A Feeling Estimation System Using a Simple Electroencephalograph *

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Abstract – *This paper proposes a system for feeling estimation. It uses a simple electroencephalograph as an interface. If quantitative feeling presumption with information from a living body is made possible, it can be considered that a computer can appropriately deal with human's natural sensibility. Input data of proposed system is electroencephalogram (EEG) data of several feelings acquired using a simple electroencephalograph. Output of the system is one of some words associated with certain feelings states. One feature of proposed system is performing classification using the neural network. The neural networks have generalization ability and can deal with data including noise. Another feature is a low burden for the user by using a simple electroencephalograph. The proposed system is applicable to the quantitative evaluation replaced with a questionnaire. It is also applicable to handling the non-verbal information that is missing at communication.*

Keywords: Feeling, estimation, EEG, electroencephalograph, neural network, wavelet transform.

1 Introduction

Dealing with sensibility and feeling in addition to human intelligence has attracted a lot of attention. In such a situation, many systems concerning sensibility have been proposed. For example, a system that supports the way of thinking and creation[1][5], and a system that realizes information retrieval based on human's feeling[4] have been proposed. In most of these systems a user just selects sensibility words prepared by the designer, and the output is obtained based on selection of the user. To change feeling into language and its expression is indispensable in these systems. In these systems, however, the feeling that a user inputted as the true feeling may differ from the feeling that the user meant.

Human being has sensibility, but a computer doesn't. In order to deal with sensibility by computers, it is required to deal with sensibility quantitatively. The method using information from a living body is often used to deal with human's condition quantitatively. And there are many papers using information from a living body[3]. Moreover, it is difficult to deal with sensibility objectively and quantitatively. Now, there are few systems that realize handling of human's natural sensibility appropriately by computers.

The neurotransmitter, a part of chemical substances, is said that the origin of cerebral activity potential, and there are some substances that are concerned with feeling. For example, the noradrenalin is related to the feeling of surprise or anger, and the dopamine is related to a pleasant or happy feeling. Since brain waves change according to feeling, we think that the states of brain waves also change when feeling changes.

Now, generally, EEG information is used in many papers in order to investigate cerebral abnormalities and illness[2][8][9]. Compared with above, there are few papers that deal with sensibility itself. We observe the possibility of estimation of feeling from the state of brain waves.

Generally, there are following problems with sensibility analysis using information from a living body.

1. A signal is easy to change.
2. There are individual differences for every subject.
3. Interpretation of a signal is difficult even if data is obtained successfully.

There is an information processing mechanism that imitates work of human's brain activity in engineering field. It is a neural network. The neural network has a lot of units corresponding to the nerve cells in a brain and it is constituted by connecting each other. It can realize various information processing systems, such as pattern recognition.

The neural network has the following features.

- It is applicable to a nonlinear relation.

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- There is no necessity to specify a model beforehand.
- It has noise tolerance.
- It can deal with the high order statistics.

Because of these features described above, we think that a neural network enable us to solve the problem of sensibility analysis with the information from a living body.

However, there are some problems in inputting the raw time series data into a neural network. Especially we know the problem that huge amount of input data requires bigger network. Therefore, it is necessary to choose a meaningful signal component from time series data, and to cut down the dimension. Namely, it is indispensable to carry out a certain preprocessing before we input the data to a neural network.

First of all, there are various methods in the analysis of brain waves. The methods using the Fast Fourier transform (FFT)[6], using the maximum entropy method[3], etc. are well known.

The technique of the "sensibility spectrum-analysis method"[7] is one of the famous researches that analyze feeling from brain waves. Correlation between brain waves and feelings is calculated. In not only this technique but also most of researches that connect feeling with brain waves, an expensive medical electroencephalograph is often used to obtain the EEG data. It is known that the advantage of using a medical instrument is the capability of acquiring a lot of information from many electrodes. However, since such an equipment is large and complicated, it is difficult to take a subject's natural feeling. Moreover, the place where data is obtained will be restricted.

In this paper, we propose a feeling estimation system from the brain-waves information acquired by a simple electroencephalograph at a small burden. We use a simple electroencephalograph. Input data of this system is the EEG data of several feeling states acquired using the simple electroencephalograph. And output of the system is one of some words associated with a certain feeling state.

This system has two stages, a feature extraction stage and a feeling classification stage. At the former stage, we use principal component analysis for reduction of input dimension after wavelet transform. Moreover, the average and the variance of the amplitude of brain waves, and the power spectrums of alpha, beta, and gamma wave are also adopted as features at this stage.

At the latter stage, the feedforward neural network learned by the back propagation algorithm is used, and feeling estimation is realized using the features acquired at the former stage.

We describe the feeling estimation system using EEG data in Section 2. In Section 3 we show computer experiments and describe a conclusion in Section 4.

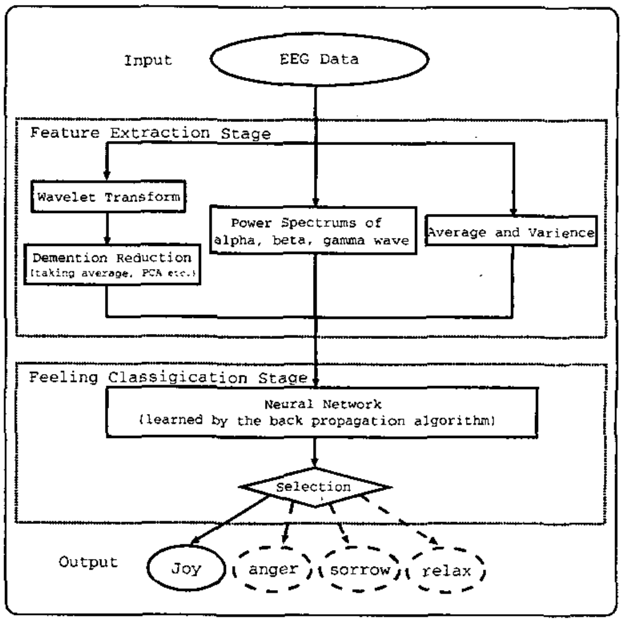

Figure 1: Outline of this system

2 Feeling Estimation System

2.1 Outline of the system

Proposed feeling estimation system has two stages, a feature extraction stage and a feeling classification stage. The outline of system is shown in Figure 1.

Input of this system is the EEG raw data. A neural network performs the feeling estimation. Output of the system is one of some words associated with certain feelings states.

Four feeling states (joy, anger, sorrow, and relaxation) are considered in the proposed system. At the feature extraction stage, wavelet transform is applied to EEG data. In order to reduce dimensions, principal component analysis is applied to the average taken at certain period of the processed data. Moreover, the average and the variance of the amplitude are separately calculated and used as a feature. And each sum of power spectrums of the alpha wave, beta wave, and gamma wave are also used as features.

At the feeling classification stage, the features are inputted into a feedforward neural network learned by the back propagation algorithm. The output unit having maximum value is regarded as the estimated result.

2.2 Getting EEG data

We acquired EEG data by using a simple small electroencephalograph, named IBVA[11]. IBVA is shown in Figure 2.

IBVA consists of a headband with three electrodes, a transmitting machine, and a receiver. We wind a head-

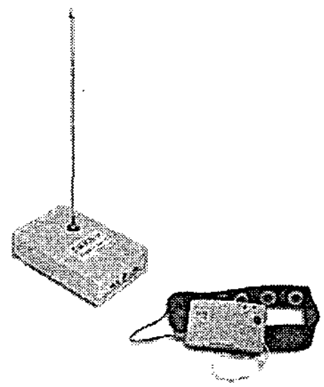

Figure 2: View of IBVA

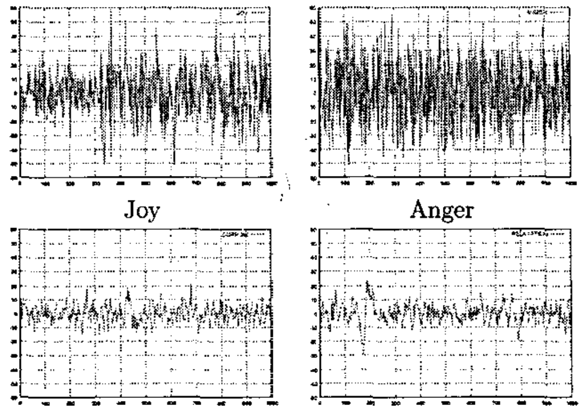

Figure 3: Comparing of four feeling data(examples)

band around the head and measure the potential of the frontal lobe. IBVA gives us one-dimensional time series EEG data. Since IBVA is lightweight and wireless, we can point out the merits that a burden to a user is small and the environment of data acquisition has little restriction.

The sampling frequency of brain-waves data is 120Hz, and the value quantized by 8 bits corresponding to −60mV-60mV for every sample is acquired.

2.3 Feature Extraction

Generally there are two approaches in the time series data analysis; frequency analysis and time analysis. As a popular way of the frequency analysis technique, there are the Fast Fourier Transform (FFT), the maximum entropy method, the wavelet transform, and so on.

Especially FFT is one of the techniques used most frequently in the frequency analysis technique, and, as a result, diverse knowledge is accessable. For example in the brain wave, while a human is relaxed, alpha wave comes out well. On the other hand, when irritated, beta wave comes out, and when excited, gamma wave comes out well. Then, we use each power spectrum of alpha wave, beta wave, and gamma wave as a feature. Incidentally, we dealt with brain waves by making from 8Hz to 13Hz into alpha wave, from 14Hz to 19Hz into beta wave, and from 20Hz to 30Hz into gamma wave[10].

And wavelet transform is suitable for time series data analysis because it can deal with not only frequency but also time. So in this paper, we use the wavelet transform at the feature extraction stage in addition to FFT.

First, the original data is divided into small data set before performing wavelet transform. In this paper, we divide a file into every 1024 samples data sets, which correspond at about 8 seconds samples.

In consideration of the data that has information from a living body with time information, we decide to divide a large data into a small data. Wavelet transform is conducted to the divided data sets. We use Gabor wavelet as a wavelet function.

The data acquired by wavelet transform has huge dimensions. Then, the expression (1) realizes dimension reduction for the value of the data after wavelet transform. In this expression, a is scale parameter, b is shift parameter, $f(a, b)$ is the result of wavelet transform, and $g(a)$ is the result of this process.

$$g(a) = \frac{1}{b}\sum_{k=0}^{b} f(a, k) \tag{1}$$

In addition, we reduce the dimensions of the input data by using principal component analysis. Principal component analysis can reduce dimensions in the selected number by loss of small information.

Moreover, when we estimate the feeling by brain waves, we know the difference among four feelings such as shown in Figure 3. It can be observed that 'joy' and 'anger' have large variance of amplitude and 'sorrow' and 'relaxation' have small variance. The variance and the average of the amplitude of the brain waves are also separately adopted as a feature.

2.4 Feeling Classification

We use the feedforward neural network for feeling classification.

When the feature extraction result is inputted into this neural network, values will be outputted from four units of the output layer corresponding to four feelings. The feeling corresponding to the unit that has biggest value is outputted, as a result, among the values of these four units. The neural network is learned by the back propagation algorithm. For learning of the neural network, we use the feature obtained at the previous stage as input data. We give '1' only to one unit corresponding to the true feeling, and '0' to others as teacher data.

Figure 4: Situation of getting EEG data

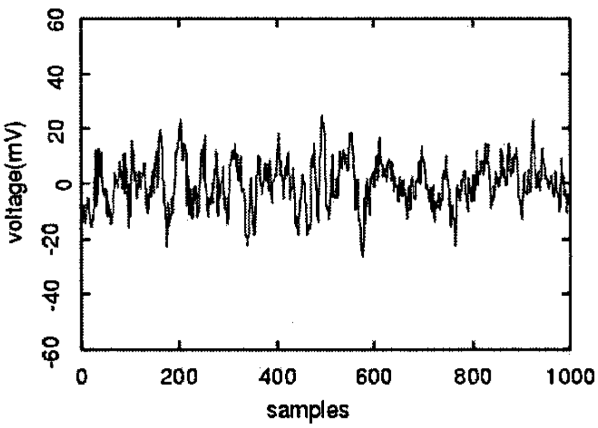

Figure 5: An example of EEG data

The output unit of neural network having maximum value is regarded as the one having the estimated result. And this system outputs one of words; joy, anger, sorrow, or relaxation.

3 Computer Experiments

We carried out computer experiments to confirm the usefulness of the proposed system. The data of four feeling states is taken in advance. When the non-learned data is inputted into a system, the feeling state is obtained.

3.1 Settings

First, we obtained the EEG data after a user had arisen four feeling. EEG data was taken from the time when the user thought that each feeling appeared. Music, television, video, or a puzzle game was used as a material of feeling remembrance. For example, a subject was relaxed by a healing music, and his/her data of relaxation was taken. The situation of brain-waves measurement is shown in Figure 4.

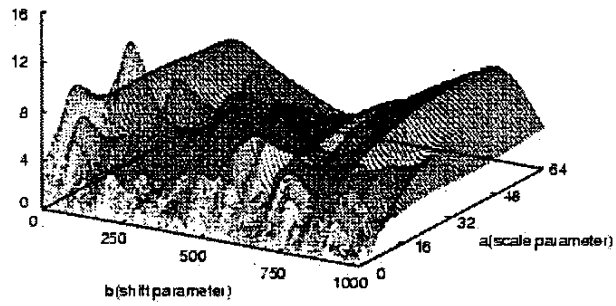

Figure 6: An example of the data after wavelet transform

Table 1: Parameter of neural network

number of input layer units	9
number of hidden layer units	15
number of output layer units	4
learning rate	0.1
number of times of learning	50000
momentum	0.2
logistic coefficient	1.0

The original brain-waves data is divided into files of 1024 points which corresponds to about 8 seconds. It is because we would like to treat the feature of brain waves which change according to the feeling. Wavelet transform is conducted to the divided file. An example of the raw brain wave is shown in Figure 5. An example of the output after wavelet transform is shown in Figure 6. In wavelet transform, the scale parameter a is set to 64 and the shift parameter b is set to 1024.

Furthermore, principal component analysis is employed to aim at reduction of the dimensions of the data. We used fifty 64-dimensional data files for each feeling as teacher data. As a result, the first principal component showed 90% or more of contribution ratio. Generally, if the feature having low contribution ratio is treated, a noise may tend to affect the result. However, dealing with the information that has low contribution ratio is diminishing the possibility that the necessary information is lost. Therefore we think that the recognition rate improved by dealing with the information that has low contribution ratio. We decided to use even the 4th primary component in which the rate of accumulation contribution exceeds 99%. Thus, we reduced the dimensions to four.

Next, we describe a setup of a neural network. After feature extraction 9-dimentional data is obtained, the number of units in the input layer is 9. The parameter of this network is summarized to Table 1.

The learning rate is 0.1, and times of training is 50000. In order to deal with the 9-dimensional data, the num-

Table 2: Result of the feeling estimation experiment

Input	Output			
	Joy	Anger	Sorrow	Relaxation
Joy	54.5%	18.7%	8.9%	17.9%
Anger	27.2%	67.7%	3.7%	1.4%
Sorrow	5.0%	5.8%	59.0%	30.2%
Relaxation	2.8%	0.0%	34.3%	62.9%

Table 3: Result without wavelet transform

Input	Output			
	Joy	Anger	Sorrow	Relaxation
Joy	43.2%	56.8%	0.0%	0.0%
Anger	24.7%	74.7%	0.0%	0.6%
Sorrow	54.4%	18.8%	19.6%	7.2%
Relaxation	50.0%	3.7%	13.0%	33.3%

ber of units of an input layer is 9. The data consists of 4-dimensional data as a result of principal component analysis, 3-dimensional data of power spectrums, and 2-dimensional data of the variance and average of the amplitude of the brain waves.

The number of units in a hidden layer is 15 and an input layer is 4 corresponding to four feeling of joy, anger, sorrow and relaxation. Feeling is judged from an output value, and one of four words, joy, anger, sorrow or relaxation, is outputted from the proposed system.

3.2 Results

The results of experiments are shown in Table 2. The data for learning is every 50 per feeling, amount to 200, and the data for the judgment is every 150 per feelings, amount to 600. The maximum judging was used for the judgment of feeling in this experiment: the feeling matched having the biggest output values in the output layer was regarded as the output.

This result is obtained in consideration of rejected data. We rejected the data when the output of the neural networks was less than 0.5.

The number of rejected data of "joy" was 16, that of "anger" was 14, that of "sorrow" was 11, and that of "relaxation" was 10.

3.3 Consideration

Table 2 shows that the rate estimated correctly was the highest of each feeling states.

We tested the importance of wavelet transform, which is one of the features of the proposed system. Table 3 shows the results without wavelet transform. The parameter of the neural network is shown in Table 4. Other parameter is the same as the previous experiment. When Table 2 is compared with Table 3, it is observed that the result using wavelet transform(Table 2) is much better than that without it(Table 3).

Table 4: Parameter of NN without wavelet transform

number of input layer units	5
number of hidden layer units	12
number of output layer units	4
learning rate	0.1
number of times of learning	50000
momentum	0.2
logistic coefficient	1.0

Table 5: Another sight of the result of this experiment

Input	Output	
	Joy+Anger	Sorrow+Relaxation
Joy	73.2%	26.8%
Anger	94.9%	5.1%
Sorrow	10.8%	89.2%
Relaxation	2.8%	97.2%

We added "joy" and "anger" to form one category and "sorow" and "relaxation" to make a new table. This result is shown in Table 5. It can be seen that the rate presumed to be joy or anger is high when joy or anger is inputted. It can be also seen that the rate presumed to be sorrow or relaxation is high when sorrow or relaxation is inputted. Therefore four feeling states can be divided into two groups, "joy and anger" and "sorrow and relaxation."

Since the result of this paper, mentioned above, was divided into two groups of "joy and anger" and "sorrow and relaxation" in high accuracy, we will consider that joy and anger are distinguished relatively with ease from the former and that sorrow and relaxation are distinguishable from the latter if the information from brain waves is used further more.

4 Conclusions

We have proposed the system for feeling estimation using a simple electroencephalograph. It is the feature on a system configuration that our system realizes feeling estimation using a simple electroencephalograph, wavelet transform, and a neural network. From the experiment, the reasonable result for estimating feelings was obtained.

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