EEG Power Spectrum

Subjects: Automation & Control Systems

Contributor: Taewoong Park , Mina Lee , Taejong Jeong , Yong-Il Shin , Sung-Min Park

The electrical activity of the brain reflected in the electroencephalogram (EEG) is determined by neurons, glia cells, and the blood-brain barrier, which is mainly caused by nerve cells.

EEG power spectrum   EEG signal processing   Mu wave

1. Introduction:

The electrical activity of the brain reflected in the electroencephalogram (EEG) is determined by neurons, glia cells, and the blood-brain barrier, which is mainly caused by nerve cells. Gliocytes, which makeup half of the brain's weight, regulate the flow of ions and molecules at the synapse, and repair structures between nerve cells. The blood-brain barrier serves to select and pass only the necessary substances among various substances in the cerebral blood vessels. Changes in brain waves caused by glial cells and blood-brain barriers occur little by little, whereas changes in brain waves caused by nerve cell activity are large, fast, and diverse.

The EEG generated in this way looks like a waveform that vibrates in a very complex pattern. Therefore, it is not very useful to visually observe the EEG waveform. Frequently, when observing EEG, power spectrum analysis that classifies according to frequency is used. Power spectrum analysis assumes that the EEG is a linear combination of simple vibrations that vibrate at a specific frequency, and decomposes each frequency component in this signal to indicate its magnitude (or power). In general, brain waves are artificially called delta (δ) wave (0.2 ~ 3.99 Hz), theta (θ) wave (4 ~ 7.99 Hz), and alpha (α) wave (8 ~ 12.99 Hz), beta (β) wave (13 ~ 29.99 Hz) and gamma (g) wave (30 ~ 50 Hz) depending on the range of oscillating frequencies

Delta wave is prominent, especially in deep sleep in normal people or in newborns. If the delta wave is much higher than the average range in awake people, it may be a malignant tumor of the cerebral cortex, anesthesia or coma. If the delta wave stands out even in the case of a healthy normal person, most of the cases when the brain waves are measured, the eyes are blinked or the body is moved heavily. The frequency-domain of the artifacts caused by these eye movements or body movements is almost identical to the delta wave frequency domain, so it may appear as if the delta wave has increased. Therefore, when an EEG measurement experiment is performed for a long time, the power spectrum of delta waves is not usually considered as an analysis factor because eye movement and body movement are essential.

Theta wave mainly occurs in the process leading to emotional stability or sleep and is more distributed in children than adults. Theta wave has been reported to be related to many different conditions such as memory, superpower, creativity, concentration, and anxiety, but the experimental protocol and subject characteristics are slightly different for each researcher, so the direction of increase and decrease in each cerebral cortex region is consistent.

Alpha wave usually appears in a relaxed state, such as relaxation, and the amplitude increases with a stable and comfortable state. In general, it appears continuously in the form of regular waves, with the largest recorded in the parietal and occipital regions and the smallest in the frontal region. In particular, when a stable alpha wave appears, it is when you close your eyes and is in a true state. When you open your eyes, look at objects, or become emotionally excited, the alpha wave is suppressed. Alpha wave is closely related to brain development and is measured at 4 to 6 Hz in infancy, but the frequency increases with age and reaches adult values by 20 years.

Beta wave usually appears in the brain's frontal area, and it appears when you are awake and doing all conscious activities, such as speaking. In particular, it may appear predominantly in anxiety, tension, and complicated calculations.

It is reported that gamma wave vibrates more rapidly than the beta wave, and is more emotionally irritated or related to advanced cognitive information processing such as reasoning and judgment.

Delta, theta, alpha, beta, and gamma wave are frequency domains of brain waves that are conveniently classified for convenience. Some researchers even analyze the sub-divisions such as Low Alpha, Middle Alpha, and High Alpha. Researchers who want to analyze EEG characteristics of a specific state usually observe power spectrum distributions first showing the distribution of power for each frequency component from 0 to 50 Hz, and then find meaning to find meaningfully changing frequency components.

This power spectrum distribution shows a slightly different pattern for each measurement area on the head surface. The cerebral cortex under the head surface is largely divided into the frontal lobe, parietal lobe, temporal lobe, and occipital lobe. For example, the occipital lobe, which corresponds to the back of the head, has the primary visual cortex, which is responsible for the processing of primary visual information.

2. Relative / Absolute Power Spectral Density (PSD)

Relative PSD is defined as the ratio of the PSD to the frequency band to be analyzed and the total frequency band. The advantage of the relative PSD is that in the conduction of the skull and scalp, the inter-individual deviation associated with absolute power due to the inter-individual difference is reduced[1]. However, the disadvantage of relative PSD by definition is that only a change in one frequency band, the total frequency band of the denominator, affects the change in the relative PSD. For example, the force of a specific frequency band and the object to be analyzed does not change, but as the PSD increases in other frequency bands, the relative PSD decreases. Therefore, it is difficult to accurately analyze brain changes from the viewpoint of a specific frequency band based on the relative PSD. Therefore, both relative and absolute PSD analysis is important for accurate analysis of the brain.

3. Signal Processing Example (mu wave)

The EEG signal is sampled at a frequency of 256 Hz and 60 Hz power line noise was removed using a hardware analog filter. The first and last moments of the acquired signal were excluded. Since the mu frequency band overlaps the rear alpha band, rhythms recorded in C3, Cz and C4 can be affected by rear alpha frequency band activity, and the rear alpha rhythm generator is more powerful than the mu rhythm generator[2]. Then, using a new feature of EEGLAB, the signal was high-pass filtered using a zero-phase Hamming window sinc finite impulse response filter with a cutoff frequency of 1 Hz.

Next, high-amplitude artifacts such as eye blinking, muscle rupture, and movement were removed using Artifact Subspace Reconstruction (ASR)[3][4]. When clean baseline data collected from a subject is entered with a 1-minute pause, ASR identifies a clean EEG region within the data that computes an unmixing matrix based on geometric median values. By applying principal component analysis to the EEG data using a sliding window, the data is decomposed into subspaces, and the subspace of the baseline is reconstructed into an unmixed matrix. To identify the damaged subspace without channel removal, a non-basic parameter of a sliding window with a threshold of 250 ms in length and 5 standard deviations was used[5][6]. Next, inappropriate EEG signals were rejected according to the following criteria: Therefore, there were no contaminated signals to analyze[7].

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