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Investigation of Human Emotion Pattern Based on EEG Signal Using Wavelet Families and Correlation Feature Selection

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Abstract — Emotions is one of the advantages given by God to human beings compared to other living creatures. Emotions have an important role in human life. Many studies have been conducted to recognize human emotions using physiological measurements, one of which is Electroencephalograph (EEG). However, the previous researches have not discussed the types of wavelet families that have the best performance and canals that are optimal in the introduction of human emotions. In this paper, the power features of several types of wavelet families, namely Daubechies, symlets, and coiflets with the Correlation Feature Selection (CFS) method to select the best features of alpha, beta, gamma and theta frequencies. According to the results, coiflet is a method of the wavelet family that has the best accuracy value in emotional recognition. The use of the CFS feature selection can improve the accuracy of the results from 81% to 93%, and the five most dominant channels in the power features of alpha and gamma band on T8, T7, C5, CP5, and TP7. Hence, it can be concluded that the temporal of the left brain is more dominant in recognition of human emotions.

Keywords – Human emotion, Electroencephalograph, wavelet, Correlation Feature Selection (CFS)

I. INTRODUCTION

These Human emotions are the advantages of God given to humans. Emotions are the overflowing feelings shown by someone to describe what they feel. Sometimes people have difficulty understanding the emotions that they feel even understanding emotions in their surroundings. Human basic emotions include positive emotions and negative emotions [1].

The advantage of human emotion recognition include emotions closely related to health [2]. Diagnosis of patients with chronic diseases affects their emotions because it changes their organs and affects their emotional responses to mental health such as depression, trauma, and anxiety. Moreover, human emotion recognition is useful in e-Learning systems. To understand the emotional state of the students during the learning period so that appropriate learning techniques can be determined.

From the advantage of human emotion recognition, then it takes technology that can describe and analyze the function of the human brain is Brain-Computer Interface technology. Brain-Computer Interface is an external device used for communication with human brains by using silicon neurons centered on measuring brain activity [3]. The signal waves generated by the brain are recorded by using electrodes and affixed to certain positions in the scalp then connected with the Electroencephalograph device.

The investigation of human emotion recognition has been done previously by [4], [5], [6]. Thejaswini used wavelet and Neural Network to investigation emotion recognition. The results showed that the Neural Network was able to classify emotions well, and its accuracy was 91.2%. Another research related to the investigation of human emotion recognition is Zheng [5] using EEG signals. This research uses the SEED Dataset with differential Entropy (DE) feature and the GELM classification. They obtained an average classification accuracy of 91.07%. The same research was conducted by Zheng [6] using the Deep Neural Network method by analyzing the effective channel count for EEG-based emotion recognition. This research results in an accuracy value of 86.08%,

and channel count affect the average accuracy and time of computing.

The main focus of this research is to investigate human emotion recognition and detect the channel selection and the dominant brain area. EEG signals used in this study because EEG signals have high sensitivity and effective in knowing human brain changes. The method used is a Discrete Wavelet Transform (DWT) because it provides a frequency-time depiction of the signal so that it is suitable for processing EEG signals that have non-stationary properties [7]. Features of the EEG signal should be known as an indicator of human emotions. Power features are used to determine the subject's emotional condition. The results of feature extraction will be utilized by the Support Vector Machine (SVM) classification, which can divide the hyperplane into two classes and used for linear and nonlinear classification. The result of systems is optimized using Correlation-based Feature Selection (CFS) method in order to increase the accuracy and detect the best channel and the brain area of investigation human emotion recognition.

II. RESEARCH METHOD

The proposed method is shown in Fig.1. The research consists of five phases: the EEG Data from the SEED database, wavelet, feature extraction, feature selection, and classification.

A. SEED Dataset

The research uses the Shanghai Jiao Tong University (SJTU) Emotion EEG Dataset (SEED) Dataset. The SEED Dataset is open for research purposes. Emotions are resurrected using movie stimulus. The film clip comes from Chinese film. The subject comes from Shanghai Jiao Tong University so that the original cultural factor can impact the emotions. The selection criteria for film clips are as follows: (a) The overall length of the experiment should not be too long; (b) The film must be pre-published without explanation; (c) The film must acquire one desired target emotion. Each emotion has 5 film clips in 1 experiment. So, the total film clips are 10 for positive emotion and negative emotion in 1 experiment. The movie footage duration is about 4 minutes. Details as in Fig.1.

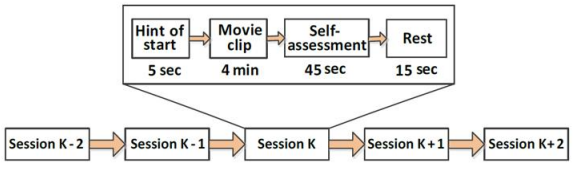


Fig.1. Details of the Duration of Each Movie Clip

Subjects amounted to 15 people (7 males and 8 females; MEAN: 23.27, STD: 2.37). All participants have normal conditions of hearing and vision. Before the experiment, participants were told about the experiment and ordered to sit comfortably, watch the film clips without distracting from the screen, and to refrain from movement.

The EEG signal is recorded using the ESI Neuro-scan system with a head covering tool that has 62 channel electrode. Position of electrodes based on the 10/20 system. The head covering tool consists of the electrode parts of the frontal (F), Central (c), Parietal (P), Fronto Polar (Fp) and Occipital (O). The numeric code of the 10/20 system is used to indicate the position of the electrode where the odd number code indicates the electrodeposition is on the left preauricular while the even number indicates located in the right preauricular. Fig.2 shows the detail of the electrodes used in research.

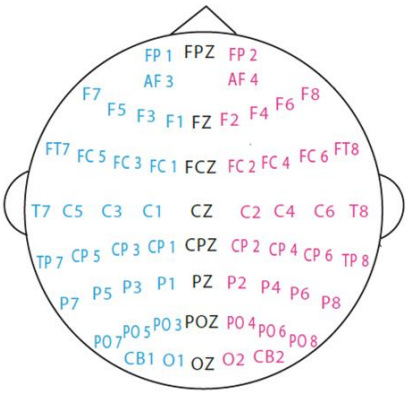


Fig.2. Details of the Duration of Each Movie Clip

The sampling frequency used at the time of recording the EEG signal was 1000 Hz. Data has been down sampling to 200Hz and filtered using band pass frequency filter from 0 to 75 Hz.

B. Time-Frequency Analysis

EEG signal is a non-stationary signal so that analysis of frequency-time is appropriate with information to the dynamic change. Discrete Wavelet Transform (DWT) is a multi-resolution analysis technique performed by passing signals into the high pass filter for high frequency analyzing and low pass filter for low frequency analyzing [8]. In this research, Discrete Wavelet Transform (DWT) was used to decompose a signal into 3 bands: Theta (3-7Hz), Alpha (7-15 Hz), Beta (15-31 Hz) and Gamma (31-63 Hz) for 62 channels with 8 levels and several types of kernel DWT namely Daubechies (db4 and db8), symlet (sym8) and coiflet (coif5). The selection of the type is due to characteristics of the scale used similar to biomedical signals such as ECG or EEG. This matrix result is 62 (electrodes) x 4 channels for one participant.

C. Extraction Feature

The extraction feature is an important aspect of signal processing. The classifications of emotions are measured based on power values in the time domain. The power feature follows in (1),

$$P = \frac{1}{T}\sum_{-\infty}^{\infty}|S(t)|^2 \quad (1)$$

Where S (t) is Power value obtained from the signal frequency in the x (t) time domain, and T is Signal Amplitude

This research analyzes for Pa, $P\beta$, $P\theta$, and Pγ. So, 128 features (62 channels x 4 P of the frequency band) extraction is generated for each subject.

D. Channel Selection

The method used for the channel selection is the Correlation Feature Selection (CFS) developed by Hall [9]. Correlation Feature Selection (CFS) is a function for feature selection that has a high correlation to the class, but one feature with other features is not correlated. Irrelevant features will be eliminated from data because it has a low correlation to the class. The evaluation function of a subset of features in the CFS follows the equation.

$$M_s = \frac{k\overline{r_{cf}}}{\sqrt{k+k(k-1)\overline{r_{ff}}}} \quad (2)$$

Where $\overline{r_{cf}}$ is the mean of the correlate feature and class is, $\overline{r_{ff}}$ is the average value of the inter-correlation features, and k is a feature.

The system with many channels can provide some attributes, and it needs high computation to extract each feature. This research proposed to select channels optimally, so the computation is more effective and efficient. The CFS method is used to select the dominant feature of data. It is simple and fast selection feature. The result of feature selection can determine which channel affects human emotions. The dominant channels grouped by brain area and obtained by dominant channels and brain areas in all subjects.

E. Classification

The next step is the classification process. The method used is the Support Vector Machine (SVM). The basic concept of SVM is to divide the hyperplane into two classes and used for linear and nonlinear classification. SVM on non-linear data using kernel approaches. Kernel functions are used to map the data set to a new dimension [10]. This research classifies the class of positive emotions and negative emotions on each participant subject because each subject has a different brain response even if the stimulus given is the same [11] [12]. SVM used in this research was a polynomial kernel.

Equation of the polynomial kernel shown in (3) as follows [13].

$$K(x_i x_j) = (x_i x_j + 1)^p \quad (3)$$

Where xi and xj are Pair of two data training, and P is Constants with value p > 0.

The accuracy value was used to evaluate the performance of the proposed method. Accuracy is the number of decisions that can be classified correctly. This research uses a confusion matrix to measure the performance of the classification. See Table 1 for the detailed confusion matrix contains information [14]. The Accuracy function follows in (4).

Tabel 1. Confussion Matrix

Confussion Matrix		Prediction class	
		Positive	Negative
Actual Class	Positive	TP	FN
	Negative	FP	TN

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} * 100\% \quad (4)$$

Where TP is outputs identified precisely as positive, TN is outputs identified precisely as negative, FP is outputs identified inappropriately as positive, and FN is outputs identified inappropriately as negative.

III. RESULT

A. Result of human emotion classification

The computation of Daubechies, symlet, and coiflet from 62 channels in each subject is processed independently in machine learning so the accuracy of each feature toward classes can be obtained. The result is showed in Fig.3. Coif5 has higher accuracy than db4, db8, and sym8. Db4 has an average accuracy value of 78%, db8 about 79%, sym8 about 80%, and coif5 has the highest average value of 81%. Feature extraction methods using Coiflet and SVM classifications generate varying accuracy values. The highest accuracy value occurs in P05 and P09 with 100%.

According to Fig.3, the Daubechies method with DB8 resulted in a higher accuracy average value of 79% than DB4 of 75%. The highest accuracy use DB4 occurs at a P05 of 100%, while the lowest accuracy value occurs in P04 with 40%. As for db8, the highest accuracy occurs at a P05 and P10 of 100%, and the lowest accuracy value occurs in P04 and P11 with 50%. P10 has increased accuracy by using DB8 with an average accuracy value of 100% while using DB4 has an accuracy value of 80%. Therefore, the P10 feature processing matches the characteristics of the DB8.

Symlet has an average value of better accuracy of 80% than the use of the Daubechies kernel type, so this type of kernel is more suitable for this research than the use of type Daubechies.

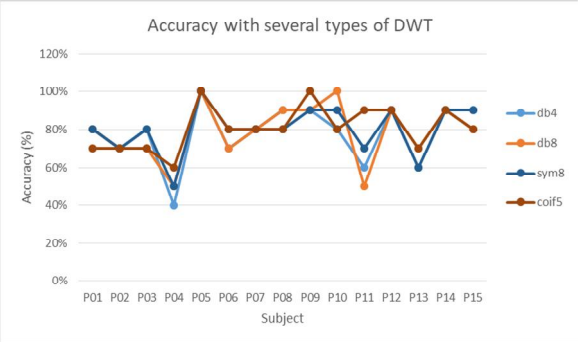
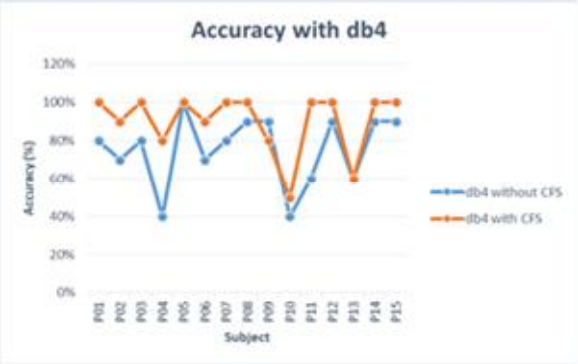


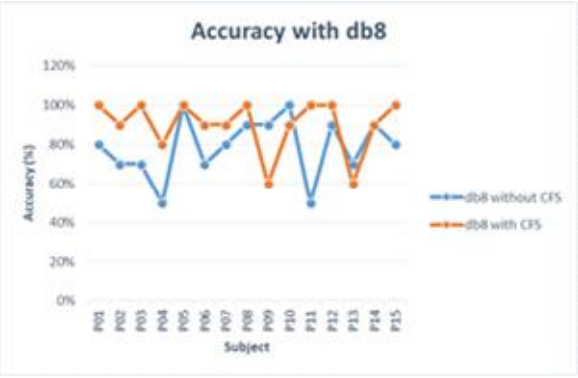
Fig. 3. Accuracy With Several Types of DWT.

B. *Result of human emotion classification with CFS*

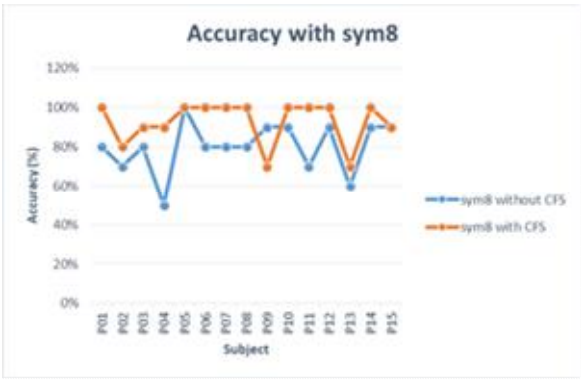
Each participant has a different feature reduction because each participant has different brain response so that the result of feature extraction will also produce different values and result in correlation value between features of each class Participants are not the same. Determining the selection feature based on ranking. The result of feature selection aims to improve the accuracy of data. Results of classification accuracy using several types of kernel DWT before and after using the CFS method shown in Fig.4 the following (K-fold cross-validation, k = 5).



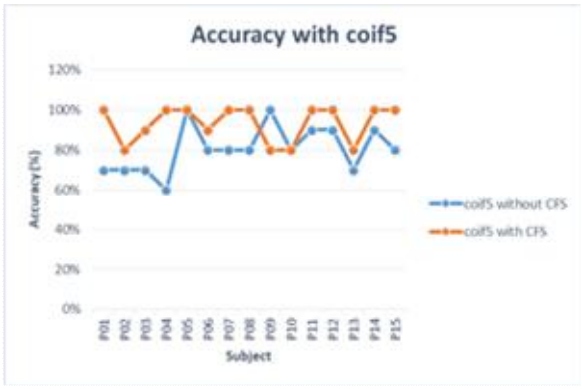
(a)



(b)



(c)



(d)

Fig.4. The Classification Result Uses Several Types of Kernel DWT: (a) db4, (b) db8, (c) sym8 and (d) coif5

Figure 4 can be seen that the CFS method can increase the data accuracy of the four feature extraction methods use. Classification using coif5 has an average increase of 13%, sym8 with 13%, db8 with 11%, and db4 with 15%. The use of db4 has greater accuracy by 15% than Coif5, sym8, and db8 kernel types. However, Coif5 has greater accuracy of 93%, so Coif5 is more suitable for this research.

C. *Investigation of human emotions by the channels*

The channel process is taken from the 6 best features of each participant and grouped by channel. CFS method provided 5 best features Pa and Pγ on T8, T7, C5, CP5, and TP7 channels are some of the most in the grouping of the best features. Four dominant channels located on the left or left brain. Fig.5 visible position of the channel selection.

D. *Investigation of human emotion by a brain area*

The human brain areas divided into 4 parts are frontal, temporal, parietal, and occipital. The selection feature results in each participant are followed by the analysis of the selected features to investigate brain area and frequency dominant in influencing human emotions. Based on Fig.5, position of the channel dominant in the temporal area.

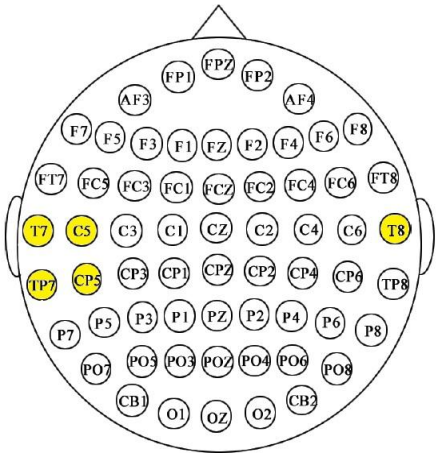


Fig 5. Position of the Channel Dominant

IV. DISCUSSION

According to Fig.3, the result is that Coiflet has the highest average accuracy. Coif5 has an average accuracy value of 81% because coiflet is symmetrical and has a suitable waveform characteristic for this study. In addition, coiflet built by Daubechies and the wavelet and the scaling function has a support of length 6 coefficient, so it leads to smoother wavelet. Another case when using Daubechies kernel type. Low accuracy value caused by several factors because the Daubechies family uses 2 coefficients of scaling and wavelet function so as not to direct to the smooth wavelet so less appropriate for this research. After that, db8 has higher accuracy average value of 79% than DB4 of 75% because greater of vanishing moment degree (n) used then the smaller error value that occurs and can represent the more complex function. Symlet has the same characteristic function as Daubechies with 2 coefficients of scaling function and wavelet function However, Symlet is closer to symmetrical than Daubechies. The average value of the wavelet used has a small difference in accuracy value. It can be said the use of Discrete Wavelet Transform is suitable for analysis of the EEG signal type. However, some types of kernel DWT used in this research are the most appropriate Coif5.

According to the Fig.4 Correlation Feature Selection method can increase the data accuracy of the 4 feature extraction methods. Coif5 has greater accuracy of 93%. In the previous study [15], it researched human emotion with Image stimulus and feature optimization with Principal Component Analysis. This result showed PCA feature selection only has an increase in accuracy by 4% while CFS feature has an increase around 12%. Moreover, CFS feature selection is better than PCA.

The purposes of the feature selection method in EEG are to reduce complexity of computation, to improve accuracy, and to know optimal channel or optimal brain region. The channel process is taken from the 6 best features of each participant and grouped by channel. T8, T7, C5, CP5, and TP7 channels are some of the most in the grouping of the best features. The left brain function is related to logic, responsible for regulating and controlling emotions, analyzing, or learning something ranging from its parts [16]. The movie clips used as a stimulus in this study triggers a person to understand the groove, regulate emotions and relate to logic as the left brain task is more dominant in this research.

T7, C5, CP5, and TP7 channels are temporal areas. The temporal brain relates to interpreting emotions and other people's reactions, in addition to coordinating the specific functions of visual memory (such as facial recognition) and verbal memory (such as understanding the language brain part is influential when viewing the footage. Participants need to concentrate and interpret other people's reactions, understand the intent of speech and recognize the face in the film footage so that the duties of the temporal lobe are more dominant in this research. In the previous study [17], this result showed that the temporal area relates to human emotion.

The most dominant frequencies are alpha and gamma frequencies. It is in sync with sub-band division of brain frequencies where when a person performs a very high mental activity like a panic condition or fear in full consciousness, then the effect is gamma frequency. In addition, the alpha frequency can produce serotonin and endorphin hormones so it can feel calm, comfortable, and happy when watching movie clips.

V. CONCLUSION

From the test results on this research can be concluded that the use of the Discrete Wavelet Transform (DWT) family (Daubechies, Symlet and Coiflet) with the use of power (P) features at the frequency of alpha (α), beta (β), gamma (γ) and theta (θ) have Small accuracy value differences. Coiflet has the highest average accuracy value of 81% without the use of the CFS feature selection. Correlation Feature Selection (CFS) is able to increase the average accuracy on db4 by 15%, Coif5 13%, Sym8 13% and db8 11%. The average accuracy generated by using the CFS at db4 of 90%, db8 with a value of 80%, sym5 of 93%, and coif5 has an average accuracy of 93%. (K-Cross validation, k = 5). The use of the CFS method can be used to determine which channels affect human emotions. The channel selection aims to reduce the complexity of an algorithm system. The most optimal canals are T8, T7, C5, CP5, and TP7. So the left temporal part of the brain in the alpha and gamma frequency bands is optimal in influencing human emotions.

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