

## An EEG Feature Detection System Using the Neural Networks Based on Genetic Algorithms

Shin-ichi Ito  
University of Tokushima  
2-1, Minami-Josanjima  
Tokushima, 770-8506, Japan  
itwo@is.tokushima-u.ac.jp

Minoru Fukumi and Norio Akamatsu  
University of Tokushima  
2-1, Minami-Josanjima  
Tokushima, 770-8506, Japan  
fukumi, akamatsu@is.tokushima-u.ac.jp

Yasue Mitsukura  
Okayama University  
2-1, Tsushima  
Okayama, 700-8530, Japan  
mitsue@cc.okayama-u.ac.jp

Rajiv Khosla  
University of La Trobe  
Victoria, 3086, Australia  
r.khosla@latrobe.edu.au

### Abstract

It is often known that an EEG has the personal characteristic. However, there are no researches to achieve the considering of the personal characteristic. Then, the analyzed frequency components of the EEG have that the frequency components in which characteristics are contained significantly, and that not. Moreover, these combinations have the human equation. We think that these combinations are the personal characteristics frequency components of the EEG. In this paper, the EEG analysis method by using the GA, the FA, and the NN is proposed. The GA is used for selecting the personal characteristics frequency components. The FA is used for extracting the characteristics data of the EEG. The NN is used for estimating extracted the characteristics data of the EEG. Finally, in order to show the effectiveness of the proposed method, classifying the EEG pattern does computer simulations. The EEG pattern is 4 conditions, which are listening to Rock music, Schmalzty Japanese ballad music, Healing music, and Classical music. The result, in the case of not using the personal characteristics frequency components, gave over 80 % accuracy. Then the result, in the case of using the personal characteristics frequency components, gave over 95 % accuracy. This result of our experiment shows the effectiveness of the proposed method.

### 1 Introduction

Recently in the world, the research of the electroencephalogram (EEG) interface is done, because it has the possibility to realize an interface that can be operated without special knowledge and technology by using the EEG as a means of the interface. The EEG is activities of electric potential inside the brain recorded from the top of the scalp. The EEG is a time series signal to change by the internal factor, which is human's thinking and conditions, or the outside stimulus those are the light and sound [1]-[4]. Moreover, the EEG is the time series signals that more than one factor was intricately intertwined, and the EEG is different by the measurement points of the EEG. Therefore, taking account of these, we must think the EEG analysis method and the

measurement point of the EEG.

In this paper, taking account of the EEG interface, we propose the method, which is focused attention on in four points of the following. First of all, the EEG is analyzed by the information of one measurement point because we assume that the information of some measurement points is unfitted in using the EEG interface [4],[5]. Second, the Genetic Algorithms (GA) is used for the EEG analysis. There are frequency components, which characteristics are contained significantly and/or much unnecessary information, of the EEG. Then those frequency components, which characteristics are contained significantly, have human equation. We see frequency components, which characteristics are contained significantly, as the personal characteristics frequency components. So, the GA is used for specifying the personal characteristics frequency components. Moreover, the feature choosing method using GA is already proposed, and the validity is also reported [6]-[8]. Third, the Factor Analysis (FA) is used for the EEG analysis. Because the EEG is the time series signals that more than one factor was intricately intertwined and the EEG contains much noise, the EEG has the information, which is difficult to obtain from direct observation data. Therefore, taking account of the correlation of the time transition of each frequency spectrum of the EEG, the latent structure, which explains that correlation, is analyzed by using the FA. We have attempted to extract the characteristics data of the EEG by using the FA. Finally, the Neural Networks (NN) is used for the EEG analysis. The NN is possible that the non-line relations, which more than one factor was intricately intertwined, are expressed. The NN is used for estimating extracted the characteristics data of the EEG.

In other words, taking account of the EEG interface, we propose the EEG analysis method, which is using the GA and the FA and the NN. In order to show the effectiveness of the proposed method, classifying the EEG pattern does computer simulations. The EEG pattern is 4 conditions, which are listening to Rock music, Schmalzty Japanese ballad music, Healing music, and Classical music.

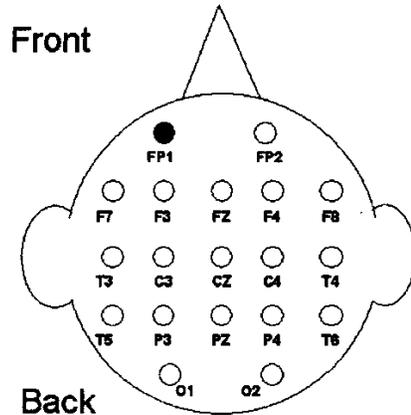


Figure 1: Measured points of the EEG

## 2 Measurement of the EEG

In this paper, as for a goal for the final of our research, the EEG control system by any music is constructed. This system uses human's physiologic and mental effect, which a music stimulus gives to human. There is causal relationship between the EEG and the music, for instance,  $\alpha$  waves appear by listening to Classical music, and  $\beta$  waves appear by listening to Rock music. This system adjusts the outputs of the music automatically by that causal relationship. Moreover, the EEG is controlled by listening to that music, which is adjusted the output of, in this system. In the constructing this system, the EEG analysis and the music analysis are absolutely imperative. The most important part of this system is that the EEG analysis. So, the EEG analysis is done in this paper. The method of measurement of the EEG is shown in the following.

### 2.1 The EEG patterns

In this paper, as basic research of constructing the EEG control system, some genre of music is classified by the EEG. The EEG patterns are 4 conditions, which are listening to Rock music, Schmaltzy Japanese ballad music, Healing music, and Classical music. We used the following questionnaire to decide the EEG pattern because classifying the genre of music becomes easier. In addition, the questionnaire is done 20 people, who are boys and girls of twentysomething.

### 2.2 Measurement conditions of the EEG

The electroencephalograph used simple electroencephalograph. The simple electroencephalograph can be measured under the practical environment. The simple electroencephalograph is made by Brain Function Research & Development Center in Japan. Measurement part place is electrode arrangement FP1 in international 10/20.

As for the data, FFT is being done, and frequency analysis is carried out to 24Hz at intervals of 1Hz by

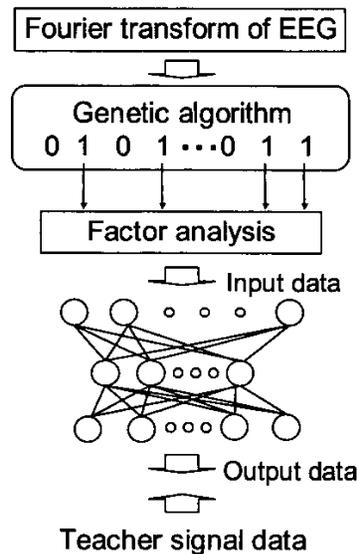


Figure 2: The structure of proposal method

attached analytic software. As a measuring condition, the EEG measuring is carried out in the laboratory with some noise. Then subjects wear a sensor band and headphone. Measuring time is for four minutes in each condition. In addition, the data of using frequency components are from 4Hz to 22Hz. Fig.1 shows measured points of EEG.

## 3 The procedure of the proposed method

In this paper, we propose the EEG analysis method, which is using the GA and the FA and the NN. The GA is used for specifying the personal characteristics frequency components. The FA is used for extracting the characteristics data of the EEG. The NN is used for estimating extracted the characteristics data of the EEG. In addition, Fig.2 and 3 show that the structure of the EEG analysis method and the flowchart of the EEG analysis method. The EEG analysis method is as follows:

First of all, the individual, which has a random chromosome, is formed as an initial group. The value of an individual chromosome is '0' or '1'. An individual chromosome copes with each frequency components (4-22Hz). The structure of chromosome is shown Fig.4. When an individual chromosome is '1', the time series data of allocated frequency component is used for the FA. When an individual chromosome is '0', the time series data of allocated frequency component is not used for the FA.

Second, the characteristics data of the EEG is extracted by using the FA. The FA is one of the statistical methods. Then the information that each variate (frequency components) with the correlation has is summarized in small number of latent factor. The FA can be denoising, dimensional compression, latent structure analysis that structure lurks behind each variate with the correlation. In this paper, the model of the FA, which is shown Fig.5, is cross-factor model because we assume that common factor, which responds to partic-

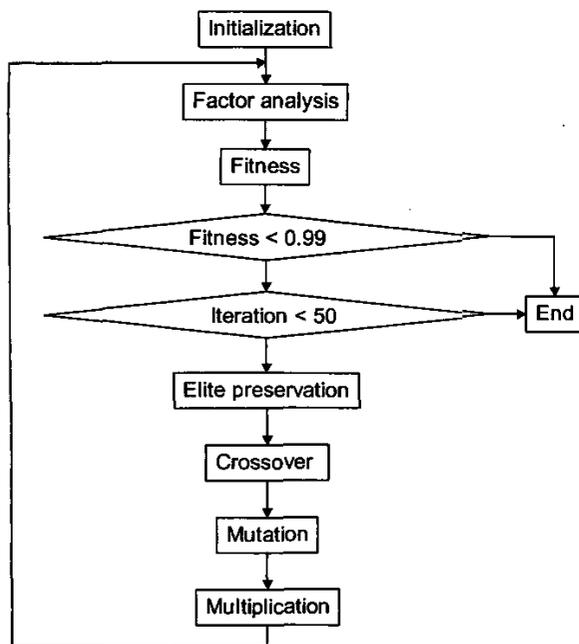


Figure 3: Flowchart

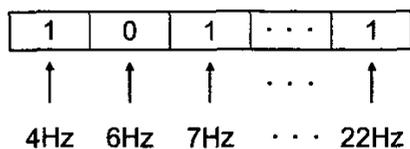


Figure 4: The structure of chromosome

ular stimulus, is able to decide when extracted common factor is noncorrelated [9],[10]. Therefore, taking account of measurement conditions of the EEG, the first common factor shows 'the EEG changing by the music', we think. The common factor is extracted by using principal factor analysis method. In this paper, the characteristics data of the EEG is the data of first factor loading.

Third, the characteristics data of the EEG is estimated by the NN. The NN, which is 3-layer class pattern, is used for learning the characteristics data of the EEG, and the EEG pattern classification. Then back-propagation (BP) method is used for the way of learning the characteristics data of the EEG, and leave-one-out cross-validation (LOOCV) method is used for test method.

Finally, the fitness of each individual is calculated by using the result (recognition accuracy) of the NN. When established termination conditions are not satisfied, next generation individuals are generated by genetic manipulations. Genetic manipulations are selection, crossover, mutation, multiplication, and a local solutions, which are used for not selection a local solution. In addition, when termination conditions are satisfied, the personal characteristics frequency components are allocated '1' of an individual chromosome, which is the highest fitness

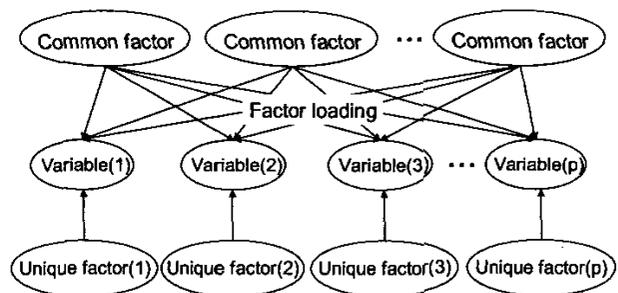


Figure 5: Cross-factor model

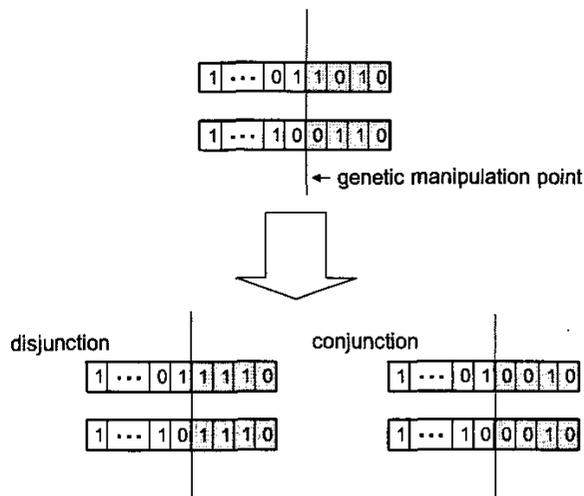


Figure 6: Genetic manipulation based on the logical operations

value.

### 3.1 The fitness value

First of all, the characteristics data is learned by using the NN. Mean squared error is calculated after learning using the learning data. Second, the recognition accuracy of an individual is calculated by using the NN. Finally, the fitness accuracy is calculated. The fitness value is as follows:

$$fitness = (Recog - \frac{Number\ of\ 1's}{NumData * Length})^2 - Err$$

Err	Mean squared error
Recog	The result of NN (the recognition accuracy)
Length	The length of gene
NumData	The number of the test data pattern
Number of 1's	The number of 1's in a gene

### 3.2 Genetic manipulations

Genetic manipulations are selection, crossover, mutation, multiplication, and the logical operations. Selection is the elite preservation strategy. Crossover is one-point crossover and using the logical operations, which

Table 1: The parameter of GA

The number of generation	50
The number of individual	50
The length of chromosome	19

Table 2: The parameter of NN

The maximum number of input layer unit	19
The number of layer unit	5
The number of output layer unit	4
The number of learning	10,000
The step size	0.01

are shown Fig.6. Multiplication is using the logical operations. The logical operations are as follows: First of all, the conjunction (Elite conjunction) of the individuals, which are selected elite, is calculated. Second, the conjunction (Not elite conjunction) of the individuals, which are not selected elite, is calculated. Finally, the gene (0 or 1) of Not elite conjunction is inverted. Then the conjunction and the disjunction of Elite conjunction and inverted Not elite conjunction are calculated.

#### 4 Computer simulations

In this simulation, the EEG pattern is classified. The EEG pattern is 4 conditions, which are listening to Rock music, Schmaltzy Japanese ballad music, Healing music, and Classical music. In addition, the subjects of this paper were 5 people who are 4 boys (The average age: 22.3 years old) and 1 girl (age: 23 years old). Furthermore, the parameter of the GA is shown in the Table 1. Then the parameter of the NN is shown in the Table 2. In addition, the step size and the number of hidden layer in parameter of the NN are being found experientially.

Compared with using the frequency components (4-22Hz) in this paper. The recognition accuracy, in the case of using the personal characteristic frequency components, and in the case of using the frequency components (4-22Hz) is shown Fig.7. In addition, the selected personal frequency components are shown in the Table 3. The result in the case of using the frequency components (4-22Hz) gave over 80 % accuracy. This result suggests that extracting the characteristics data of the EEG by using the FA is significant in the EEG analysis. Then the result in the case of using the personal frequency components gave over 95 % accuracy. This result suggests that specifying the personal frequency components is significant in the EEG analysis.

However, there are the selecting common frequency components as 6,8,12Hz. Therefore, we do computer

Table 3: Selected frequency components by the GA

	The extracted frequency components
subject1	6,8,10,12,19-21Hz
subject2	4,6-8,10,17,18Hz
subject3	6,8,10-12,22Hz
subject4	6-8,12,17,18,20Hz
subject5	5,6,8,12-14,16,17,21Hz

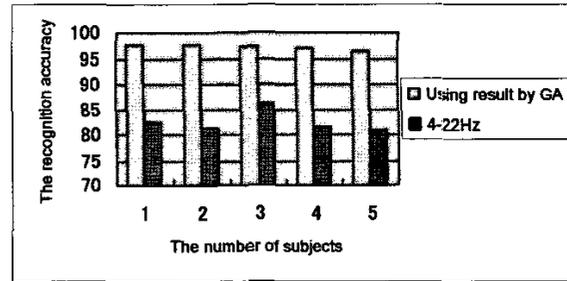


Figure 7: The recognition accuracy, in the case of using the personal characteristics frequency components, and in the case of using the frequency components (4-22Hz)

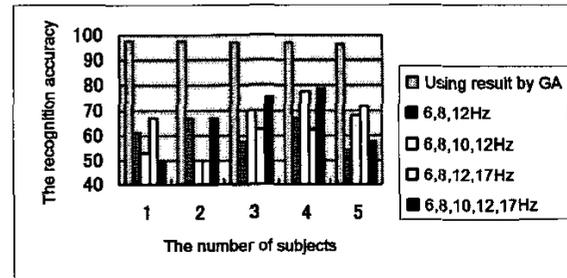


Figure 8: The recognition accuracy, in the case of using the personal characteristics frequency components, and in the case of using the common frequency components

simulations, in the case of using the common frequency components, and in the case of using the personal frequency components. The recognition accuracy, in the case of using the personal characteristics frequency components, and in the case of using the common frequency components is shown Fig.8. The result in the case of using the personal characteristics frequency components is admittedly good result. This result suggests that specifying the personal frequency components are significant in the EEG analysis.

#### 5 Conclusions

Taking account of using the EEG interface, the simple electroencephalograph of the band type is used for measuring the EEG. We propose the EEG analysis method, which is using the GA and the FA and the NN. The GA is used for specifying the personal characteristics frequency components. The FA is used for extracting the characteristics data of the EEG. The NN is used for estimating extracted the characteristics data of the EEG. In order to show the effectiveness of the proposed method, classifying the EEG pattern does computer simulations. The EEG pattern is 4 conditions, which are listening to Rock music, Schmaltzy Japanese ballad music, Healing music, and Classical music. The result, in the case of not using the personal characteristics frequency components, gave over 80 % accuracy. Then the result, in the case of using the personal characteristics frequency components, gave over 95 % accuracy. The result of

our experiment shows the effectiveness of the proposed method.

In this paper, in such a way that classifying the EEG pattern is easy, we used the following questionnaire to decide the EEG pattern. Future studies will focus on boosting the number of classifying the EEG pattern, which is listening to the genre of music. Moreover, we will analyze the music.

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