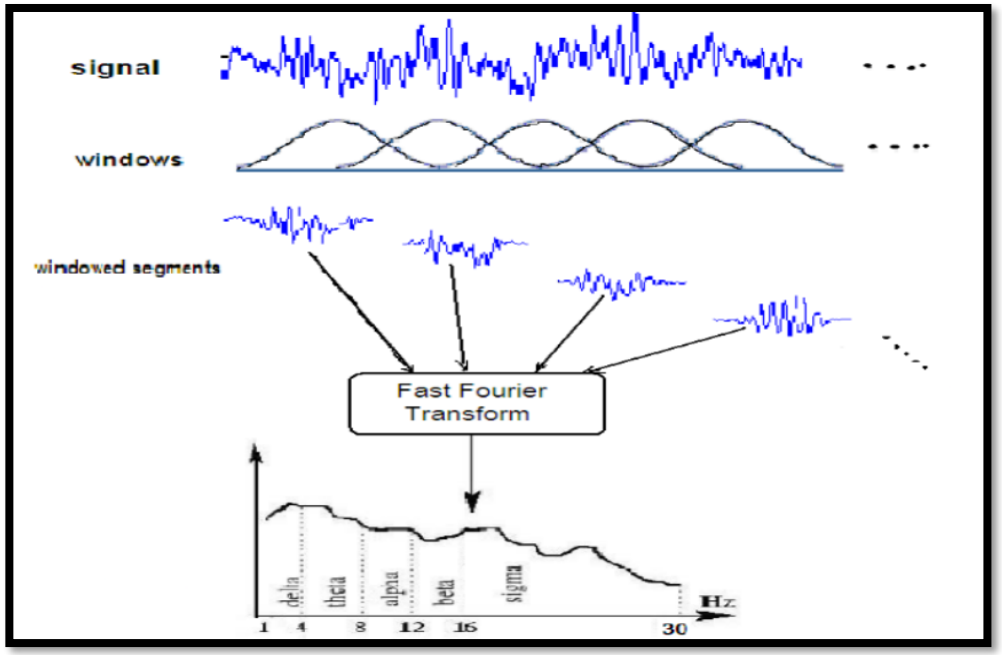
3. The **FFT** is applied to each windowed segment, converting it from the time domain to the frequency domain

$$X_{\mathrm{STFT}}[m,n] = \sum_{k=0}^{L-1} x[k]w[k-m]e^{-j2\pi nk/L}$$

❑ Short Time Fourier Transform:

4. The process is repeated for all segments by sliding the window along the signal. For overlapping segments, the window shifts by a fraction of the segment length

5. The outputs of the FFTs are combined, providing a representation of how the signal's frequency content changes over time.



Feature Extractions

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

❑ Feature vectors Generation:

1. Once the frequency spectrum is obtained by summing the FFT results over time, the next step is to divide this spectrum into **30 frequency bands**, each of 1 Hz width

2. This step isolates the power in each specific 1 Hz band

3. After the power values for each of the 30 bands are calculated and normalized, we end up with a *Feature vector* of **30 values**

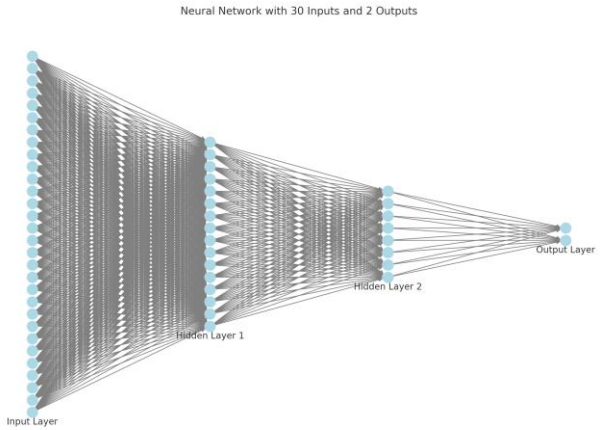
4. This feature vector (representing the frequency content of the signal) is used as input to a **neural network** for further processing or classification.

Classification Algorithm

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

❑ Artificial Neural Networks(ANN) : Design

1. Number of inputs, outputs and layers, and the activation function of neurons
2. The number of neurons in the **input layer corresponds to the number of features** in the input feature vector(e.g. 30)
3. The number of hidden layers is determined by the practical situation(e.g. 2)
4. The number of neurons in the **output layer** depends on the number of tasks being classified (e.g. mental arithmetic, a right click on the mouse,)
5. The hidden layers use a **sigmoidal function** as their activation function
6. The output layer uses a **linear activation function**

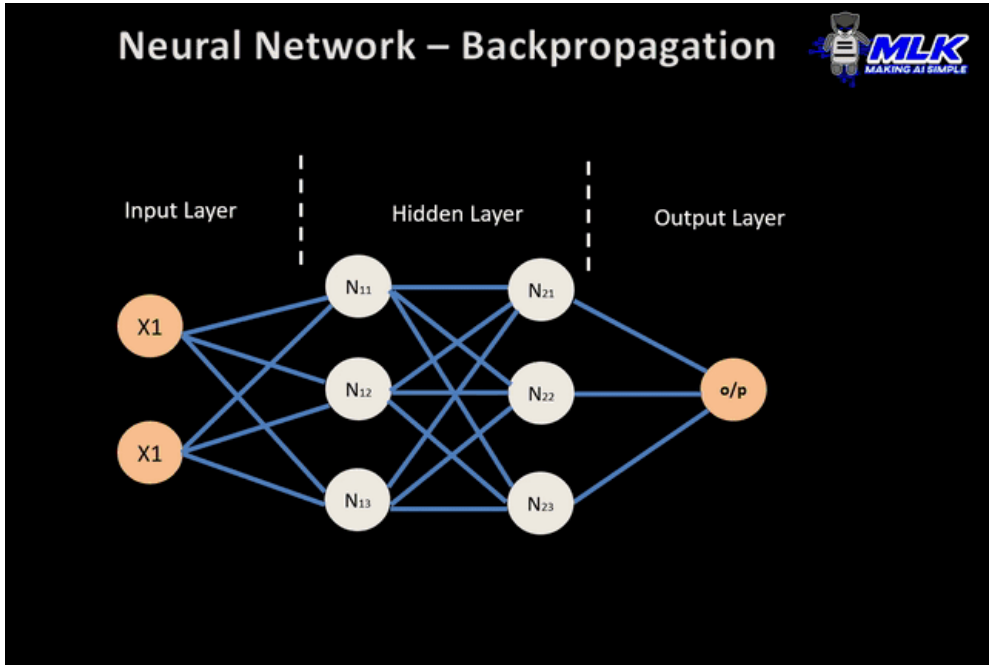


Classification Algorithm

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

❑ Artificial Neural Networks(ANN) : Training and Testing

1. The training phase consists of determining the weights of the connections of the network through a learning algorithm such as *Back propagation* on a pre-classified labeled data



Christian-Albrechts-Universität zu Kiel

Technische Fakultät

❑ Artificial Neural Networks(ANN) : Training and Testing

2. The training continues until the **Mean Square Error (MSE)** falls below 0.0001, or a maximum of 20,000 iterations is reached

3. Once trained, the ANN can classify new, unseen feature vectors (i.e., New Input EEG Signal) which can be used for specific tasks

Classification Algorithm

Christian-Albrechts-Universität zu Kiel
Technische Fakultät

❑ **References:**

1. *Nicolas-Alonso, Luis Fernando, and Jaime Gomez-Gil. "Brain Computer Interfaces, a Review." Sensors 12, no. 2 (February 2012): 1211–79. https://doi.org/10.3390/s120201211.*

2. *Pawar, Dipti, and Sudhir Dhage. "Feature Extraction Methods for Electroencephalography Based Brain-Computer Interface: A Review" 47, no. 3 (2020).*

3. *Suleiman, Abdul-Bary Raouf and Toka A. Fatehi. "FEATURES EXTRACTION TECHNIQES OF EEG SIGNAL FOR BCI APPLICATIONS." (2011).*

Christian-Albrechts-Universität zu Kiel
Technische Fakultät