PSD-Based Features Extraction For EEG Signal During Typing Task

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Abstract. Electroencephalograph (EEG) is an electrical field that generated by our brain incessantly. The EEG signal released by the brain is different when a people is performing different activities in their daily life. And such EEG signals consist complicated information that can be interpreted. The aims of this study is to analyse the specific EEG channels of a user when they are performing a typing task with laptop. Meanwhile, this research also aimed to verify the performance of the different sub frequency band which is alpha and beta to recognize the specified tasks. The frequency sampling was set at 1024 Hz and the impedance was kept below 5k ohm of each channels. The Truscan EEG (Deymed, Diagnostic, Czech Republic) device consists of 19 channels and only selected channels which is F3 and F4 is filtered through butterworth bandpass filter (1Hz-80Hz) in the pre-processing stage. Power Spectra Density was calculated by using Welch and Burg Method to extract the features from filtered data. K-Nearest Neighbour (KNN) classifier and Linear Discriminant Analysis (LDA) were used in classification. It is found that the combination of channel F3 and F4 for Alpha frequency using Welch method gives the highest accuracy which is 98.45%.

1. Introduction
Brain is an unique structure that is very essential to human being. The brain cells communicate to each other through electrical impulses and it can be measured by the electrode place on the human scalp. The EEG signals of a people is different when they are perform different kind of activity in life, and it is vary from one person to other person. In [1], the EEG is showing the different level of electrical activity in the different stage of sleep. Besides that, the anatomy of brain is also divided into 4 main lobes which is Frontal lobe, Temporal lobe, Parietal lobe and Occipital lobe and all these lobe are respective to different functions [2], [3].

In this paper, the EEG signals of subjects are recorded during they are performing the typing tasks. Then, it is evaluated based on the use of different feature extraction method and classification. The structure of this paper is organized as few sections which are experiment protocol and methodology, result and discussion, and lastly the conclusion.

2. Experiment Protocol and Methodology
2.1. Data Set and Protocol
Twenty subjects with right-handed and without mentally disorder or brain injury were enrolled from the undergraduates of UniMAP in this research. The Truscan EEG device that consists of 19 channels were
used to collect the EEG signal of the subjects. The sampling rate during the data collection was set at 1024 Hz and the sensitivity of the voltage was set at 70μV. The subjects were asked to perform the 3 times of the typing task in this experiment. Figure 1 and Figure 2 show the photo during the data collection and the flow of the experiment. Then, EEG signal processing will be applied to extract most informative features from the raw data.

![Figure 1. Subject performing typing task.](image)

![Figure 2. The flowchart of experiment protocol.](image)

2.2. EEG Signal Processing

The collected EEG signals were converted to the ASCII form which can be readable easily by the MATLAB software. Basically, the EEG signal processing consists of 3 stages which is pre-processing, feature extraction and classifier. In this research, the F3 and F4 channel is selected.

2.2.1. Pre-processing

The Butterworth bandpass filter was implemented during the pre-processing stage. The butterworth filter provides a response that is no ripple and maximally flat in the passband and stopband [4]. It provide good average transient characteristics and expense wide transition region from band pass to band stop thus enable a good compromise between amplitude response selectivity [5]. In fact, the collected EEG raw data consist of all frequency band such as Delta, theta, alpha, beta, and gamma. It is then pre-processing with the Butterworth bandpass filter to separate the signal accordingly. The frequency band chosen is the alpha which is 8 Hz to 13 Hz, beta that are from 13 Hz to 30 Hz. In this paper, the raw EEG signals from frontal channel F3 and F4 for typing task 1, typing task 2 and typing task 3 were extracted for EEG signal processing. The frontal channels F3 and F4 were selected because the frontal lobe of the brain is related with the voluntary action [2].

2.2.2. Feature Extraction

The power spectral density (PSD) was used as the feature extraction method in this study. PSD is a good tool for stationary signal processing and suitable for narrowband signal. It is a common signal processing technique that distributes the signal power over frequency and show the strength of the energy as function of frequency [6]. Under the PSD, the Welch method and Burg method were adopted in this study.

A. Welch Method

Welch method is a modified segmentation scheme and used to evaluate the average periodogram. Generally the Welch method of the PSD can be describe by the equations below, the power spectra density equation is defined first. Then Welch Power Spectrum that mean average of the periodogram for each interval is expressed.

\[
P(f) = \frac{1}{M} \left| \sum_{n=0}^{M-1} x(n) w(n) e^{-j2\pi f} \right|^2
\]  

(1)
\[
P_{\text{welch}}(f) = \frac{1}{L} \sum_{i=0}^{L-1} P(f)
\]  

(2)

B. Burg Method

Burg method is a method that diminishing the forward and backward prediction errors so it satisfy the Levinson-Durbin Recursion [7]. With higher order of Burg Model, the accuracy become lower, and false peaks will be inferred in the spectra. Which is that, the Burg method is highly suitable for short data records as it can generate accurate prediction and always produces a stable model [7]. Overall, the Burg method of PSD can be computed through following equation:

\[
P_{\text{burg}}(f) = \frac{\epsilon_p}{\left[1 + \sum_{k=1}^{P} \alpha_k e^{-2j\pi f}\right]^2}
\]  

(3)

2.2.3. Classifier

a. K-Nearest Neighbour (K-NN)

K-Nearest Neighbour is known as non-parametric method and instant-learner because it does not make any assumptions on the input data and directly take the available data as training [8]. The principle of K-NN is classification through recognizing the nearby neighbour (data) by the mean of similarity or the distant between the distributed data [9]. The word “K” mean the number of the referred neighbour. K-NN is used by many researcher as its simplicity, fast, and able to achieve high recognition accuracy [9].

b. Linear Discriminant Analysis (LDA)

It is a method to explain the distinctive nature of more than two classed of group by finding a linear combination of the extracted features [10], [11]. In the Linear Discriminant Analysis, it assumes that the conditional probability density functions of the classes are normally distributed with same covariance matrix [12]. The criteria of separability for class is done through the within-class and between-class scatter [13]. After that, the transformation of data is done to provide the definite boundaries to classify the data. The LDA draws the linear decision region between the given classes [14].

3. Result and Discussion

The mean value obtain from after the feature extraction is displayed in Figure 3. After the feature extraction, the EEG signals exhibits a similar level in typing task 1 and typing task 2. However, a significant increase is observed in mean value of typing task 3. The value of beta is greater as the frequency band is domain to the human active state and motor movement. The Alpha frequency band exhibit the best accuracy 98.45% for classification in the combination of F3 and F4 channels. The graph of performance for Welch Method EEG data is shown in Figure 4. Whereas for the Burg Method EEG

![Figure 3](image-url)

Figure 3. The mean value result for Welch method and Burg Method of EEG signals.
data, the combination of the Alpha and Beta frequency band exhibit the best accuracy 94.12% for classification in the combination of F3 and F4 channels as shown in Figure 5 below.

In an overview, the classification of the signal is better when combination of channels F3 and F4 is used. The Welch method feature extraction is suitable use for classification because it give higher in percentage in general. Meanwhile, the LDA classification has been carried out. However, the obtained result isn’t as good as the K-NN classification. It can be said that the classifier LDA is generally not good with few category variables though it performs very well with linear data [15]. A summary of the result is shown in the Table 1. Based on the Table 1, it can be shown that highest result is 98.45% by the combination of F3 and F4 channels in the Welch Method Alpha frequency Band in K-NN classifier. While the highest result of Burg Method EEG data in K-NN classifier is 94.12% by the combination of F3 and F4 channels for combination of Alpha and Beta frequency Band.

**Table 1.** Classification result for Welch method and Burg method EEG signals.

| Frequency Band          | Channel | KNN  | LDA  |
|-------------------------|---------|------|------|
| Alpha (Welch)           | F3      | 93.35| 52.16|
|                         | F4      | 91.69| 45.58|
|                         | F3 & F4 | **98.45** | 37.26 |
| Beta (Welch)            | F3      | 86.86| 53.37|
|                         | F4      | 84.73| 50.01|
|                         | F3 & F4 | 96.19 | 34.18 |
| Alpha & Beta (Welch)    | F3      | 88.27| 57.81|
|                         | F4      | 72.84| 36.83|
|                         | F3 & F4 | 92.72 | 31.07 |
| Alpha (Burg)            | F3      | 82.48| 44.77|
|                         | F4      | 90.17| 49.06|
|                         | F3 & F4 | 92.53 | 51.49 |
| Beta (Burg)             | F3      | 79.29| 44.59|
|                         | F4      | 75.53| 50.67|
|                         | F3 & F4 | 89.26 | 53.21 |
| Alpha & Beta (Burg)     | F3      | 74.38| 47.81|
|                         | F4      | 74.23| 46.35|
|                         | F3 & F4 | **94.12** | 30.08 |

4. Conclusion

In this study, the PSD is used as feature extraction and the Welch method and Burg method is used. The average value in the first time user and second time user is low and almost similar. However, it is
observed that the average mean value has been lifted significantly in third time repeated user. In general, the combination of both frontal channels F3 and F4 give better result in KNN classification. The highest accuracy can go up to 98.45% for the combination of F3 and F4 channels in the alpha frequency band. The Welch method feature extraction is more suitable as it can give better classification result than Burg method in this case. For the performance of sub frequency band, the combination of Alpha and Beta frequency band exhibit better result in the Burg Method feature extraction in K-NN classifier than single frequency band is used.

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