Signal processing

Signal processing and analysis forms a basic step in feature extraction and classification of signal components. The paper presents a specific method to find signal change-points based on differences of its frequency components in selected frequency

bands fundamental for EEG signal analysis.

An initial step in acquiring the desired features from the EEG signals is preprocessing the collected EEG signals and using digital filters to remove any undesirable frequency components such as transient noise, eye movements and so on. The proposed algorithm

allows processing of general multi-channel signals in the graphical user interface enabling selection

of filter structure and having possibilities of different kinds of visualization. Methods of

signal segmentation using signal frequency components form the main part of the contribution.

Time Domain Analysis

Our first approach was to feed the EEG data of the participant directly into the classifier

Frequency Domain Analysis

Any time-dependent signal can be decomposed into a set of sinusoids. In this way, lengthy and noisy EEG recordings could be plotted in a frequency (power) spectrum in a convenient. This domain transformation reveals various features regarding the recorded data that where not previously detected. By adding all the sinusoids up after FFT, the original signal can be restored, so no information is lost

Discrete Wavelet Transform

The decomposition of the EEG signal into the different frequency bands is achieved by the process of simply performing low-pass and high-pass of the time domain signal which yields approximation (A) and detailed (D) coefficients respectively. The low pass filter’s output is further subjected to the same process of low-pass and high-pass filtering. This is repeated until the number of levels of decomposition desired is reached. The outputs from both the filters are down sampled at each stage. For this reason, the sampling frequency of the signal should be at least two times that of the maximum frequency to be analyzed. Another point worth mentioning is the importance of the number of levels of decomposition in addition to selection of suitable wavelet in the analysis of signals using (discrete) wavelet transform. The number of levels of decomposition is chosen based on the dominant frequency components of the signal. We chose the decomposition levels on a basis such that we retain parts of the signal that correlate well with the frequencies required for classification. The wavelet can be chosen depending on how smooth the signal is and also on the basis of the amount of computation involved. In this work, the sampling frequency is 128 Hz and thus the highest frequency that the signal could contain, from Nyquist’ theorem, would be 64 Hz. Frequency bands corresponding to five decomposition levels for wavelet db4 (4 taps) with sampling frequency of 128 Hz.

**Delta band (1 - 4 Hz)**

Being the slowest and highest amplitude brainwaves, oscillations in the 1 – 4 Hz range are characterized as delta waves. Delta waves are characteristically present during deep NREM sleep (stage 3) which is known as slow-wave sleep (SWS). In sleep labs, delta band power is examined to assess the depth of sleep. The stronger the delta rhythm, the deeper the sleep. Delta frequencies are stronger in the right brain hemisphere, and the sources of delta are typically localized in the thalamus. Since sleep is associated with memory consolidation, delta frequencies play a core role in the formation and internal arrangement of biographic memory as well as acquired skills and learned information.

**Theta band (4 - 8 Hz)**

Brain oscillations within the 4 – 8 Hz frequency range are referred to as theta band. Studies consistently report frontal theta activity to correlate with the difficulty of mental operations, for example during focused attention and information uptake, processing and learning or during memory recall. Theta frequencies become more prominent with increasing task difficulty. This is why theta is generally associated with brain processes underlying mental workload or working memory. Theta can be recorded from all over cortex, indicating that it is generated by a wide-ranging network involving medial prefrontal areas, central, parietal and medial temporal cortices. Apparently, theta serves as carrier frequency for cognitive processing across brain regions that are further apart.

**Alpha band (8 - 12 Hz)**

Alpha is defined as rhythmic oscillatory activity within the frequency range of 8 – 12 Hz. Alpha is generated in posterior cortical sites, including occipital, parietal and posterior temporal brain regions. Alpha waves have several functional correlates reflecting sensory, motor and memory functions. You can see increased levels of alpha band power during mental and physical relaxation with eyes closed. By contrast, alpha power is reduced, or suppressed, during mental or bodily activity with eyes open. Alpha suppression constitutes a valid signature of states of mental activity and engagement, for example during focused attention towards any type of stimulus. You could also say that alpha suppression indicates that your brain is gearing up to pick up information from various senses, coordinating attentional resources and focusing on what really matters in that particular moment.

**Beta band (12- 25 Hz)**

Oscillations within the 12 – 25 Hz range are commonly referred to as beta band activity. This frequency is generated both in posterior and frontal regions. Active, busy or anxious thinking and active concentration are generally known to correlate with higher beta power. Over central cortex (along the motor strip), beta power becomes stronger as we plan or execute movements, particularly when reaching or grasping requires fine finger movements and focused attention. Interestingly, this increase in beta power is also noticeable as we observe others’ bodily movements. Our brain seemingly mimics the limb movements of others, indicating that there is an intricate “mirror neuron system” in our brain which is coordinated by beta frequencies (Zhang et al., 2008).

**Gamma band (above 25 Hz)**

At the moment, gamma frequencies are the black holes of EEG research as it is still unclear where exactly in the brain gamma frequencies are generated and what these oscillations reflect. Some researchers argue that gamma, similar to theta, serves as a carrier frequency for binding various sensory impressions of an object together to a coherent form, therefore reflecting an attentional process. Others argue that gamma frequency is a by-product of other neural processes such as eye-movements and micro-saccades, and therefore do not reflect cognitive processing at all. Future research will have to address the role of gamma in more detail.

The DEAP dataset is composed of two main components. The main component of interest is the first one which is the ratings from an online self-assessment. A total of 120 one minute sample of music videos was shown to and rated by the volunteers based on arousal, valence, dominance and liking. Each one of the 32 (male and female) volunteers watched a subset of 40 videos from the priori mentioned music videos. EEG and physiological signals were recorded whilst watching the videos and each participant rated the videos according to the video’s impact on them.

For the purpose of our experiment, we use the preprocessed data which was down sampled from 256 Hz to 128 Hz with artifacts removed via filtering. The physiological/EEG data recordings from the DEAP experiment were provided in MATLAB and Python format. This format is especially beneficial for testing different classification or regression techniques without hassle of explicitly processing all the data first.

The dataset contains 40 experiments for each of the 32 participants. The labels array contain the valence, arousal, dominance and liking ratings for each participant for each of the 40 experiments. The data array contains 8064 physiological/EEG signal data from 40 different channels for each of the 40 experiments for each of the 32 participants. We then select a subset of 12 channels from the original 40 channels. These 12 channels are the frontal, frontopolar, temporal and centeral channels as these channels carry the most significant information regarding the brain activity.