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EEG Emotional Feature Extraction Method Based on VMD-FuzzyEn

Zhonggao Li[1,a], Yanping Cai[1,b,*], Tao Wang[1,c], Wan Chen[1,d]

[1]*Room 305, Rocket Force University of Engineering, Xi'an, China*
[a]*lizhonggao525@163.com*, [b]*caiyanping502@ 163.com*, [c]*taotaowang0927@sina.com*,
[d]*chenwan_hgd@163.com*
[*]*corresponding author*

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Abstract: EEG feature extraction is very important for emotion recognition. In order to better extract useful features and improve recognition accuracy, an emotion recognition method based on VMD and FuzzyEn was proposed. Firstly, the original signal was decomposed into five rhythm waves by wavelet transform, and then the selected rhythm waves were decomposed into variational mode. Fuzzy entropy features were extracted from the decomposed variational mode functions, and then the features were fused, and the feature sorting and selection were carried out by Fscore feature selection method. Finally, the SVM classification model was used for emotion classification. Experiments were carried out on the first group of data in SEED-IV data set. The results showed that more refined classification of signals was helpful to eliminate redundant information and improve the accuracy of emotion classification, and feature fusion had higher classification accuracy than single feature.

1. Introduction

Emotion is the reaction of people's attitude experience to objective things and related behaviors. Positive emotion is beneficial to people's physical and mental health. On the contrary, if long-term in a negative emotional state, it is easy to produce mental illness, so as to affect their own work and life, serious even affect others [1]. Emotion recognition plays an important role in life and plays an important role in various fields encephalography. Electroencephalography (EEG) is widely used in emotion recognition because it is not easily changed by subjective consciousness.

Feature extraction is crucial for emotion recognition. There are many methods for feature extraction, and there are four main categories commonly used, including time domain feature, frequency domain feature, time frequency domain feature and nonlinear feature [2]. Due to the non-stationarity of EEG signals, both time-domain and frequency-domain features will lose some useful information. However, the time-frequency features combine time-domain and frequency-domain information and are very suitable for capturing time-varying and non-stationarity signals, which is often used for emotion recognition [3]. Literature [4] uses wavelet transform (WT) and Empirical Mode Decomposition (EMD) to achieve signal decomposition, extract its energy features for classification and recognition. However, the interpretation of EMD signal decomposition and information extraction is not clear enough. Literature [5] use discrete wavelet transform, multivariate empirical mode decomposition and fuzzy entropy are used to extract features. Although the problem of too wide band in signal decomposition is solved, mode aliasing is easy to occur in EMD. Literature [6] uses Variational Mode Decomposition (VMD) to decompose the signal and then extract the features after processing the decomposed information, achieving a good classification effect. EEG also has nonlinear characteristics, so the research on nonlinear characteristics has become a hot topic in recent years. Approximate entropy, sample entropy [7] (SampEn), Fuzzy Entropy [8] (FuzzyEn), Common spatial patterns [9] (CSP) and other nonlinear feature extraction methods have been widely used in many literatures. Literature [7] sample entropy features were extracted from EEG signals of three imaginary movements, achieving a good classification effect. However, sample entropy requires a matching template, and the effect is significant only for small samples, which will have an impact on the extraction of emotional features. FuzzyEn is an improved algorithm based on SampEn, which can establish the input-output relationship in the case of fuzzy sample data, and is very suitable for the study of EEG.

In this paper, the time-frequency analysis method and nonlinear analysis method are combined to decompose the variational mode of the selected rhythmic EEG signal, and then extract fuzzy entropy features from the decomposed signals, and then carry out fusion classification of the extracted features, in order to achieve better results.

2. Method of Emotional Feature Extraction of EEG Signal

2.1. Experimental Data and Preprocessing

SEED-IV dataset [9] was used in this study, and was provided by Shanghai Jiao Tong University. The data set contains 62 channels of signals from 15 subjects. The channel layout is shown in Figure 1, with four emotions: happiness, sadness, fear and neutral. Each experiment requires watching 24 movie clips, which respectively contain 4 kinds of emotions. Each clip is about 2min. After watching the movie, a self-assessment is conducted. The data was preliminarily preprocessed, the sampling frequency was reduced to 200Hz, and the band-pass filter was used to filter the data. Previous studies [10] have shown that the γ band is highly correlated with emotional processes, so this paper selects the γ band for experiments. In order to maintain the unity of the data, the ICA method was used to further remove the electronic ocular artifact of the data, and the first 40s data of each subject were cut and divided into 10 4s segments, so there were 3600 samples (15 people ×24 films ×10 segments) in each experiment.

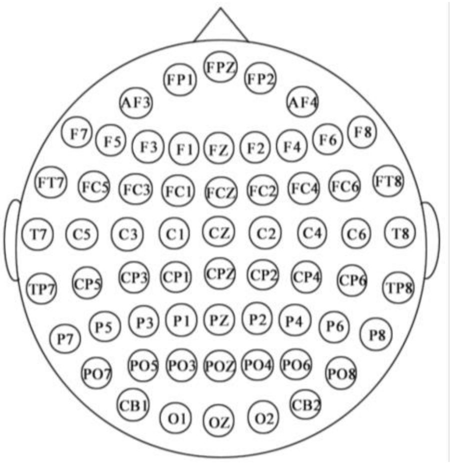


Figure 1: Layout of Channel 62

2.2. Signal Decomposition

2.2.1. Wavelet Decomposition

Existing studies have shown that EEG with different frequency bands has different performance in emotion recognition, and signals are usually divided into five rhythm waves, namely delta (0~4Hz), theta (4~8Hz), alpha (8~13Hz), beta (13~25Hz) and gamma (25~50Hz). In order to explore the performance of different frequency bands in emotion, it is helpful to reduce the complexity of the method and improve the accuracy of emotion recognition. In this paper, a 6-layer db4 wavelet transform was designed to extract five rhythms, and then emotion recognition was carried out on a single frequency band. Finally, a frequency band with high recognition accuracy was selected for feature extraction and fusion. The wavelet decomposition is shown in Figure 2.

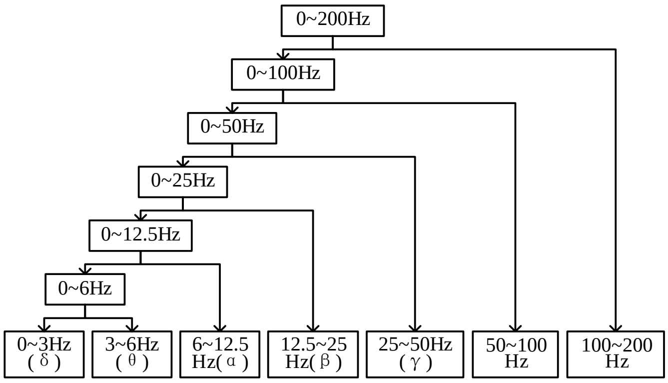
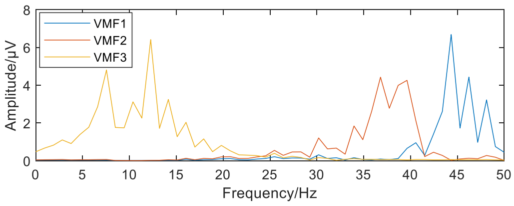


Figure 2: Wavelet decomposition diagram

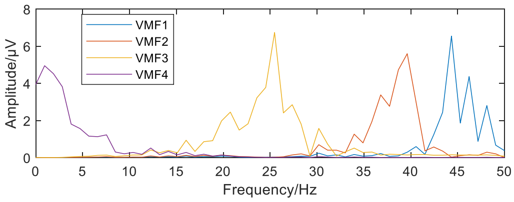
2.2.2. VMD

Variational mode decomposition is a signal decomposition estimation method, which can capture slight changes in EEG signals well, and adjust center frequency and bandwidth adaptatively to realize signal separation. VMD decomposes signals into K variational mode functions (VMF). The setting of K value is very important, because large K value is easy to generate false components through overdecomposition, which not only affects subsequent signal analysis, but also increases the amount of computation. Small K value, easy underdecomposition leads to mode aliasing, can not effectively decompose information [11].

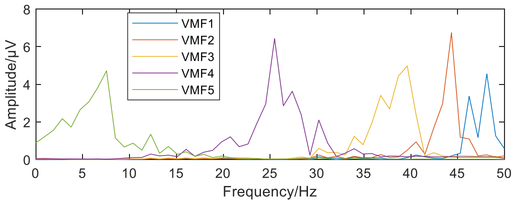
In order to select an appropriate VMD decomposition number, a segment of gamma signal was randomly selected for VMD decomposition. Figure 3 shows the spectrum diagram of gamma band with k values of 3, 4 and 5 respectively. As can be seen from the figure, when k=3, the low-frequency signal contains more information; When k=5, the first four orders of signals overlap more. When k=4, signals can be well separated. VMF4 is a low-frequency signal with a lot of noise, and ophthalmogram is mainly concentrated in low frequency band. In this paper, beta (13~25Hz) and gamma (25~50Hz) segments are mainly studied, and the first three order VMF components contain most features. The first 3 VMF components were selected for feature extraction.



(a) k=3



(b) k=4



(c) k=5

Figure 3: Spectrum diagram of gamma band under different k values

2.3. Feature Fusion and Classification

The extracted features are sequentially spliced for fusion. Usually, the extracted EEG features contain some irrelevant features, which will affect the recognition accuracy of the classifier, and too many features will also increase the complexity of the algorithm. Therefore, before classifying EEG features, Feature optimization can improve recognition accuracy and reduce algorithm complexity to a certain extent. Fscore feature selection method is used to rank features by calculating feature scores, and it shows good performance in EEG feature selection. The basic idea is to find feature subsets in feature space that make the distance between data points of different categories as large as possible and the distance between data points of the same category as small as possible. Therefore, the larger the Fscore, the stronger the feature identification ability.

In this paper, LIBSVM [12] toolkit was used to classify emotions. Kernel function was radial basis kernel function, mesh optimization parameter, and 5-fold cross validation was used to avoid overfitting.

2.4. VMD-FuzzyEn Method

VMD is a signal decomposition and estimation method, which can capture slight changes in EEG signal well, adjust center frequency and bandwidth adaptively, and realize signal separation. Fuzzy entropy is an improved method of approximate entropy and sample entropy. Adding fuzzy factor on the basis of sample entropy has a strong adaptability, and has a good effect in the extraction of nonlinear EEG features. The classification method of VMD-FuzzyEn proposed in this paper is shown in Figure 4. The steps are as follows:

Step1: The original EEG was removed by ICA method, and the required signal frequency band was extracted by small decomposition.

Step2: Perform VMD decomposition for the selected frequency band and extract FuzzyEn features of the decomposed signals;

Step3: Use Fscore feature selection method for feature sorting and selection;

Step4: Use SVM classification model for emotion classification.

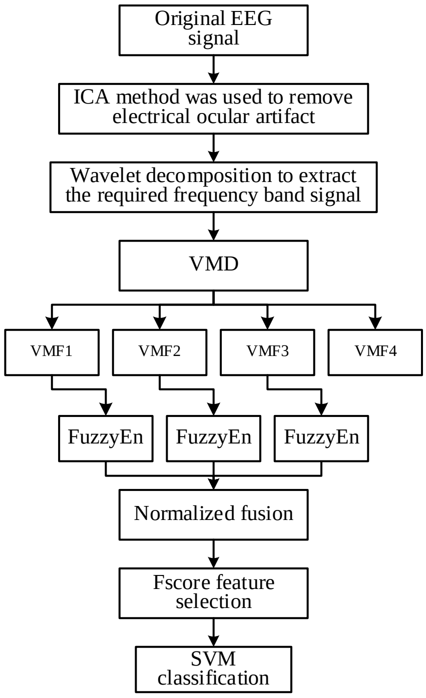


Figure 4: Flow chart of VMD-FuzzyEn method

3. Experimental Analysis

3.1. Single Character Classification of Emotions

After gamma signal was decomposed into VMD, FuzzyEn features were extracted for the first 3 VMFS of the separated signals, and then classified by SVM. The classification and recognition accuracy was shown in Table 1. It can be seen from the table that the average classification accuracy of the first 3 VMF components was higher than that of the original signals after the signals were decomposed into VMD. It indicates that there is redundant information in the original signal, which affects the emotion classification. Through VMD signal decomposition, the redundant information can be screened out, and the elimination of redundant information is helpful to improve the accuracy of emotion recognition. Moreover, the classification accuracy of the third VMF is higher, indicating that the signals in this section contain more emotional information.

Table 1: VMD-FuzzyEn emotion classification accuracy

Classification	Gamma band	VMF1	VMF2	VMF3
Neutral and sad	59.35	60.94	62.48	62.05
Neutral and fearful	64.69	61.50	63.24	65.81
Neutral and happy	63.25	64.54	65.42	66.20
Sadness and fear	57.27	62.34	62.88	65.59
Sorrow and happiness	64.06	60.66	64.54	62.88
Fear and joy	63.80	64.54	65.04	66.48
Average	62.07	62.42	63.93	64.84

3.2. Emotional Classification by Feature Fusion

In order to further check the effect of feature fusion, the above features were fused and the Fscore method was used to select the features. The classification results are shown in Table 2. It can be seen from the table that the classification accuracy of the three features fusion is better than that of the two features fusion. The highest classification accuracy reached 71.91%, and the average accuracy was as high as 70.05%. Compared with the average classification accuracy of γ band, the average classification accuracy increased by 7.98 and 12.86%, indicating that the VMD decomposition of the signals to be classified, the removal of redundant information, and then the emotion classification recognition is conducive to the analysis and judgment of signals. The method of subdividing the signal, screening the effective information, and then extracting the feature fusion has a higher recognition accuracy than the unprocessed signal feature recognition.

Table 2: Classification accuracy of VMD-FuzzyEn feature fusion

Classification	VMF1+ VMF2	VMF1+ VMF3	VMF2+ VMF3	VMF1+ VMF2+ VMF3
Neutral and sad	63.83	63.39	65.10	67.90
Neutral and fearful	66.48	67.04	70.79	71.36
Neutral and happy	65.93	65.65	67.04	69.37
Sadness and fear	65.93	68.70	66.48	70.87
Sorrow and happiness	63.71	65.37	65.93	68.87
Fear and joy	69.25	68.70	70.52	71.91
Average	65.86	66.47	67.64	70.05

3.3. Performance Analysis of VMD-FuzzyEn Method

In order to further verify the effect of the proposed method, repeated experiments were carried out on the remaining two groups of data in the data set. The average classification accuracy of different features in the three groups of experiments was shown in Table 3. It can be seen that in the three groups of experimental data, the emotional classification accuracy of each feature was very close, and the classification accuracy of fusion feature was higher than that of single feature. The accuracy of the fusion of the three features is the highest. The experiment proves again that multi-feature fusion can more comprehensively reflect the emotional changes in EEG signals, and is more conducive to the classification and recognition of emotions.

Table 3: Average classification accuracy of different features in the three groups of experiments

Number of groups	VMF1	VMF2	VMF3	VMF1+ VMF2	VMF1+ VMF3	VMF2+ VMF3	VMF1+ VMF2+ VMF3
The first group	62.42	63.93	64.84	65.86	66.47	67.64	70.05
The second group	62.15	63.24	63.95	64.47	66.02	67.59	69.21
The third group	62.44	64.82	65.03	66.12	66.37	69.41	70.96

4. Conclusion

Feature extraction is very important to improve the accuracy of EEG emotion recognition. In this paper, a method based on variational mode decomposition is proposed to extract FuzzyEn features from the decomposed VMF, then the features are fused, the feature ranking and selection are conducted by Fscore method, and finally the emotion classification is conducted by SVM. SEED-Ⅳ data set was used for analysis, and the experimental results showed that the more refined classification of signals to find out more effective information was helpful to eliminate redundant information and improve the accuracy of emotion classification, and feature fusion had higher classification accuracy than single feature. Finally, the proposed method is used to classify emotions on the data set, and good classification results are obtained, which proves that the proposed method has good effectiveness and robustness.

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