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Artefacts Removal of EEG Signals with Wavelet Denoising

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Abstract. The recording of EEG signals often still contains many contaminants electrical signals that originate from non-cerebral origin such as ocular muscle activity called artefacts. The amplitude of artefacts can be quite large relative to the size of amplitude of the cortical signals of interest. In this paper, an application of wavelet denoising method for artefacts removal of EEG signals is proposed. The experiment result shows that contaminant artifact of EEG signals can significantly removed.

1 Introduction

Biomedical signal in various form is a source of information that comes from human body and useful in medical interpretation. The Brain is an organ of the human body is composed of neuron that can generate the electrical potential energy known as *neuroelectric potentials* [1]. Electroencephalography (EEG) is a non-invasive measurement of brain electrical activity obtained by placing electrodes on the scalp in areas of the brain [2]. EEG provides brain signal information based on recording data result in non-invasive method to analyze the brain activity that is important for medical (i.e. diagnosis, monitoring, and managing diseases or disorders of the nerves) and research (i.e. neuroscience, cognitive science, cognitive psychology, neurolinguistics and psychophysiological research) uses. The EEG signals is often contaminated by artefacts that often comes from muscle activity, which may reduce its usefulness for clinical or research by disturbing interpretation of the signal [2 - 5].

The main sources of artefacts are the EOG artefacts, ocular artefacts (eye movement and eye blink), noise muscles (EMG), heart signal, and various kinds of noise which is mixed with brain signals and often be the artefacts in EEG recordings [6-10]. Removal of artefacts is the real solution for quantitative analysis in the EEG recordings. The researchers eliminate artefacts in the EEG signals called the raw EEG data [11] to obtain a signal that is "clean EEG signal" that can be further analyzed. Quantitative methods for the analysis of EEG has been developed by many researchers.

The method is widely used to treat and reduce the noise of the brain signals including bandpass filters, autoregressive models [arjon], Finite Impulse Response (FIR). In this paper, a method of using wavelet denoising with daubechies wavelet (db1) and 3rd decomposition level is proposed. Wavelet is a mathematical model that fits in detecting and analyzing the events that occur in different scales, providing information on the time and frequency domains [13]. The wavelet method has the

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ability to transform a time domain signal into time and frequency that helps to better understand the characteristics of the signal. Denoising has an important role in signal analysis by removing the signal noise and retain important information. In a state of statistical usually often associated with discrete and rarely sampled on continuous functions. Nowadays, the stationary wavelet transform (SWT) from the EEG signals mixed artefacts has been widely used in the denoising signal.

2 Methodology

Sample data of EEG signal obtained by experiments. Experiments in this study conducted by eight untrained subjects, who are males aged 20-22 years with good health, thin hair and without any abnormalities. The tools used in this experiment is the Emotiv EPOC wireless EEG Neuroheadset which has 14 electrodes and 2 reference and the package comes with an application programming interface (API). This will record EEG signals from the experimental activities in which there are 128 data per second of one epoch. Before the electrodes set on the tool, preferably sprinkled with a liquid electrolyte is inserted to improve conductivity of the electrode. The coated electrode attached to the subjects scalp based on channels F7, T7, O1, O2, T8 and F8, respectively (See Figure 1).

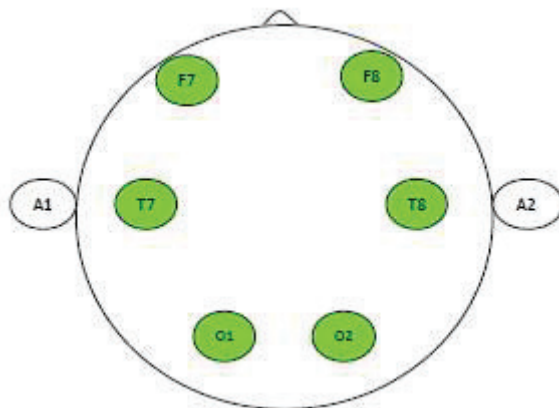


Fig. 1. A top view of the brain that shows the locations for EEG recording according to the 10-20 system.

Recording of sample data and design of the experiment with their stimulus were conducted with software embended with OpenViBE system. Stimulus scenario used in the experiment are given in Table 1 and 2.

Table 1. Stimulus (1st and 2nd) scenario of the Experiment with OpenViBE system.

Time (seconds)	Activity	Information
0-30	Normal	1st Stimulus
31-32	+ (preparation)	
33-63	Closed of eyes (trial 1)	2 nd Stimulus
64-65	+ (preparation)	
66-96	Normal	
97-127	Closed of eyes (trial 2)	
128-130	Selesai	

Table 2. Stimulus (3rd) scenario of the Experiment with OpenViBE system.

Time (seconds)	Activity	Time (seconds)	Activity
0-18	Silent	50-55	Eye blinking
18-20	+ (preparation)	55-60	Eye blinking
20-25	Eye blinking	60-65	Eye blinking
25-30	Eye blinking	65-70	Eye blinking
30-35	Eye blinking	70-75	Eye blinking
35-40	Eye blinking	75-80	End
45-50	Eye blinking		

In the first scenario with the first stimulus, the data is recorded at normal conditions for 30 seconds. In the 31-32 seconds period, the sign '+' will appear in the screen to indicate a preparation for the second stimulus. When the arrow stimulus appear (second stimulus), subject must close their eyes for 30 seconds. For the third stimulus, start with the normal conditions for about 18 seconds. Then in 18-20 seconds periods, the sign '+' will appear again which is indicates the preparation for next stimulus. When the arrow stimulus appear, the the subject start to blinking. The detail of all scenario are given in Table 1 and 2.

2.1 EEG signal processing

Wavelet theory is a relatively new concept developed. The properties of the wavelet are given as follow: The time complexity is linear. Wavelet transform can be done perfectly with the time that is linear; Wavelet coefficients that are rarely elected. Practically, most of the wavelet coefficients of low value or zero. This condition is very beneficial, especially in areas of compression or data compression. Wavelet can be adapted to different types of functions, such as functions that are not continuous, and the function defined on bounded domains [15]. In general, a common function of wavelet is defined as the following equation [18 - 21].

$$\psi_{s,t}(t) = |s|^{\frac{1}{2}} \psi \left[\left(\frac{t-\tau}{s} \right) \right] \tag{1}$$

where s and τ , $s \neq 0$, denotes the scale and translation parameters, and t indicates time. In the continuous wavelet transform, the signal is analyzed using a set of basic functions that are related to scaling and simple transition. The development of the CWT is presented in the following equation.

$$X_{WT}(\tau, s) = \frac{1}{\sqrt{|s|}} \int x(t) \psi \left(\frac{t-\tau}{s} \right) dt \tag{2}$$

Wavelet decomposition is embodied in the input signal and the filtered, lowpass filter generates a waveforms called approximation and highpass filter generates a random waves called detail. The correlation of both filter with wavelet functions arranged in a hierarchy scheme called multiresolution decomposition, where decomposition separates the signal into "details" at different scales and "approximation". Decomposition and reconstruction schemes, and its procedure are given in Figure 2 and 3.

The wavelet denoising aims to remove noise in the form of artefacts in EEG signals recorded on while preserving the signal characteristics, regardless of the frequency content.

The process of denoising (noise reduction) based on the elimination or reduction of the data signal is considered noise. In the use of wavelet denoising, there are many methods used to reduce noise. Denoising is applied by downloading the form of signal threshold wavelet. Input coefficients used discrete wavelet transform. With thresholding, wavelet transform will be able to remove noise or other undesirable signals in the wavelet domain. Then, the desired signal will be obtained after performing the inverse of the wavelet. With this method, we need to understand the concept of wavelet coefficients that represent a measurement at a frequency between the signal and wavelet functions are selected. Wavelet coefficients calculated as a convolution of the signal and the wavelet function which is associated with a bandpass filter. When we analyze the signal at a high scale, we obtain the global information of a signal called approximation. And on a smaller scale, we obtain information from a signal called details [26-28].

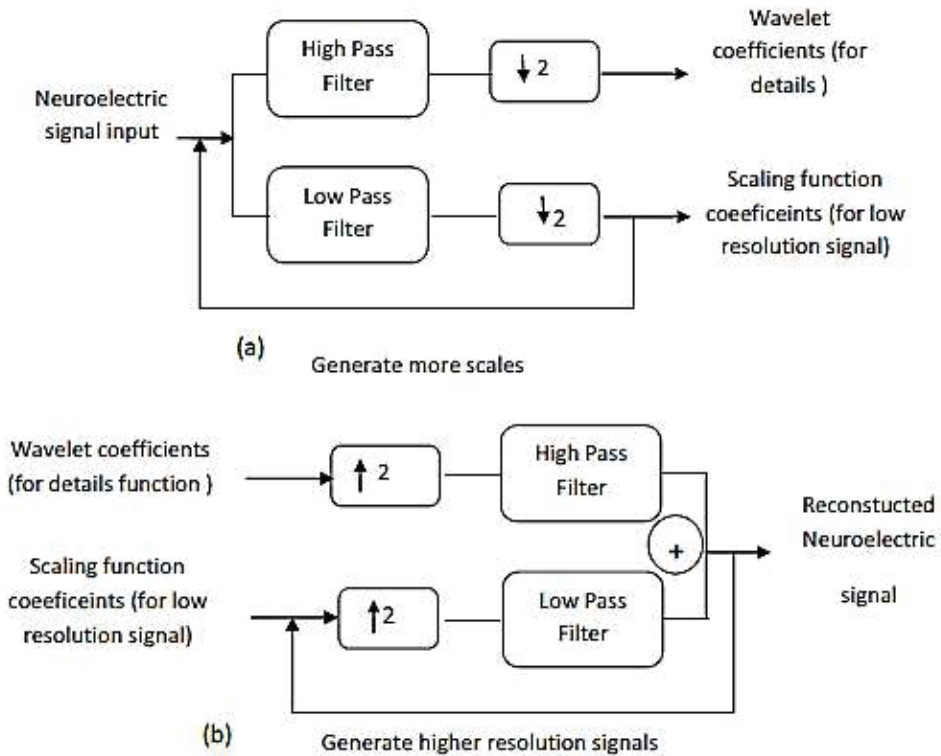


Fig. 2. (a) Schematic of discrete wavelet decomposition, (b) reconstruction of wavelet multiresolution.

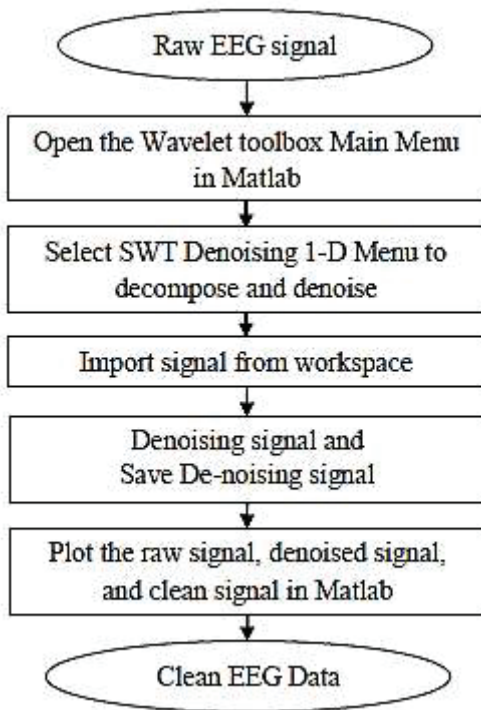


Fig. 3. Signal processing scheme using wavelet denoising method.

3 Results and discussion

In removing the artefact with wavelet denoising method, a description of the recording EEG signal denoising is described in the EEG model form with embedded noise as follows.

$$X[n] = S[n] + G[n] \tag{3}$$

with the **X** signals indicates the corrupted recorded signals with noise, **S** indicates the clean EEG signals, and **G** indicates the added noise and *n* is a point shots. The denoising procedure consists of three stages, namely: The decomposition, thresholding detail coefficients, and the reconstruction. The extracted signals of three subjects (subject 1, 4, and 6) are given below (Figures 4 – 12) to indicates the robustness of developed method.

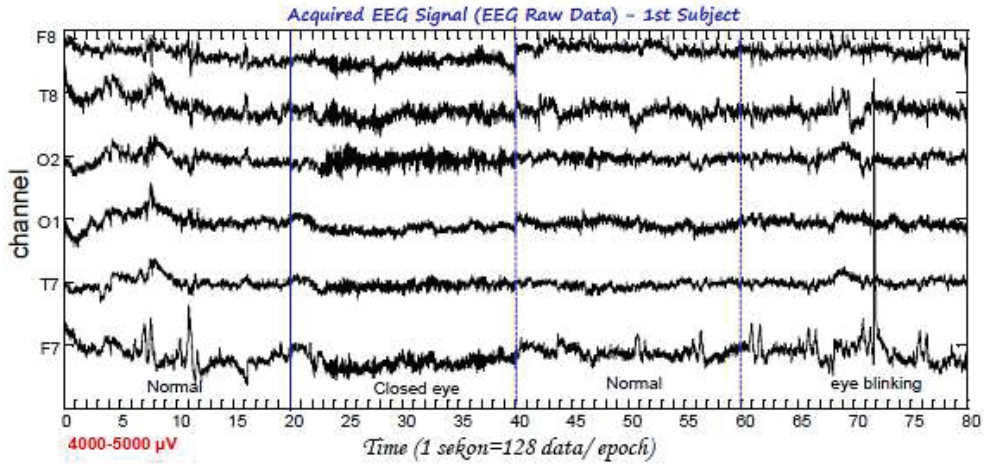


Fig. 4. Raw data EEG signals of the subject-1

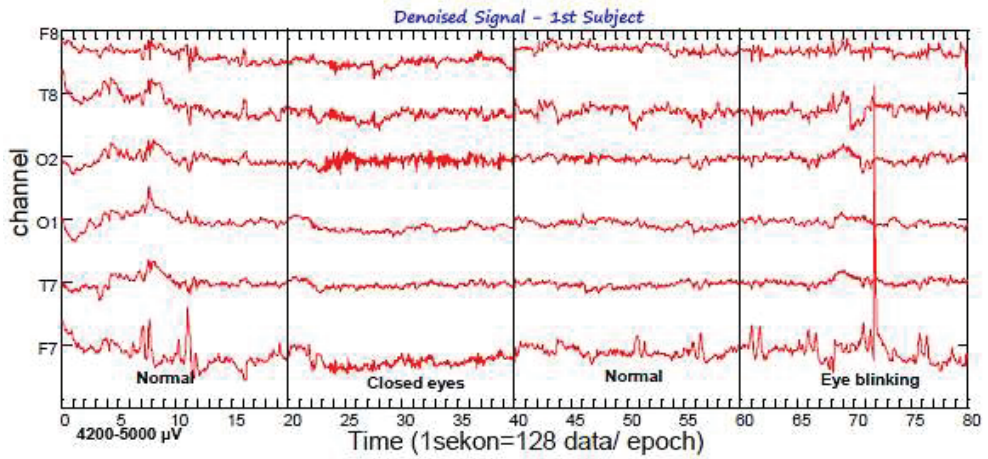


Fig. 5. The denoised EEG signals of the subject-1

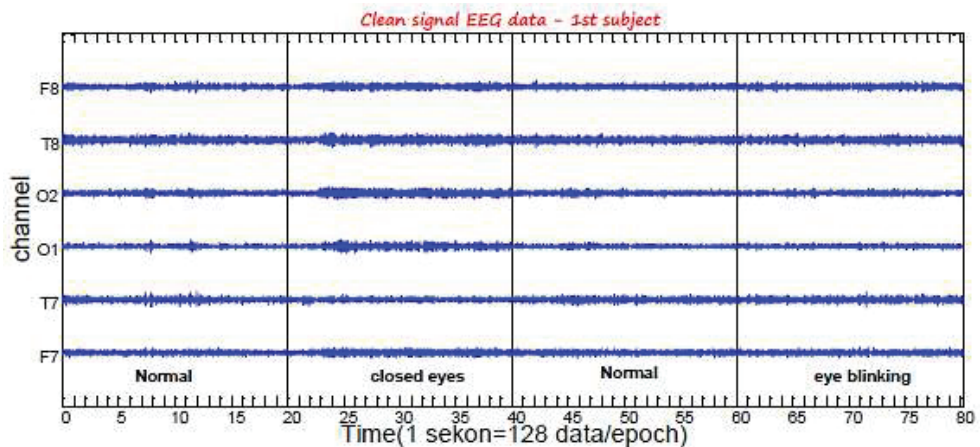


Fig. 6. Clean EEG Signals of the subject-1

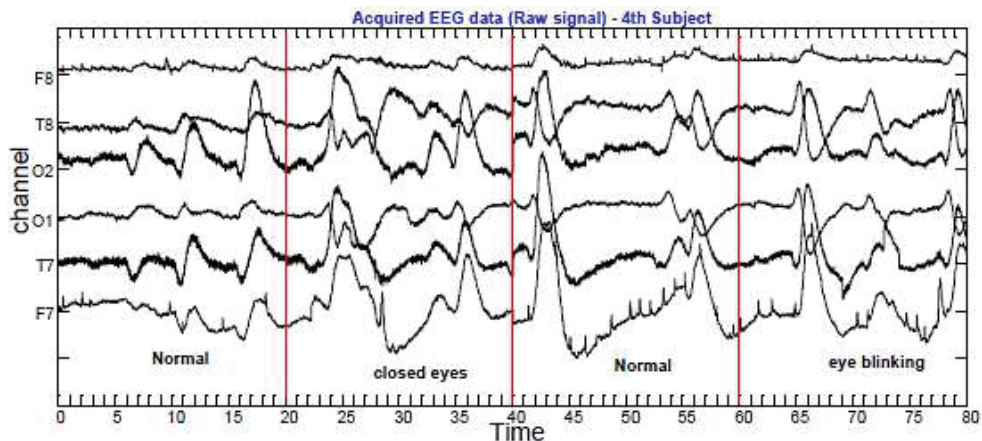


Fig. 7. Raw data EEG signals of the subject-4

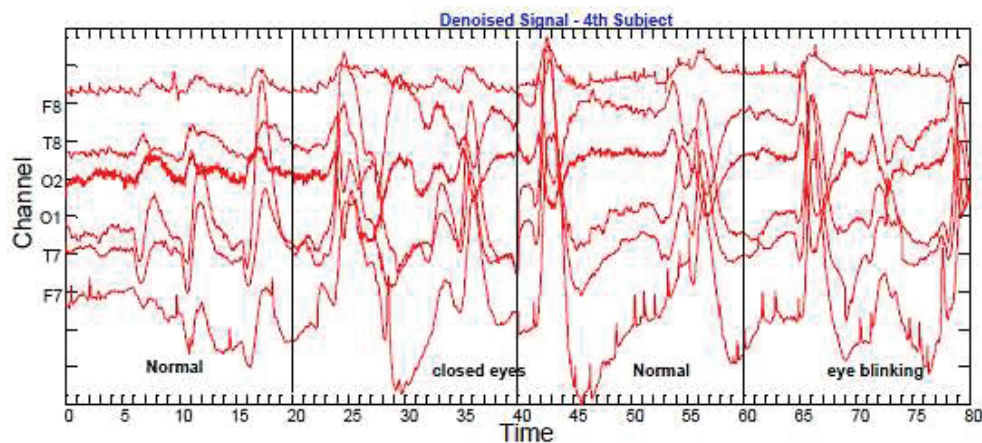


Fig. 8. The denoised EEG signals of the subject-4

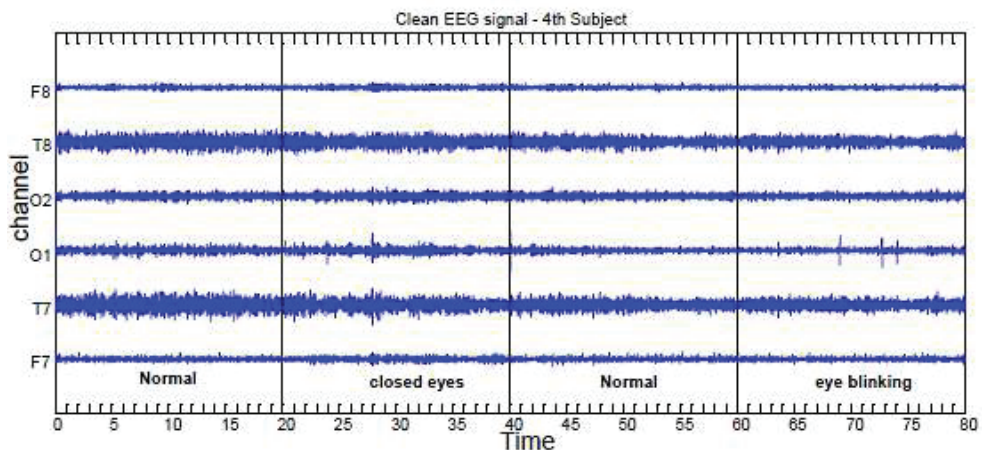


Fig. 9. Clean EEG signals of the subject-4

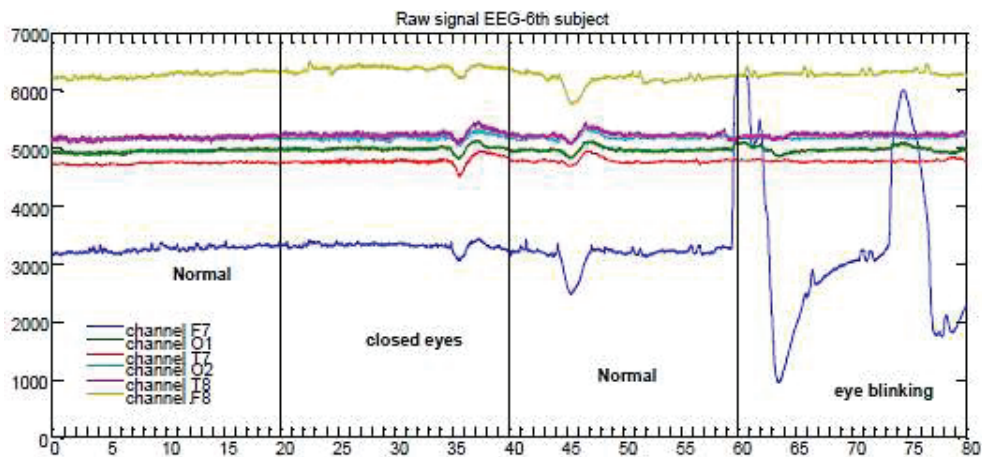


Fig. 10. Raw data EEG signals of the subject-6

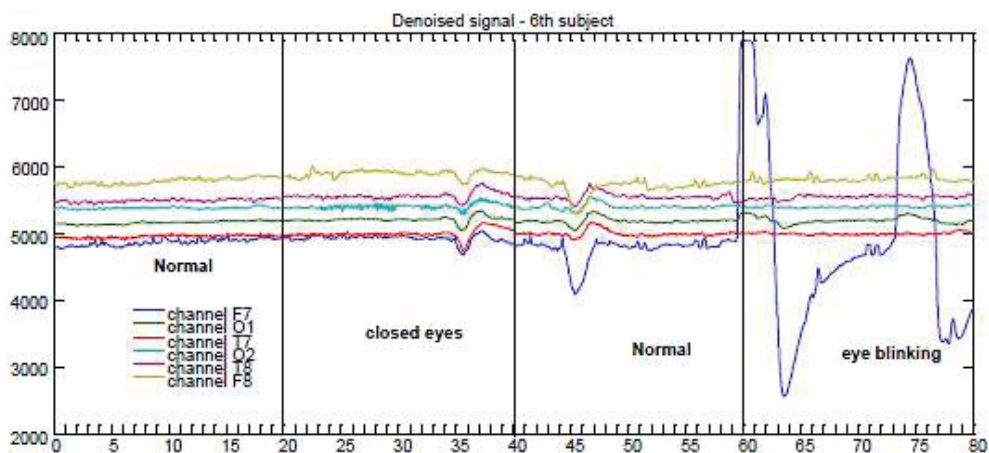


Fig. 11. The denoised EEG signal of the subject-6

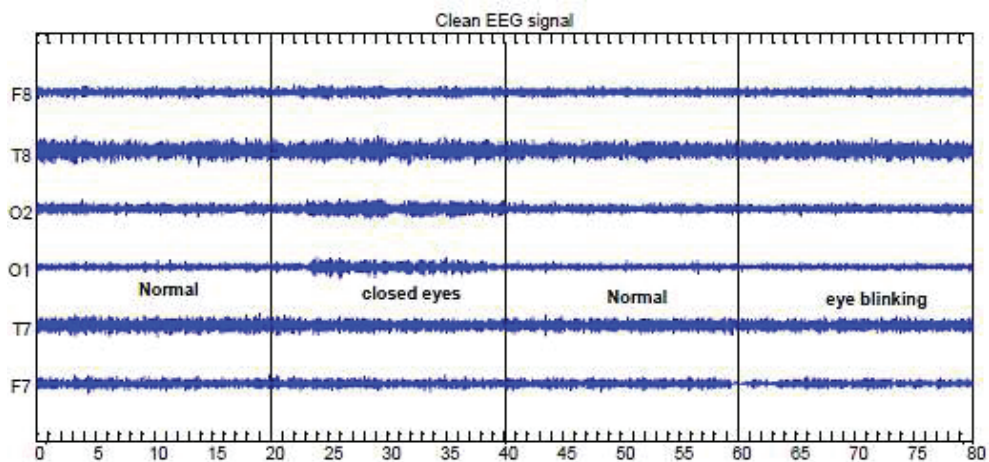


Fig. 12. Clean EEG signals of the subject-6

The input signal is the raw EEG data then decomposed by the decomposition of the signal with noise on wavelet bases where there is information on signal wavelet coefficient. Denoising can be obtained by thresholding wavelet coefficients. Denoising is done by separating the wavelet coefficients with the download threshold. Generally, wavelet coefficients associated with low frequency (hereinafter referred to as the coefficient of approximation). While the high frequency (hereinafter referred to as the coefficient of detail) is to be at denoise.

The wavelet denoising method using one of the families that Daubechies wavelet (dbN). Daubechies db1 used is the decomposition level 3. Wavelet group is used to pass the signal through wavelet transform blocks for the decomposition process, then the signal will be decomposed into wavelet coefficients which will be in thresholding and denoising where the process occurs. Thresholding function to eliminate noise and preserve the information that is important to the maximum signal.

Raw EEG data was still contains some high frequency where the artefacts are at this frequency. Wavelet method is performed to obtain signal finer and enhance noise removal of artefacts by eliminating high frequency in order to obtain the final result of clean EEG signals with amplitude 2-6 μV range of values where the value is smaller than the signal Raw EEG signal. So the value of the amplitude of the wavelet denoising result is closer to the EEG signal amplitude range.

4 Conclusion

The data sample has been obtained (hereinafter referred to as the raw EEG signal) and then processed the signal artefacts that tend to be the dominant high frequency, signal denoising with wavelet denoising. In order to obtain clean EEG signals with amplitudes of 2-6 μV and the range of values of the dominant frequency is in the frequency of 8-13 Hz which includes a group of alpha wave rhythm at the time of trial that showed subjects fully awake and relaxed. So the proposed research method produces a signal with amplitude and frequency ranges that approach the EEG signal. Wavelet denoising in this study using Daubechies db1 signal denoising level 3 of SWT denoising 1-D, the necessary analysis using different types of Daubechies to compare the results of denoising signal.

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