SINGLE TRIAL VEP EXTRACTION USING DIGITAL FILTER

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ABSTRACT

We describe a method to extract single trial Visual Evoked Potential (VEP) buried in ongoing Electroencephalogram (EEG) activity. The common method for separating VEP from EEG is to use signal averaging. But we use digital filters to extract VEP assuming that VEP spectra are in the gamma band. As an application, a Fuzzy ARTMAP (FA) neural network classifier with voting strategy is used with this extracted VEP to discriminate alcoholics from normal subjects. The VEP is extracted from subjects while seeing visuals of Snodgrass and Vanderwart picture set. The high FA classification of 96.5% shows the validity of the proposed method to successfully remove EEG contamination.

1. INTRODUCTION

VEP are signals generated in the brain in response to visual stimulus. Its analysis has become very useful for neuropsychological studies and clinical purposes. The VEP signal is embedded in the ongoing EEG with additive noise causing difficulty in detection and analysis of this signal. Furthermore, SNR of VEP to EEG is very low, approximately –5 dB [5], which complicates the situation further. The traditional technique of solving this problem is to use ensemble averaging [1]. However, this approach requires many trials and the averaged signal might tend to smooth out inter-trial information.

In addition, inter trial variation in latency and amplitude might serve to distort the VEP signal. In this paper, we propose a method to extract single trial VEP buried in the spontaneous EEG activity using digital filters and use it to discriminate alcoholics and control subjects.

2. VEP EXTRACTION FROM EEG

The extracted signal is first filtered to eliminate EEG signals since EEG signal spectra are in the range of 0 to 30 Hz. We assume that the spectra of the VEP signals lie in the gamma band centred at 40 Hz.

The z transform of the filter is

$$G(z) = (1 - z^{-1})^{2N} (1 + z^{-1})^{N} . \tag{1}$$

The integer value N can be increased to reduce the bandwidth of the filter. After some experimental simulation, we found that a value of 2 for N is sufficient for our purpose. This band-pass filter extracts spectra from 29 to 48 Hz (using 3 dB cutoff and rounded to nearest integer) with a sampling frequency of 128 Hz. The first half of (1) acts as high pass filter while the second half acts as low pass filter, which when combined gives a band-pass filter with a maximum gain at 39 Hz, which is close to the ideal gamma band centre of 40 Hz. This fact can be shown by replacing z with $e^{j2\pi fT}$ in (1) which gives us

$$G_N(f) = \left|2\sin \pi fT\right|^{2N} (2\cos \pi fT)^{N} . \tag{2}$$

As an example, consider a VEP segment buried in two EEG segments as shown in Figure 2. The signal is given by

$$x(n) = x_{VEP}(n) + x_{EEG1}(n) + x_{EEG2}(n), \tag{3}$$

where $x_{VEP}(n) = A_{VEP}\sin(2\pi n f_{VEP} / f_s)$,
$x_{EEG1}(n) = A_{EEG1}\sin(2\pi n f_{EEG1} / f_s)$ and
$x_{EEG2}(n) = A_{EEG2}\sin(2\pi n f_{EEG2} / f_s)$.

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We assume that f_{VEP}=40 Hz. We choose f_{EEG1}=15 Hz and f_{EEG2}=10 Hz, arbitrarily. SNR value of –5 dB corresponds to A_{EEG1}= A_{EEG2}=1.8 with A_{VEP}=1.0, approximately. Figure 1 shows the plot for $x(n)$ obtained by using these values for two seconds of data with a sampling frequency, f_s of 128 Hz. As shown in the figure, assume that the 3 signals exist at different points in time.

Figure 2 shows the data output from the filter with order N=2 for input $x(n)$ given by (1). For the filtered case, the SNRs of VEP/EEG1 and VEP/EEG2 are approximately 14 dB and 30 dB, respectively. This improved SNR values indicates the ability of the digital filter to remove EEG contamination successfully.

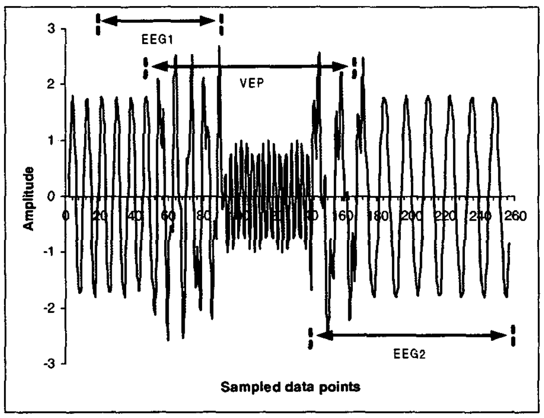

Figure 1. VEP segment buried in two EEG segments.

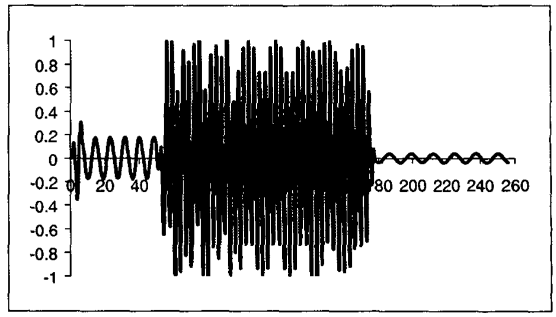

Figure 2. Filtered VEP.

The filter can be realised using only adder and delay circuits as shown in Figure 3.

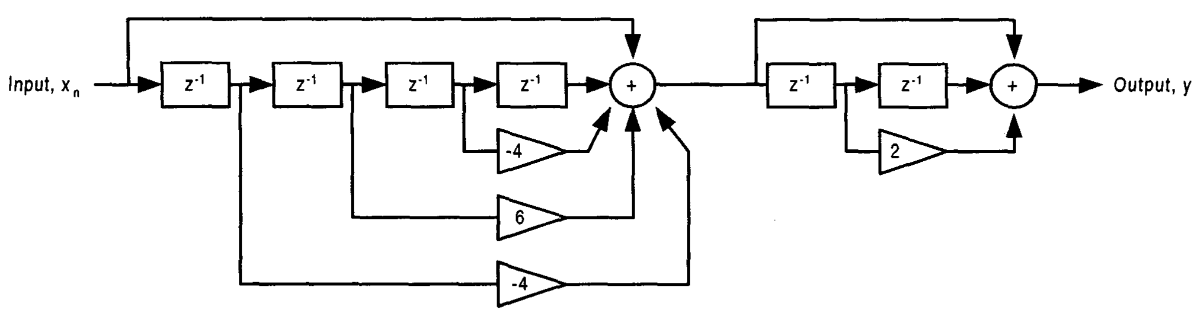

Figure 3. Filter with N=2.

3. EXPERIMENTAL METHOD

VEP signals are extracted from 20 (10 alcoholic and 10 normal) subjects with each completing 40 trials. Measurements are taken for one second from 64 electrodes placed on the subject's scalp, which are sampled at 256 Hz. The VEP signals are low pass filtered using

$$z(n) = y(n) + y(n-1), \tag{4}$$

where $y(n)$ is the output of filter discussed in Section 2 and $z(n)$ is the low pass filtered output. This will remove any frequency above 128 Hz. Next, the VEP signals are downsampled by half to obtain an equivalent sampling frequency of 128 Hz. This is since we are not interested in frequencies higher than 64 Hz for evoked potential analysis. The electrode positions are located at standard sites (Standard Electrode Position Nomenclature, American Encephalographic Association). The electrode positions are as shown in Figure 4. The VEP data is extracted from subjects while being exposed to a single stimulus, which are pictures of objects chosen from the 1980 Snodgrass and Vanderwart picture set [6]. These pictures are common black and white line drawings like aeroplane, hand, banana, bicycle, ball, etc. executed according to a set of rules that provide consistency of pictorial representation.

The extracted signals are separated from EEG contamination by using the proposed digital filter. VEP signals with artefact contamination like eye blinks are removed in the preprocessing stage - VEP signals above 70μV denotes occurrence of eye blinks.

Periodogram (using Discrete Fourier Transform method) with Welch averaging [7] is used to obtain the power spectral density (PSD) of the extracted VEP. The Welch method is applied with 50% overlap.

The peak PSD from each channel is concanated into a single feature array to be used by a Fuzzy ARTMAP (FA) classifier to classify these VEP patterns as belonging to the alcoholic subjects class or normal subjects class. Fast learning method is employed to speed up training FA and voting strategy run with 10 simulations are used to improve FA classification [4]. FA vigilance parameter is varied from 0 to 0.9 in steps of 0.1.

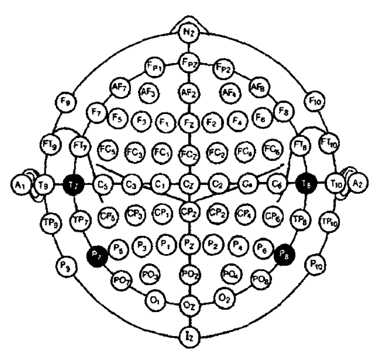

Figure 4. 64 channel electrode system.

Two experiments are simulated in the experimental study. First, the VEP signals are filtered and used in FA classification while the second classification experiment uses VEP data without filtering. This procedure is to show the advantage of using the filter to remove overlapping EEG from VEP.

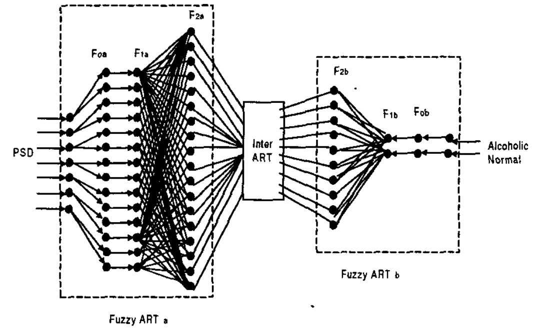

Figure 5. Fuzzy ARTMAP structure.

4. RESULTS

Table 1 shows the results of the experimental study. It can be seen that FA classification using the filtered data is higher than the case of without filtering. This is since VEP signals are contaminated with EEG and the filtering process successfully removes this contamination thereby allowing the visual stimulus to be represented in the VEP signal. In general, it can be seen that a better classification is obtained with a higher vigilance parameter with a maximum classification of 96.5% for vigilance parameter value of 0.9.

Table 1. FA classification results.

	VEP classification	
Vigilance parameter	**With filter**	**Without filtering**
0	87.25	73.25
0.1	87.75	72.25
0.2	88.25	73.00
0.3	87.00	67.75
0.4	86.75	71.75
0.5	86.50	77.00
0.6	88.00	77.25
0.7	88.50	79.00
0.8	90.25	79.50
0.9	96.50	76.25

5. CONCLUSION

This paper has proposed a method of detecting and extracting single trial VEP signals buried in EEG and noise using digital filters. FA classification using PSD of the extracted VEP data obtained from subjects during the presentation of visuals from Snodgrass and Vanderwart picture set gives 96.5% accuracy in differentiating alcoholics from control subjects. The high classification shows that the proposed method is advantageous in single trial VEP detection and classification.

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