THE AMERICAN UNIVERSITY IN CAIRO

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CSCE 363/3611 - Digital Signal Processing

Attention State Assessment using EEG

Seif Eldawlatly

Neural Engineering

- Neural Engineering is a field of research that focuses on engineering methods to investigate the function of the central and peripheral nervous system and manipulate its behavior

- Neural Interfaces are systems that can help restore sensory function, communication, and control to impaired humans

- The main principle is that disabled people would have their brains or parts of their brains fully functional

- Neural Interfaces make use of functional parts to restore a lost function

- Objectives of Neural Engineering:

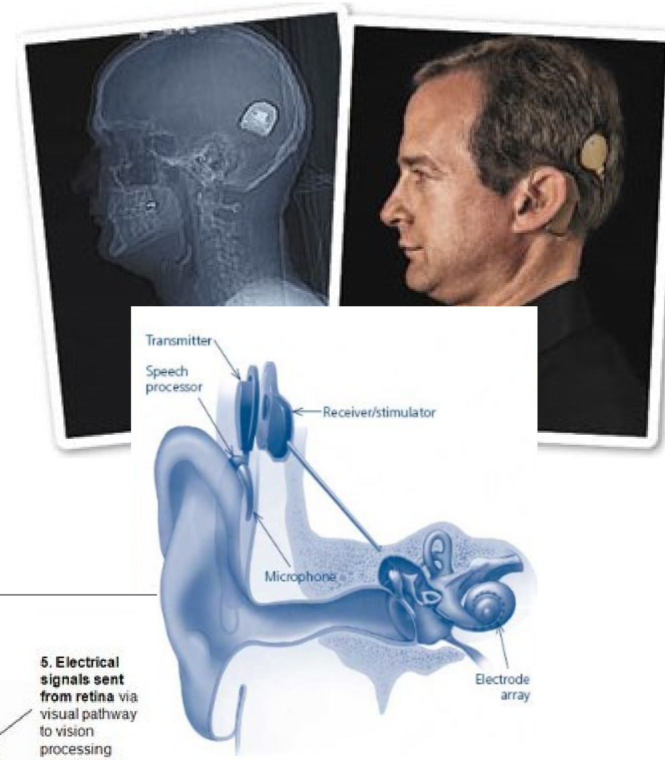
  1- Understand Brain Function

  2- Provide Therapeutic, Assistive and Augmentative Technology

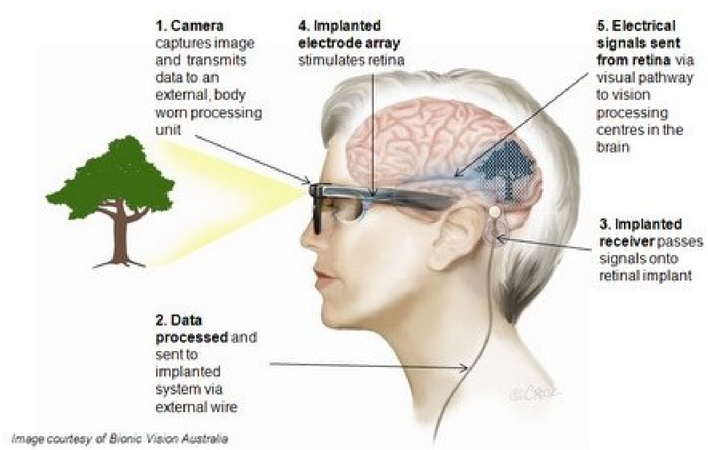
Neural Engineering

- Examples of Neural Interfaces:

Motor Brain-Machine Interface



Cochlear Implant

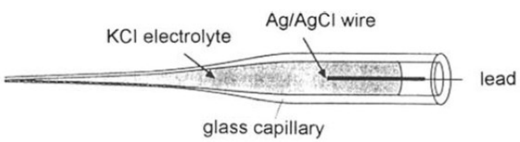


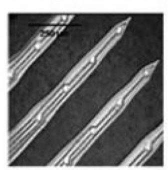
Visual Prosthesis

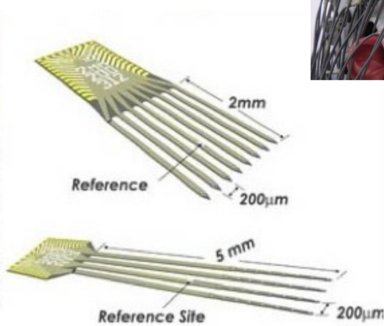
Neural Engineering

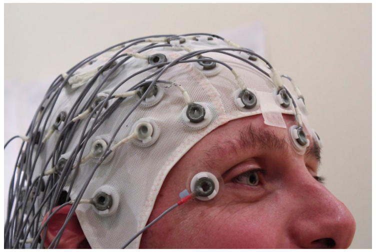
- Types of Neural Interfaces

- **Neural Interfaces**
  - **Invasive**
    - **Single Recording Sites**
    - **Multiple Recording Sites**
  - **Non-Invasive**
    - **EEG**
    - **fMRI**





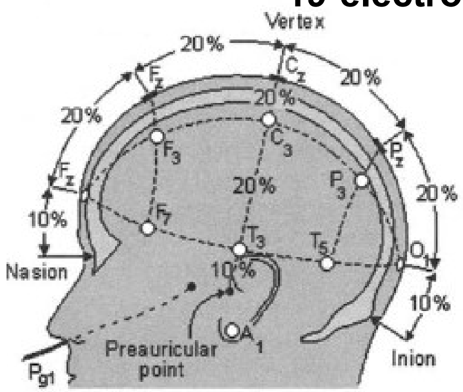


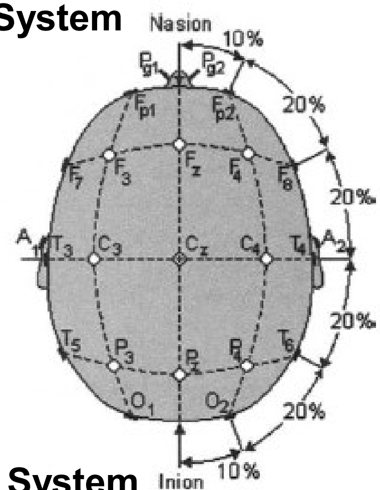


Electroencephalography (EEG)

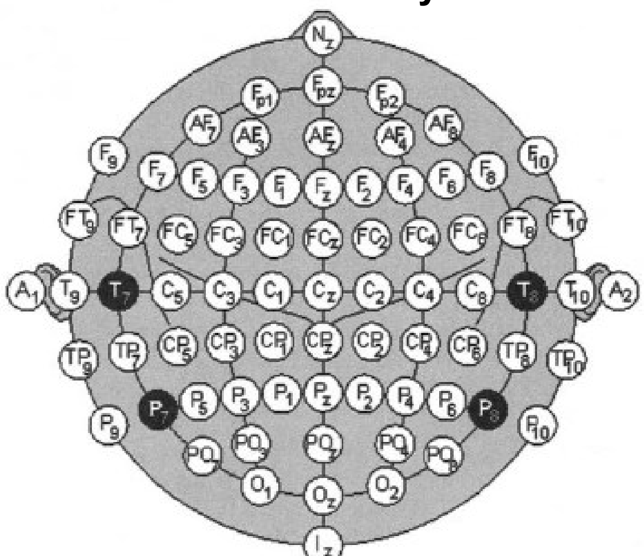
- Many EEG-based systems use an electrode placement strategy suggested by the International 10/20 system

19-electrode System





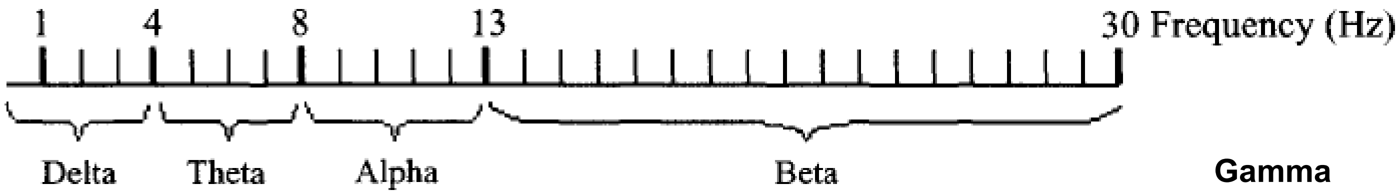
64-electrode System



F: Frontal
C: Central
P: Parietal
O: Occipital
T: Temporal

EEG Frequency Bands

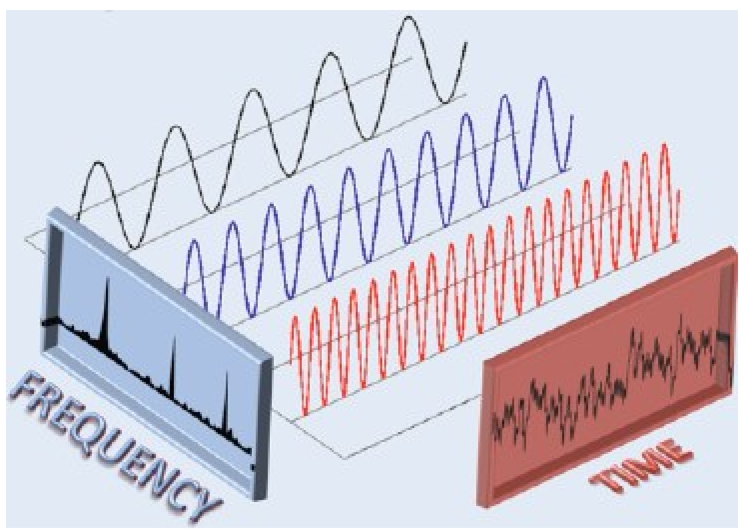
- Signals recorded from EEG are split into several bands



Gamma

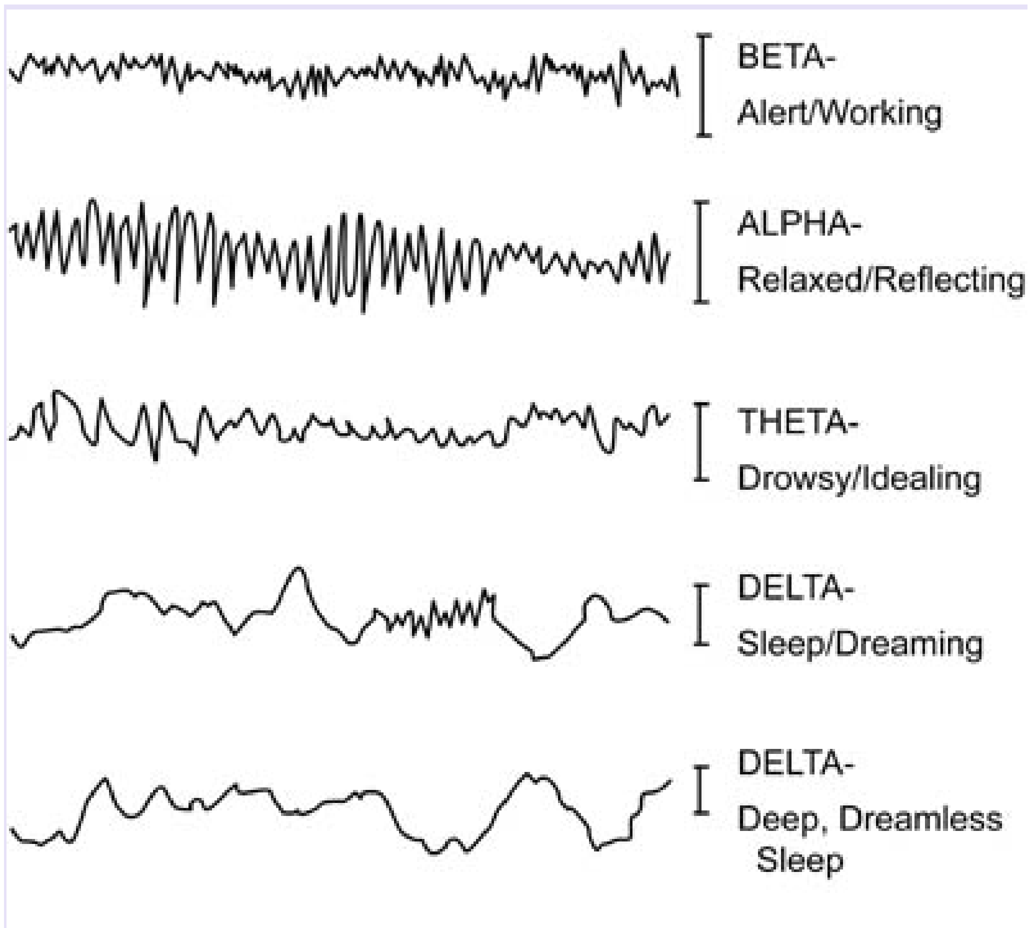
0.5 – 4Hz 4 – 8 Hz 8 – 13 Hz 13 – 30 Hz 30 – 45 Hz

- Each frequency band has some correlation with different mental functions



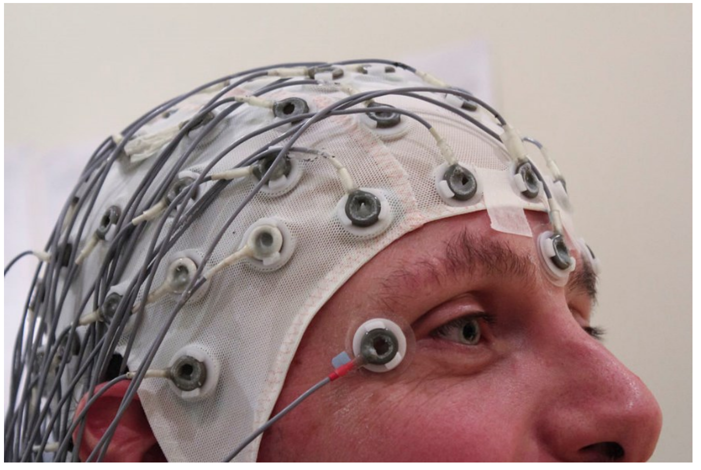
EEG Frequency Bands

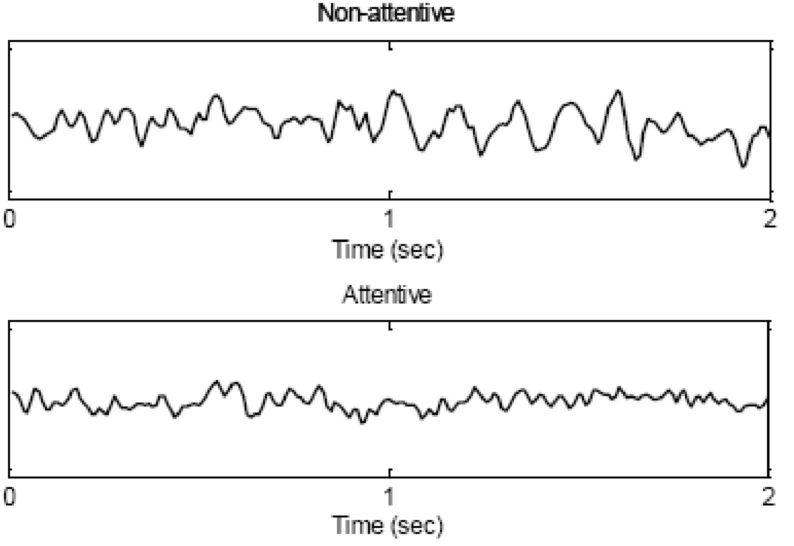
- EEG frequency bands and consciousness



Attention State Assessment

- EEG electrodes are used to record brain activity from the scalp





- EEG signal processing can help in monitoring attention levels

Applications

- Driver attention assessment

https://www.youtube.com/watch?v=30W9SzPooSg

- Focus enhancement

https://www.youtube.com/watch?v=VG9N9A1dzbY

Algorithm to Implement

1. Apply Common Average Reference (CAR) filter to the data

2. For each electrode do the following:
   - 2.1 For each trial of each class of attention (focused versus drowsy):
     - 2.1.1 Compute the Fourier Transform of the trial signal
     - 2.1.2 Compute the power in each of the delta, theta, alpha, beta, and gamma bands as the mean of the power of the frequencies in each band
   - 2.2 Form a feature vector as required in each deliverable in the project description
   - 2.3 Apply K-Nearest Neighbor (KNN) classifier examining K from 1 to 10 using the training and test datasets
   - 2.4 Compute the classification error for each value of K

Common Average Reference (CAR) Filter

- Eliminates the common noise across electrodes
- The mean of all channels at each time instant acts as a reference
- This reference is subtracted from each channel. It can be represented as follows

$$r_i(j) = s_i(j) - \frac{1}{N}\sum_{k=1}^{N} s_k(j)$$

where $s_i(j)$ represents the raw signal recorded on electrode i at time j, $r_i(j)$ represents the filtered signal and N is the total number of channels

K-nearest Neighbor (KNN) Classifier

- Most basic instance-based method

- Uses Euclidean distance to determine how dissimilar a pair of points are

$$d(\mathbf{x}_i, \mathbf{x}_j) = \sqrt{\sum_{r=1}^{n} (x_{ir} - x_{jr})^2}$$

- For any new input vector, the nearest K points are considered

- A majority voting scheme is used to classify the new input vector

K-nearest Neighbor (KNN) Classifier