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A Study of Informative EEG Channel and Brain Region for Typing Activity

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Abstract. Electroencephalography (EEG) is an electrophysiological monitoring method to record electrical activity of the brain. Brain consists of four lobes which is frontal, parietal, temporal and occipital lobe. Each lobe has their own respective function and it release different rhythmic wave when carry out different actions. However, when performing a specific activity, not all the EEG channels tend to be informative to the particular activity. The need to optimize the number of channels is crucial to reduce computational complexity. The aim of this paper is to determine the informative EEG channel/s and brain region for typing activity. 20 healthy with right-handed subjects from Universiti Malaysia Perlis (UniMAP) were enrolled in this study. Typing task was performed for 3 trials and 5 minutes per trial. In EEG signal processing, Notch filter and Butterworth bandpass filter were used to remove powerline artefact and to filter the signal into alpha (8-13Hz) and beta waves (13-30Hz). Welch method was applied to extract features from typing task. The obtained results were then undergoing the statistical analysis before load into the K-Nearest Neighbour (KNN) and Linear Discriminant Analysis (LDA) classifier. Based on this study, it is found that channel P3 in parietal region and channel T6 in temporal region give highest accuracy which is 99.44% for typing task activity.

1. Introduction

Brain is a gifted structure for human being as it controls and coordinates the actions and reactions, moreover enable us to feel, memories, learn and think for that every single particular [1]. The brain can be divided into four lobes that respect to different function which is frontal, parietal, temporal, and occipital lobe. The frontal lobe related to personality, emotion, focus, planning, voluntary action, and problem solving [2]. Whereas orientation, proprioception, recognition, and perception of stimuli are more related to parietal lobe [2]. The smallest lobe which is occipital lobe take care of visual processing [2]. Temporal lobe is related to perception and recognition of auditory stimuli, speech and memory [2].

The brain consists billions of nerve cells that communicate with each other through electrical impulses [3]. These electrical activity can be measure by the electrodes that place on human scalp and it is known as Electroencephalogram (EEG) [2], [4]. The cost of EEG recording device can be reduce if one can identified the relevant and effective EEG channels for a specific activity. This is because not all the EEG channels are informative for an activity. As stated by [5], besides the informative channels, the other channels will be either impair or do not influence the identification results. Hence, the channels of EEG and brain regions during typing activity are evaluated to identify the degree of informative and identification result in this paper. The EEG signals are recorded when the subjects were asked to perform



the typing tasks. In this research, the parietal lobe from the brain were assumed to have the most informative channel and region compare to the other in this typing activity as it is correlated to forming motor intention task [6].

2. Experiment Protocol and Methodology

2.1. Data Set and Protocol

Twenty undergraduate students from Universiti Malaysia Perlis (UniMAP) who are right handed and mentally healthy are recruited to join the study. The EEG recording device used in this research is “Truscan32” (Deymed Diagnostic, Czech Republic) consists of 19 channels and using 10/20 International System for electrode configuration. The EEG sampling rate is 256 Hz. The subjects were asked to perform typing task for 5 minutes and it were repeated for 3 times. Rest condition with closing eyes for 30 seconds was given between the trials. Figure 1 and Figure 2 show the photo during the data collection and the flow of the experiment.



Figure 1. Subject performing typing task.

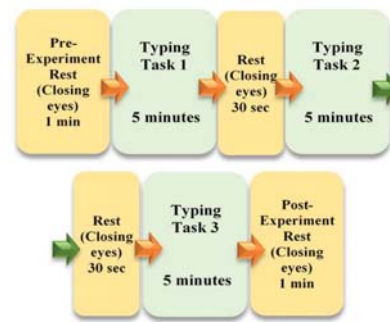


Figure 2. The flowchart of experiment protocol.

2.2. EEG Signal Processing

The recorded EEG signals were analysed through the MATLAB software. Three main stages were carried out in the EEG signals processing which is pre-processing, feature extraction and classification.

2.2.1. Pre-processing

The raw EEG signals require denoising as it contain noise such as eye blinking, powerline interference and etc. In the pre-processing, the Notch filter and second order Butterworth bandpass filter was implemented. Notch filter is used to remove the 50Hz powerline interference while the Butterworth filter provides a good transient characteristics response that is maximally flat in the passband and stopband and almost no ripple [7]. Most of the previous study were done on Alpha and Beta therefore this two frequencies is selected in this research [8]. The frequency band of the Alpha and Beta are 8 Hz to 13 Hz and 13 Hz to 30 Hz respectively [9]. The raw EEG signals of 3 typing trials which is 5 minutes long for each trial were framed into 300 columns (represent 300 seconds) and filtered for 20 subjects in each channel.

2.2.2. Feature Extraction

Feature extraction is a process that reduces the attribute of a data therefore making the data become a smaller and richer set of attributes which will ease the result of classification later. In this study, the Power Spectral Density (PSD) was used as the feature extraction method as it is a common technique that distributes the signal power over frequency and show the strength of the energy as function of frequency [9]. The Welch method were adopted under PSD in this research. In this study, Welch method was adopted to extract the features. The filtered EEG signals of 3 typing trials from 20 subjects were combined and undergo the Welch method feature extraction separately in 19 channels. As a result, there are 19 channels' EEG signals which represent the average value from 20 subjects over 3 typing trials

are readily to use in the classification stage. Welch method is usually used for estimate the power spectrum over time by dividing the signals into modified segments and obtain the average spectra periodogram after computes the magnitude of it [10]. It is a non-parametric spectral methods that commonly used for tackling the EEG signals [11].

2.3 Statistical Features

The location parameters such as computation of means or medians and the dispersion parameters like standard errors or interquartile range are often used as statistical features analysis of EEG data [12]. Once the feature extraction is done to the framed data, it will be having 129 rows of value in each column. The featured data is then undergoing calculation of statistical features which is mean, median, standard deviation, and variance. The obtained data will be combined as input for EEG classification.

2.4 Classifier

2.4.1 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. The rule of the algorithm of K-NN is training the samples themselves without require any supplementary data [13]. "K" means the number of the referred neighbour and this value plays an important factor in the classification since it described the distance metric. Larger the value of K, the noise effect on the classification of noise can be minimize [13]. The value of K used in this classification is 5. This mean that, 5 closest training samples are selected based on a distance metric and then a voting for most number of samples per class is done. So if 3 samples belong to Class-1 and 2 belong to Class-5, then that test sample is classified as Class-1. So the value of k indicates the number of training samples that are needed to classify the test sample.

2.4.2 Linear Discriminant Analysis (LDA)

It is a method to explain the distinctive nature of more than two classes of object by finding a linear combination of the extracted features [14]. In the Linear Discriminant Analysis, it assumes that the conditional probability density functions of the classes are normally distributed with same covariance matrix [4]. This classifier will compute the mean of all sample for each class. Then it is subtracting from each observation of that class with their sample mean to obtain the covariance. The situation where the class-frequencies unequal can be tackled by LDA handy [14].

3. Result and Discussion

To evaluate the most informative EEG channels and brain region for typing activity, the raw EEG signals of 20 subjects from all 19 channels has been processed. In this part, the brain region will be evaluated by few groups according to the channel location. For example, first group is the frontal region that represent by FP1, FP2, F7, F3, FZ, F4, and F8. Second group is temporal region that consists of T3, T4, T5 and T6. While central region only consists 3 channels which is C3, CZ, and C4. Next, it is parietal region that indicate the channels of P3, PZ and P4. Lastly the group is occipital region which mean O1 and O2 channels. Table 1 shows the classification result for evaluating the most informative EEG channels.

Based on Table 1, it can be seen that the most informative individual channel is P3 which it is able to provide 99.44% result in the Alpha frequency through KNN classification. Based on the result, the most informative brain region is around the parietal lobe of the brain, which is P3, Pz and P4. Its informative allow the classification achieved 98.33% in Alpha frequency band and 95.56% in Beta frequency band in average. The performance from temporal region also not much significant difference and similar to the parietal region which it able to achieve 98.20% in Alpha frequency band and 92.92% in Beta frequency band in average. The T6 channel in the temporal region can obtained same accuracy result with P3 channel from parietal region which is 99.44%.

Table 1. The classification results of EEG channels from different brain regions.

Classifier		Classification Accuracy (%)			
		KNN		LDA	
Frequency Band		Alpha	Beta	Alpha	Beta
Frontal	Fp1	86.03	82.68	64.25	57.06
	Fp2	86.11	83.89	73.89	56.67
	F7	96.67	90.00	93.33	81.11
	F3	97.22	90.45	90.56	70.22
	Fz	83.80	73.33	64.25	66.86
	F4	94.38	77.78	76.11	71.67
	F8	96.67	88.33	88.33	80.56
	Average	91.55	83.78	78.67	69.16
Temporal	T3	97.78	89.44	93.89	84.44
	T4	96.67	94.44	83.33	86.67
	T5	98.89	92.78	95.00	93.33
	T6	99.44	95.00	96.11	87.22
	Average	98.20	92.92	92.08	87.92
Central	C3	98.89	95.56	86.11	85.56
	Cz	81.67	78.33	73.74	78.89
	C4	97.22	95.00	89.44	90.00
	Average	92.59	89.63	83.10	84.82
Parietal	P3	99.44	93.89	94.44	86.11
	Pz	98.33	97.22	92.22	85.00
	P4	97.22	95.56	92.78	91.11
	Average	98.33	95.56	93.15	87.41
Occipital	O1	97.78	90.00	95.56	80.56
	O2	96.67	94.44	91.11	86.67
	Average	97.23	92.22	93.34	83.62

Keyboard typing is a complex perceptual, cognitive, and motor process which involves the generation of motor commands that are not directly related to letter shape [15]. The parietal lobe contains the primary sensory cortex which is responsible for forming of motor intention and interpreting the somatosensory signals like touch, movement coordination, visual perception [6], [16]. Whereas in the medial surface of the temporal lobe, which is responsible for the recognition memory [16]. During the 3 typing trials, the subjects tend to recognize an incoming object such as the words or letter which is fixed content in this experiment through recollection and familiarity through repeating the typing trials for 3 times [16].

In the research done by [17], it is reported that the anterior part of the left superior parietal lobule (SPL) is the crucial area for the neural process for typing. Their study also stated that the left posteromedial portion of the left Intra-Parietal Sulcus (IPS) was dominant in typewriting [17]. This can be explained that channel P3 has higher accuracy because it located at left hemisphere of brain.

Typing activity required positioning the finger to touch the keyboard so therefore the parietal lobe more active during the given typing task. Hence, it can be concluded that typing activity is closely related and dominant in the parietal lobe. The results were led by parietal then follow by the temporal, occipital, central and lastly frontal as shown in Figure 3 and Figure 4. In general, the KNN classifier is performed better than LDA classifier to determine the most informative EEG channels in typing task study.

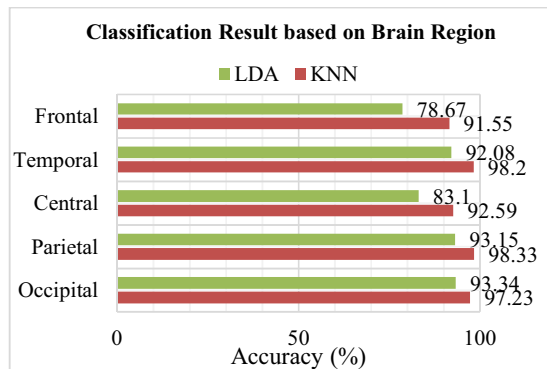


Figure 3. The Classification Accuracy for Alpha waves.

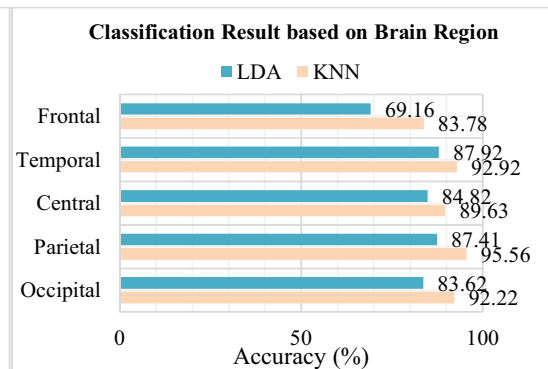


Figure 4. The Classification Accuracy for Beta waves.

4. Conclusion

In this study, the Welch method under PSD is used as feature extraction where KNN and LDA are used as classifier. The goal in this research is to determine the most informative EEG channels and brain region for typing trial activities. The highest performance of individual EEG channel is P3 and T6 that able to give result of 99.44% in the Alpha frequency band through KNN classification. When the channels are grouped according to their brain region, the parietal lobe has seemed to be the most informative brain region for because it achieve the 98.33% in Alpha frequency band and 95.56% Beta frequency band in average for KNN classification. It is followed by the temporal region which able to achieve 98.20% in Alpha frequency band and 92.92% in Beta frequency band which is very close result to the parietal region. In general, the result obtained in this study suggested that the parietal region is the most informative region for typing activity, then followed by the temporal region.

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