GENETIC ALGORITHM TO SELECT FEATURES FOR FUZZY ARTMAP CLASSIFICATION OF EVOKED EEG

R.Palaniappan and P.Raveendran

Faculty of Information Science and Technology,
Multimedia University, Jalan Ayer Keroh Lama,
75450, Melaka, Malaysia.
Email: palani.rama@mmu.edu.my

Dept. of Electrical,
Faculty of Engineering, University of Malaya, Kuala
Lumpur, 50603, Malaysia.
Email: ravee@fk.um.edu.my

ABSTRACT

In this paper, we propose a technique that uses genetic algorithm (GA) to select optimal features for classification applications using Fuzzy ARTMAP (FA) neural network (NN). The technique is applied to select features for classification of two groups of subjects: alcoholics and controls, using multi-channel single trial Electroencephalogram (EEG) signals evoked during visual response. The results show that the proposed technique is successful in selecting the features that contribute towards classification. This serves to reduce the number of required features while improving the classification performance. The results also indicate that the gamma band spectral power could be used to support evidence on the residual effects of long-term use of alcohol on visual response.

1. INTRODUCTION

In any classification application, a reduction in the number of features becomes useful since this allows a reduction in computational time and design complexity. This is especially true in cases involving classification of multi-channel EEG signals.

In this paper, a technique that uses GA to select the features for FA NN classification of alcoholics and controls is proposed. FA classifier is used for evaluating the fitness function of the GA populations and is specifically chosen due to its relatively low computation training. Speed is crucial to applications involving GA since GA incurs the cost of evaluating all the populations in each generation. The features are extracted from multi-channel single trial EEG signals evoked during visual stimulus. The technique selects features that contribute towards classification, which serves to reduce the number of required features while improving classification performance.

These extracted EEG signals are known as Visual Evoked Potential (VEP) in medical literatures. The human generates Visual Evoked Potential in response to visual stimulus and over the years, it has proved to be very useful for clinical study [3,5,6,8]. In particular, the effects of alcohol on evoked responses have been reported, where it was concluded that long-term use of alcohol impairs the visual short-term memory [8].

Unlike the study in [8] which focused on analysing visual short-term memory of alcoholics, our study focuses on classification of alcoholics and controls using selected features extracted from visual responses.

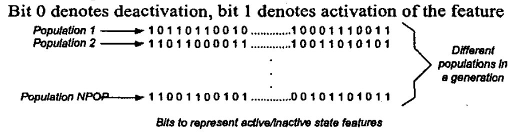
Since the studied alcoholics have been abstinent for a minimum period of one month, the identified features actually supports evidence on the residual effects of long-term alcohol use on the visual response ability.

2. THE PROPOSED METHOD

The proposed method is presented in the form of algorithm to save space and to allow easier understanding. The parameters used in GA and FA are given in Table 1.

Step 1. Initial GA populations

Generate NPOP initial populations with NBITS of binary numbers (0 or 1)
Each bit represents each of the feature
Bit 0 denotes deactivation, bit 1 denotes activation of the feature



Step 2. Population fitness calculation

Fuzzy ARTMAP training and testing using training and testing data

$$fitness_{population} = Pattern_{correct} / Pattern_{total} + NBIT_0 / NBITS$$

$Pattern_{correct}$ represents FA correctly classified patterns
$Pattern_{total}$ represents total patterns in the testing data
$NBIT_0$ represents number of inactive features
NBITS is the total number of features

Step 3. Next generation GA populations are generated

GA operators: reproduction, crossover, mutation are applied based on population fitness from step 2

Step 4. Iteration

Repeat steps 2 and 3 until maximum iteration or population convergence

Table 1: GA and FA parameters

	Coding of genes	*Binary coding*
	Population size (NPOP)	*10*
	No. of genes (NBITS)	*7 bits*
	Reproduction	*Tournament selection (pool of 3 population)*
GA	*Crossover*	*Two-point crossover*
	Crossover rate	*0.5*
	Mutation	*Random mutation*
	Mutation rate	*0.01*
	Convergence	*Maximum 500 generations or population convergence*
	Population convergence	*If 80% of populations are similar*
	Vigilance parameter	*Varied from 0 to 1 in steps of 0.1*
	Choice function	*0.01*
	Learning rate	*1 (Fast learning mode)*

3. DATA

VEP data is recorded from 10 alcoholics and 10 controls. The alcoholics have been abstinent for a minimum period of one month and are also off all medications for the same period of time. The controls are carefully matched for age, socioeconomic status and are not alcohol or substance abusers. Measurements are taken for one second from 64[1] electrodes placed on the subject's scalp, which are sampled at 256 Hz. The electrode positions (as shown in Figure 1) are located at standard sites using extension of Standard Electrode Position Nomenclature, American Encephalographic Association.

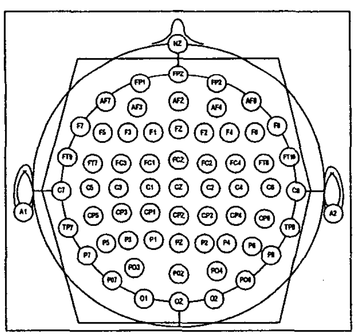


Figure 1: 64 channel electrode system (channels used outlined by the hexagon)

[1] Data from 61 channels are used to extract features; the other 3 are reference channels.

The VEP data is recorded from subjects while being exposed to a single stimulus, which are pictures of objects chosen from Snodgrass and Vanderwart picture set [7]. These pictures are common black and white line drawings like airplane, banana, ball, etc. executed according to a set of rules that provide consistency of pictorial representation. Figure 2 illustrates the presentation of these pictures. Further details of the data collection process can be obtained from [8].

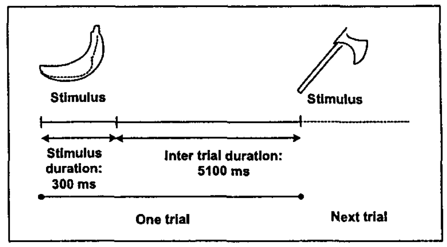


Figure 2: Presentation of Snodgrass and Vanderwart stimulus

For this study, VEP signals with eye blink artifact contamination are removed in the pre-processing stage using a computer program written to detect VEP signals with magnitudes above 100 μV. These VEP signals detected with eye blinks are then discarded from the experimental study and additional trials are included as replacements. The threshold value of 100 μV is used since blinking produces 100-200 μV potential lasting 250 milliseconds [5]. Each subject gives 10 artifact free trials, therefore giving a total of 200 VEP patterns for the experimental study.

4. FEATURE EXTRACTION USING IIR DIGITAL FILTER

A series of constant gain and uniform bandwidth Infinite Impulse response (IIR) filters are designed to extract VEP features in spectral range of 2 to 50 Hz comprising of 7 spectral bands. Information about these bands is as listed in Table 2.

Table 2: Information about spectral bands

Band name	Centre Frequency (Hz)	Approximate 3 dB Passband (Hz)
1.Delta & theta	5	2-8
2.Alpha	12	9-15
3.Beta 1	19	16-22
4.Beta 2	26	23-29
5.Gamma 1	33	30-36
6.Gamma 2	40	37-43
7.Gamma 3	47	44-50

The filter is designed using the theory of placing conjugate poles and zeros inside the z-plane unit circle. The transfer function for this filter is

$$H(z) = \frac{z^2 - zr\cos\phi}{z^2 - 2zr\cos\phi + r^2} \quad (1)$$

which expressed recursively in time domain is

$$y(n) = (2r\cos\phi).y[n-1] - r^2 y[n-2] + x[n] - (r\cos\phi).x[n-1] \quad (2)$$

Using (2), BPF is designed for the different bands listed in Table 2 by changing the value of ϕ for different centre frequencies. A value of r=0.85 is chosen since it gives approximately 3 dB pass-band width of 6 Hz. The spectral power ratio in each band is obtained from the filtered output, $y(n)$ by applying Parseval's time-frequency energy equivalence theorem using

Spectral power ratio (i^{th} band)

$$= \sum_{n=1}^{N} \left[y_i(n)\right]^2 \Big/ \sum_{i=0}^{7} \left[\sum_{n=1}^{N} \left[y_i(n)\right]^2 \right], \quad (3)$$

where N is the total number of data. The 7 spectral power ratios from each of the 61 channels are used as features representing the particular VEP pattern.

5. EXPERIMENTAL STUDY AND RESULTS

The proposed method is applied to select the VEP spectral power ratios for classification of alcoholics and controls. The dataset consisting of 100 alcoholic and 100 control VEP patterns is used here. The feature set consists of 7 spectral bands from 61 channels giving a total of 427 features. Half of the data set is used in training while the remaining data is used in testing. The patterns for training and validation are chosen randomly.

The method is used to select the most useful power ratio(s) from the 7 spectral power ratios for classification purposes. Therefore, NBITS consist of 7 bits to represent the active/inactive state of the spectral power ratios. The method is run three times to ensure that thefi nal GA population is independent of the starting point in search space. In all the three trials, GA gave the same final population that maximises the fitness function given in Table 1, i.e. 2 spectral power ratios: gamma2 and gamma3 bands. Referring to Table 2, these two bands have centre frequencies of 40 and 47 Hz. Combining both the spectral bands, it can be seen that the 3 dB spectral range of 37 to 50 Hz contributes towards discriminating alcoholics and controls.

FA classification experiments using the 7 spectral power ratios and the selected 2 spectral powers are conducted to show that the classification performances using the selected features are better than classification performances using the complete feature set.

A total of 400 VEP patterns are used in this experimental study, where half of the patterns are from alcoholics and the remaining half from controls. The number of patterns for training and testing are 200 and 200, respectively and are chosen randomly. This VEP dataset is different from the VEP dataset used earlier by GA to ensure unbiasness in the FA classification.

Tables 3 and 4 give the results of FA classification, the time taken for classification of 200 patterns and the number of clusters (nodes) formed by the FA during training. The results are given for varying vigilance parameter values of 0 to 0.9 in steps of 0.1. Table 3 gives the results of using the 7 spectral power ratios extracted from 61 channels (case A), while Table 4 gives the results using the 2 discriminatory spectral power ratios (gamma2 and gamma3) extracted from the 61 channels (case B). These results are obtained from simulations carried out on a Pentium III 800 MHz PC with 128 MB RAM and software written in C language.

Table 3: Results using 7 spectral power ratios from 61 channels (case A)

	FA classification		
Vigilance parameter	**%**	**Time (s)**	**No. of clusters**
0.00	86.5	2.04	2
0.10	86.5	2.09	2
0.20	86.5	2.03	2
0.30	87.0	4.06	4
0.40	85.5	5.10	5
0.50	86.0	8.24	8
0.60	87.5	10.24	10
0.70	87.0	21.59	21
0.80	87.0	38.12	37
0.90	84.5	79.26	77
Average	**86.4**	**17.28**	**16.8**

From Tables 3 and 4, it can be seen that the average performance of 86.4% is obtained for case A and 89.0% is obtained for case B. The average time taken for case B is 4.14 s, which is much faster than 17.28 s for case A. This is because the input features for case B is 122, while for case A is 427. In addition, it can also be noted that the average number of clusters formed in Fuzzy

ART_a during training for case B is less than case A. The lower number of inputs and less Fuzzy ART_a clusters reduces the cost and the complexity of the design.

The results also indicate that gamma band in 3 dB range of 37-50 Hz contribute the most towards classification.

Table 4: Results of using gamma2 and gamma3 spectral power ratios from 61 channels (case B)

Vigilance parameter	FA classification		
	%	Time (s)	No. of clusters
0.00	89.0	0.55	2
0.10	89.0	0.54	2
0.20	89.0	0.22	2
0.30	89.0	0.83	3
0.40	89.0	1.16	4
0.50	89.0	1.65	6
0.60	88.5	2.75	10
0.70	89.0	4.78	17
0.80	89.0	9.23	33
0.90	89.5	19.71	70
Average	**89.0**	**4.14**	**14.9**

6. CONCLUSION

In this paper, we have proposed a method using GA combined with a FA classifier to identify the useful feature set for classification of alcoholics and controls using spectral power ratios of VEP signals. Constant gain and uniform bandwidth IIR filters have been utilised in extracting VEP spectral power ratios of 7 bands in the range of 2 to 50 Hz from 61 channels. Experimental results show that the proposed method identifies the useful spectral power ratios, which improves the classification performance. The number of discriminatory spectral bands is reduced from 7 to 2, thereby improving computational speed and simplifying the design.

The selected spectral bands are from the gamma band range of 37-50 Hz. This fact indicates that gamma band spectral power could be used to support evidence on the residual effects of long-term use of alcohol on visual response.

Although the method has been applied successfully to case discussed in this paper, our preliminary analysis on other classification problems also gives good success, thereby indicating that the method is general and suitable for any problem to select features for classification applications.

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