Feature Extraction and Classification of Visually Evoked Potentials and its Application in Forensic Science

Department of Electronics and Communication Engineering
BMS Institute of Technology and Management, Bangalore, India

Abstract:
In forensic science, there are various criminal analysis techniques used such as polygraph, narco-analysis test, brain fingerprinting. In any criminal act, the brain is always there, planning, executing and recording the crime. The fundamental difference between a perpetrator and a falsely accused innocent person is that, the former, having committed the crime, has the details of the crime stored in the brain whereas the latter who is innocent will not have the details in the brain. Various techniques like P300, P300-MERMER which are classes of EEG are used in interrogating a criminal mind. An analysis of Event Related Potentials(ERP) such as Visually Evoked Potential(VEP) within EEG signal is mainly limited to clinical diagnostics. In our work we developed an algorithm to extract and classify the features of visually evoked potentials (VEP). This technique proposed can be applied in the field of forensic science.

I. INTRODUCTION

Forensic science is the scientific method of gathering and examining information about the past which is then used in a court of law. It is used to for the scientific assessment of DNA, blood samples, bones and so on. Forensic plays an important role in criminal investigations. There are various other scientific methods such as psychological test, narco analysis test, polygraph test, brain Mapping etc. EEG is a promising tool in forensic science since this is a non-invasive technique and it does not induce any drugs in human body. More over the EEG signals are directly taken from human scalp and are electrical variations in various parts of human brain and it is also a function of persons thought and emotions. Hence this is one of the best method to retrieve the kind of information stored in the brain. Novel approaches in the detection and processing of EEG signals and its analysis is very important since these techniques are very promising not only in the field of forensic analysis, but in various other clinical diagnosis also. Till date, various techniques like P300, P300-MERMER which are event related potentials a class of EEG signals are used to interrogate a criminal mind. In this paper, an analysis of a class of event related potentials that is visually evoked potential is proposed that can be applied in the field of forensic science. Visually Evoked Potentials(VEP) within EEG signals are mainly used in clinical diagnostics. VEP is exploited in the field of forensics in the present project. A visual evoked potential is an evoked potential caused by a visual stimulus, such as an alternating checkerboard pattern on a computer screen. Responses are recorded from electrodes that are placed on the back of your head and are observed as a reading on an electroencephalogram (EEG). These responses usually originate from the occipital cortex, the area of the brain involved in receiving and interpreting visual signals. The EEG (electroencephalography) based system determines whether specific information is stored in a person's memory or not. Information of a crime registered in the brain is revealed by a distinctive pattern in the VEP (Visual Evoked Potentials) extracted from EEG. We are presently demonstrating this by the variation in the EEG pattern for a particular class of images. These variations may be observed for features extracted from persons EEG signals and a level of abnormality in the feature values can be utilised for further analysis. There are number of methods used in the extraction of features from EEG signals. Asish Panat et all, [1] uses wavelet transform to extract the features related to the mood/emotions of a person. A real time data of 256 samples per second is were used in the analysis. Four level decomposition of wavelet transform was implemented for feature extraction. The Statistical Parameters considered were mean, standard deviation, variance, skewness, entropy, power, and RMS value. It is observed that there is a significant change in the values calculated for RMS value, Power and Entropy of the signal when calculated for the EEG of the person when he is in ‘Angry’ mood and when he is in ‘Sad’ mood. Then values of features Power and RMS value of the data hold the higher values in case of the Angry emotion as compared to the Sad emotion, whereas, the values of feature Entropy show a lower value in the Angry emotion as compared to the sad emotion. Murugappan [2] et all, used the combination of surface Laplacian (SL) filtering, time-frequency analysis of wavelet transforms (WT) and linear classifiers are used to classify discrete emotions (happy, surprise, fear, disgust, and neutral). The validation of statistical features was performed using 5-fold cross validation. In this work, K nearest neighbour (KNN) outperformed linear discriminant analysis (LDA) by offering a maximum average classification rate of 83.04% on 62 channels and 79.17% on 24 channels, respectively.

Methodology.
We have analysed Visually Evoked Potential (VEP) within the Electroencephalographic (EEG) signals by extracting its features and classifying them. We have extracted the following features of Visually Evoked Potential (VEP) signals.

- Variance
- Standard Deviation
- Simple Square Integral
EEG response after viewing different pictures (visual stimuli) was stored in three classes i.e. stimulus1 (S1), stimulus2-match (S2-match) and stimulus2-no match (S2-no-match). The EEG signals which were obtained after viewing repeated pictures (S2 repeated as S1) were categorized as “match” group and the EEG signals obtained after viewing non-repeated pictures (S2 is completely different from S1) were categorized as “no-match”. A random EEG signal corresponding to S1 is taken and classified into either match or no-match using KNN classification technique. For this particular classification technique, the above mentioned features are extracted using wavelet transform. These features are extracted using wavelet transform with the help of six-level wavelet decomposition. With the help of these extracted features, the EEG signals were classified into “match” group and “no-match” group using K-Nearest Neighbour (KNN) classification technique. The block diagram of the proposed model is as shown in figure 1. It consists of testing and training signals. The testing data contains 10 EEG signals (S1 stimuli) and training data has 20 EEG signals (S2 stimuli with both ‘match’ and ‘no-match’). The wavelet decomposition and feature extraction are implemented on both the testing and training signals. The features of testing signals are compared with the features of training signals and based on close resemblance of features with the training signals, the testing signals are either classified into either ‘match’ or ‘no-match’ group using KNN classification technique.

Wavelet Decomposition
In wavelet decomposition, the EEG signal is divided into a number of segments depending upon the decomposition levels used and the input to the wavelet transform is shown in above figure 2. The input shown in figure 2 is a visual evoked potential signal in which the potential is evoked by showing a visual stimulus. In our case the visual stimulus is the image which falls under match and no-match category. We have used a six-level wavelet decomposition technique. This results to six decomposed segments. The mother wavelet used is Daubechies. During wavelet decomposition, down sampling (decimation) is used after every level of decomposition and for this reason, the number of samples keeps on reducing with the increase in the number of decomposition levels as shown in figure 3.

Feature Extraction
Six statistical parameters like Variance, Standard Deviation, Simple Square Integral, RMS, Waveform Length and Entropy are calculated. The features are calculated on each component of the decomposed signal individually[7]. Figure 4 shows the plot of extracted features of an EEG signal which consists of six plots for six features separately. The first one is the plot for standard deviation in which x-axis shows six decomposed signal level and y-axis shows the magnitude values of standard deviation. In a similar way, variance, simple square integral (energy), entropy, waveform length and RMS value are plotted in figure 4.
Classification

Using the extracted features, the EEG signals are classified into either ‘match’ or ‘no-match’ group. First, the Euclidean distance between the testing signal and training signal are calculated, that is, the Euclidean distance is calculated between the signal corresponding to S1 stimulus and S2 stimulus (match/no-match).

\[ \sqrt{\sum_{i=1}^{n}(a_i - b_i)^2} \]

If the testing signal lies nearer to ‘match’ training signal, then the testing signal is classified into ‘match’ group otherwise it is classified into ‘no-match’ group. Figure 5 shows the K-Nearest Neighbour plot for a single testing signal with only one feature being considered i.e. variance.

![Figure 5. KNN Plot of a single testing signal](http://ijesc.org/)

In figure 5, the Euclidian distances of the variance between a single testing signal and each of the 20 training signals are calculated. If the distance between the testing signal and the ‘match’ training signal is less i.e. if the distance is closer to zero, then the testing signal is classified into ‘match’ group else the testing signal is classified into ‘no-match’ group. Nine out of ten testing signals were classified into match group with 90% efficiency.

![Figure 6. KNN plot of all the ten testing signals.](http://ijesc.org/)

The Euclidian distances of all the features between 10 testing signal and each of the 20 training signals are calculated. If the distance between the testing signal and the ‘match’ training signal is least i.e. if the distance is closer to zero, then the testing signal is classified into ‘match’ group else the testing signal is classified into ‘no-match’ group. In figure 6, nine out of ten test signals comes under match class with 90% efficiency.

II. CONCLUSION

In this work, a person’s response to the visual objects is studied. It states that if a person is subjected to different types of visual inputs, different variations in EEG were obtained which facilitated in classifying the signals into different classes. The extracted features using wavelet decompositions and further classification shows 90% efficiency. We hereby propose that, in criminal investigations we can use this method by analysing the familiarity of the person with the crime scene. If the person is familiar with the crime scene, there is 90% chance that, his/her VEP signal falls under the category of match signal.

III. SCOPE OF FUTURE WORK

Till date the forensic analysis using EEG signals is concentrated to standard studies of P300, P300-MERMER Polygraph etc. The present project proposes to record deviations in EEG signals and use the same to decipher the sanctity of an event occurred in past. This idea, after further studies may be of helpful in forensic detection of mental thoughts.

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IV. REFERENCES


