Int. Conf. on Signal, Image Processing Communication & Automation, ICSIPCA

A Review Paper on Extraction of Visual Evoked Potential Techniques

Bhargav N [1] and Dr. Viswanatha V.M [2]
[1] Research Scholar, Department of ECE, Acharya Institute of Technology,
Bengaluru, Karnataka, India
Email: bhargavn@acharya.ac.in
[2] Professor & HOD, Department of ECE, SLNCE, Raichur, Karnataka, India
Email: vmviswantha@gmail.com

***Abstract*—Evoked Potentials (EP) or Event Related Potentials (ERP) is the potential developed in the body due to the application of external stimulus. The stimulus can be visual or auditory or sensual accordingly they are called Visual Evoked Potential (VEP), Auditory Evoked Potential (AEP) Somata Sensory Evoked Potential (SEP). These evoked potentials are embedded in the Electroencephalogram (EEG) signals and have very low amplitude. The proposed approach focuses to use Complex Wavelet Transform technique to estimate VEP by developing an algorithm in which wavelets will improve the SNR compared to the conventional techniques, overcomes the existing problem of removal of background noise from Evoked potential, is Shift Invariant & will preserve the notion of phase of the transformed coefficients by choosing an appropriate Thresholding method which is critical in EP Reconstruction and Estimation.**

***Index Terms*— Evoked Potential, Electroencephalogram, Visual Evoked Potential, Ensemble Averaging, Weighted Averaging, Parametric Modeling, Adaptive Filtering, Wavelet Transform.**

I. INTRODUCTION

Biological signals are those signals which are generated by the physiological activities of the body, which can be measured & monitored continuously and is an interdisciplinary subject. These signals take on one of the forms of chemical or electrical or acoustics, it can be continuous or discrete in nature. It is of utmost importance to study these signals which helps us to know the functioning of the human body. There are different types of biological signals, to name a few are Electrocardiogram (ECG), Electro-encephalogram (EEG), Electromyogram (EMG), Magneto encephalogram (MEG), Mechanomyogram (MMG) & Electrooculography (EOG) which measure the electrical activities of a particular organ in the human body.
VEPs are produced by electrical activity of the visual cortex in response to light or pattern stimulation of the eye. Presentation of an external stimulus “evokes” an electrical potential, as a response from the nervous system which is called the Evoked Potential. It is different from the spontaneous potential detected by electroencephalography (EEG), electro-myography (EMG), or other electro-physiological recording method.
The Evoked potential is classified as follows:

- Visual Evoked Potential (VEP)
- Auditory Evoked Potential (AEP)

Grenze ID: 02.ICSIPCA.2017.1.50

- Somatosensory Potential (SEP)

When an intensive light stimulus is applied (causing a Visual Evoked Potential), the electrical activity of the brain is altered observably. Computerized averaging techniques have made it possible to use the visual evoked potentials which are generally of low amplitude.

AEP an electrical signal that can be recorded from electrodes attached to the scalp of a human subject, when a sound is presented. Somatosensory evoked potentials (SEPs or SSEPs) are a beneficial, unintrusive method of evaluating somatosensory system functioning. It is conceivable to judge the diffusion of the receptive salvo from the outermost up to the cortex by merging SEP recordings taken at different levels of the somatosensory pathways.

II. EXISTING TECHNIQUES

A. Ensemble Averaging Technique

The Ensemble Averaging Technique is the most commonly used technique for determining Evoked Potential estimate. Ensemble averaging is to create a combined model with anticipated results by generating and combining several models by the process of averaging the successive sets of data that are collected starting from the same data point for collecting data from the repeated signal, as opposed to creating just one model.

EP is measured by recording the electric potential generated from the brain which is recorded from the scalp. Critical Care, Operating Room Monitoring and the diagnosis of various neurological disorders can be done using EP measurement. EP Signal estimation is one such example of the application of this technique. Various errors of the model average out as a whole. Zero mean random noise is cancelled out when characteristics of noisy signals are highlighted by their repetitive additions. Putting it mathematically:

$$(\mathrm{SNR})_f = (\mathrm{SNR})_0 \sqrt{N}$$

Where,

$(\mathrm{SNR})_0$ – Original signal to noise ratio of the signal.

$(\mathrm{SNR})_f$ – Final signal to noise ratio.

N –Number of repetitions (scans).

Ensemble Averaging Technique suffers from the drawback of the requirement of several thousands of sweeps count which are then averaged to measure the EP over several minutes causing undue motion artifact in some cases like infant patients. Reducing the acquisition time of EP measurement is thus very desirable.

B. Weighted Averaging Technique

Ref. [6] Each signal to be averaged is assigned a weight in this Technique before averaging to obtain weighted averages of brain evoked potential and these weights maximize the SNR of the resulting average if certain criterion is met. Efficient Technique of approximating the SNR weights is possible by making simplifying assumptions about signal and noise correlation matrices.

C. Parametric Modeling Technique

In a parametric model of random processes, all the parameters are in finite-dimensional parameter spaces. When a white noise sequence drives a shift invariant system, the discrete time random processes can be modeled as output. Such output can be characterized by statistics of input noise and parameters of shift variant system. Estimation of the EP signals can be done using this Technique.

D. Adaptive Filtering Technique

EP signal can be extracted using adaptive filtering technique in which the Mean Square Error (MSE) is minimized between successive ensembles and requires fewer ensembles to attain adequate signal quality. Least Mean Square (LMS) and Recursive Least Square (RLS) are the two algorithms under adaptive filtering. The SNR is also improved in this Technique.The time adaptive filters require a reference signal for each trial that is generally calculated as the average of all trials except the trial being considered. Ref. [1] The outcome suffers from test-test inconsistency to produce a worthy reference signal for each sample as they bank on averaging multiple tests.

III. LIMITATIONS OF EXISTING TECHNIQUES

The few existing techniques for the extraction of VEP are Ensemble Averaging, Weighted Averaging, Parametric Modelling, Adaptive Filtering & Wavelet Transform, all of which suffers from low signal to noise ratio (SNR).

Apart from this wavelet transform suffers from the following drawbacks: -

- It cannot be used to extract VEP's from noise
- Ref. [2] It is not shift Invariant (These results in the fact that the energy distribution between wavelet sub bands is sensitive to a small-time shift of the input signal)
- Ref. [3] Has a higher threshold value (this inevitably leads to loss of dominant information by signal distortion)
- Ref. [2] Notion of phase of transformed coefficients is not preserved

Ref. [4] Furthermore, the wavelet coefficients of neuronal signals in EEG could have small values compared with noises because the SNR is relatively small

IV. PROPOSED WORK

A. Wavelet Transform Technique

Ref. [8] When long time intervals are used, more precise low frequency information can be obtained and shorter time intervals/regions are used to obtain high frequency information. This windowing technique with variable-sized regions constitutes wavelet analysis.

The continuous wavelet transform (CWT) of a one dimensional signal *x(t)* with respect to a mother wavelet $\psi\ (t)$ is defined as:

$$Wx(a,b)=\frac{1}{\sqrt{|a|}}\int_{-\infty}^{+\infty}x(t)\psi\left(\frac{t-b}{a}\right)dt \qquad \text{---- (1.1)}$$

Ref [7] Where, *a*, *b* are the scale and translation parameters, respectively. As its name implies, CWT has continuous scales and translations, which result in information redundancy and high computational load. Contracted versions of the wavelet function match the high frequency components of the original signal, while dilated versions match low frequency components.

In practice, the scale and translation parameters are discretized for fast implementation. In fact, the scales on the powers of two {2*l*} are sufficient and this will yield the dyadic wavelet transform:

$$W_x(l,n)=\frac{1}{\sqrt{2^l}}\int_{-\infty}^{+\infty}x(t)\,\psi\left(\frac{t-n}{2^l}\right)dt \qquad \text{----- (1.2)}$$

The WT gives a time-frequency representation of a signal and has an optimal resolution both in the time and the frequency domains.

Fig. 1.1 Decomposition of EP Signal

V. PROPOSED ALGORITHM

1. Decompose the signal into L detail levels by applying the discrete wavelet transform on the signal where L depends on the sampling frequency as $Fs=2^{L+1}$ as shown in Fig.1.1.
2. Thresholding (Hard/Soft) [5] the wavelet coefficients by the proposed algorithm to Remove the high frequency Noise signal i.e. detailed coefficients and retain the low frequency signal components i.e. approximation coefficients.
3. Reconstruct the EP signal by applying Inverse Discrete Wavelet Transform of the decomposed signal as shown in Fig.1.2.
4. Calculate the output SNR for different sweeps.

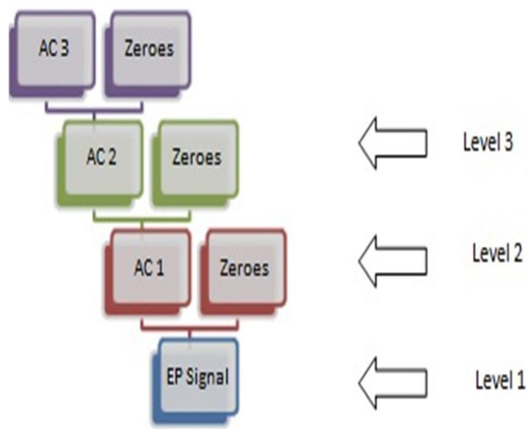

Fig. 1.2 Reconstruction of EP Signal

VI. POSSIBLE OUTCOMES

- Measure the SNR of Conventional Techniques
- Improved SNR in comparison with existing Techniques
- Present Modified Complex Wavelet Transform Technique which improves the SNR of VEP using MATLAB
- Demonstrate the Proposed Technique outperforms the other Conventional Techniques

VII. RESULTS

Synthetic signals consisting of 300 samples are generated, which comprises of Noise & evoked Potential. Figure 1.3 shows three sweeps of such signals.

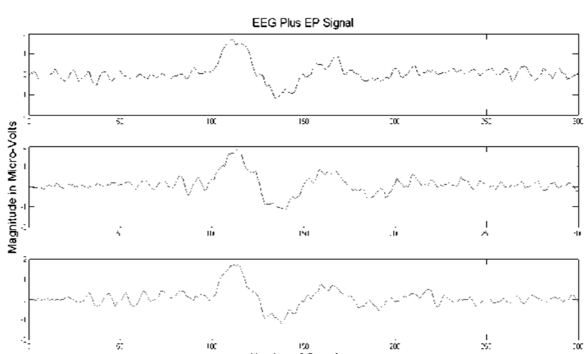

Fig. 1.3 EEG Plus EP Signal

Ensemble Averaging Technique waveform is as shown in figure 1.4. Considering figure 1.3 and figure 1.4, the noise in the sweep is reduced in the latter. Hence, the quality of the signal is enhanced using this technique and also the SNR improves with the number of sweeps taken, which is interpreted in figure 1.5.

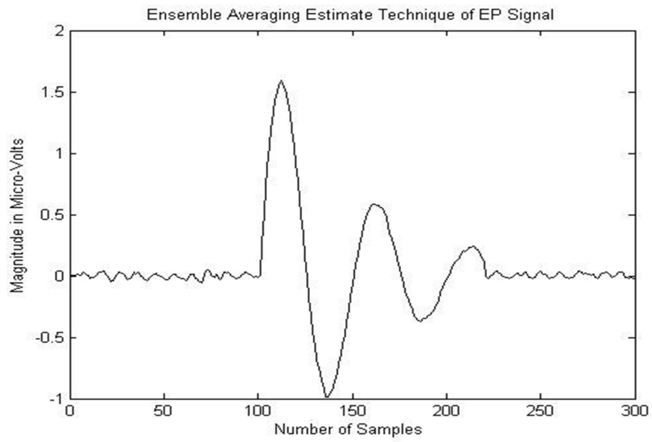

Fig. 1.4 Ensemble Averaging Technique

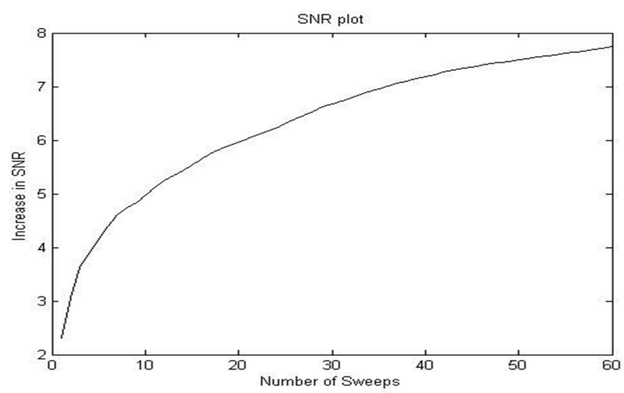

Fig. 1.5 Plot of SNR & number of sweeps

VIII. CONCLUSION

Four techniques have been reviewed in this paper: Ensemble Averaging, Weighted Averaging, Parametric Modelling and Adaptive filtering techniques. Ensemble Averaging is the utmost predominant technique still being practiced, even though it banks on modest assumptions of idealistic data sets. Maximizing SNR depends on the weights assigned in Weighted Averaging Technique. Parametric Modelling is not beneficial for template based feature extraction. Adaptive Filtering is limited to gauging smaller number of sweeps and their application is restricted because of its non-intuitive aspects.

REFERENCES

[1] Yu XH, He ZY, Zhang YS. “Time-varying adaptive filters for evoked potential estimation”. IEEE Trans Biomed Eng. 1994; 41: 1062–1071.

[2] Arnaud Jacquin Elvir Causevic Roy John Jelena Kovacevic, “Adaptive Complex Wavelet-Based Filtering of EEG For Extraction of Evoked Potential Responses”, Everest Biomedical Instruments NYU Medical Center Carnegie Mellon University.

[3] Ling Zou, Yingchun Zhang, Laurence T. Yang and Renlai Zhou, "Single-Trial Evoked Potentials Study by Combining Wavelet Denoising and Principal Component Analysis Methods", Journal of Clinical Neurophysiology, Volume 27, Number 1, January 2010

[4] Paraschiv-Ionescu A, Jutten C, Aminian K et al., "Source separation in strong noisy mixtures: a study of wavelet de-noising pre-processing", Proc IEEE Int Conf Acoust Speech Signal Process ICASSP. 2002;2:1681–1684.

[5] David Alexander Goodwin, "Wavelet analysis of temporal data", The University of Leeds, February 2008

[6] Willis.J.Tompkins, "Biomedical Digital Signal Processing", PHI Publications

[7] Stephane Mallat, "A wavelet tour of signal processing", PHI Publications

[8] Robi Polikar, "The engineer's ultimate guide to wavelet analysis".