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REVIEW: Previous Deception detection methods and New proposed method using independent component analysis of EEG signals.

Roshni D. Tale*, Bhavana P.Harne**
* (Department of Electronics and Telecommunication engineering, S.S.G. M. College of Engineering, Shegaon, India, 444203.) **
(Department of Electronics and Telecommunication Engineering , .S.S.G. M. College of Engineering, Shegaon, India, 444203)

ABSTRACT
Deception detection has important legal and medical applications, but the reliability of methods for the differentiation between truthful and deceptive responses is still limited. Deception detection can be more accurately achieved by measuring the brain correlates of lying in an individual. For the evaluation of the method, several participants were gone through the designed concealed information test paradigm and their respective brain signals were recorded. The electroencephalogram (EEG) signals were recorded and separated into many single trials. To enhance signal noise ratio (SNR) of P3 components, the independent component analysis (ICA) method was adopted to separate non-P3 (i.e. artifacts) and P3 components from every single trial. Then the P3 waveforms with high SNR were reconstructed. And then group of features based on time, frequency, and amplitude were extracted from the reconstructed P3 waveforms. Finally, two different class of feature samples were used to train a support vector machine (SVM) classifier because it has higher performance compared with several other classifiers. The method presented in this paper improves the efficiency of CIT and deception detection in comparison with previous reported methods.
Keywords**-** Electroencephalogram, Independent component analysis, Support vector machine, Concealed information test

I. INTRODUCTION

Detection is one of the most emotive and hotly debated of all human technological endeavors. The ability to detect deception has important legal, moral and clinical implications, and has recently received revived interest from the scientific community. Deception is ubiquitous in human societies and is essential for proper social interactions. Lying is a complex process requiring suppression of the truth, communication of a coherent falsehood, contextual knowledge of that false situation, and modifications and changes of behaviors to convince the receiver of one's actions.[1] This complex and universal process would seem amenable to detection by brain imaging. The ability to measure noninvasively the Correlates of lying in the brain within an individual could offer a significant improvement over currently available tools to detect deception. Currently, the most widely used technique for the quantitative discrimination between deceptive and truthful responses is polygraph test, which relies on measures of autonomic nervous system response, i.e. emotional efferents. Traditional polygraphy, however, has been criticized for having unacceptable level of reliability. Consequently, a number of other recording modalities have recently been investigated for the possible application to deception detection; other method includes functional magnetic resonance (fMRI) and electroencephalography (EEG). Until recently, the reported EEG studies in deception detection have primarily focused on the topography and time-domain analyses of the P300 component. However, there is still disagreement about the features that may best discriminate between deceptive and truthful responses.[2]

In this paper we will discuss about the new method of deception detection using electroencephalograph (EEG) analysis of guilty and truthful suspect. Here the most powerful technique Independent component analysis is used to separate the eeg signal as eeg signal is superposition of many signal arising from brain and different noise such as Electroculogram EOG) and EMG. Buried in the EEG are signals that reveal information about brain processes. These signals are detected by changes in timing in the EEG after events such as listening to a sound or seeing a picture. The resulting signal is called an event related potential (ERP), which clearly stands above the background brain activity. The ERP can be divided into several basic components represented as positive or negative fluctuations in the ERP waveform at different delays after the stimulating event.ERP component contains signals such as P1, P2, N1, N2, N400 and P300. The signals generally arising after 250 milliseconds are thought to reflect higher level cognitive processes such as memory or language. The P300 is a specific electrical brain wave that is triggered whenever a person sees a object familiar to him. The P300 waves have been understood in electrophysiology to mean that the subject is able to consciously identify and categorize a stimulus. For instance, if a subject has been listening to trombone noises and a flute tone is played, a P300 wave will appear 300 ms later on the EEG machine. The P300 event-related potential can be used to determine concealed knowledge that only a criminal would know. By placing details of the crime randomly among a list of non-relevant items, one can distinguish criminal from citizen. If an individual recognizes a detail of the crime, it produce a P300 EPR and is likely guilty of, or at least familiar with, the crime.

II. THE DEVELOPMENT OF DECEPTION DETECTION TECHNOLOGY

The U.S. judicial system places great weight in the belief that juries are effective and reliable in determining the credibility of the witness. Yet, behavioral and social research has shown that humans are good at lying and quite poor at lie detection. For example, an average person’s ability to detect deception in a face-to-face interaction with another individual is only modestly better than chance. Thus, the critical importance of truthful testimony and the inadequacy of human lie detectors have prompted the perennial search for a technology-based, objective method of lie detection or truth verification; this search continues today. Let us take a review on previous work and research regarding deception detection.

II.1. DETECTING DECEPTION VIA ANALYSIS OF VERBAL AND NON VERBAL BEHAVIOUR

In the early ages technique called deception detection via analysis of verbal and nonverbal behavior had been developed. In this they examined the hypotheses that a systematic analysis of nonverbal behavior could be useful in deception detection and that lie detection would be most accurate if both verbal and nonverbal indicators of deception to be consider. Seventy three nursing students participated in a study about “telling lies” and either told the truth or lied about a film they had just seen. The interviews were audio and video recorded and the nonverbal behavior (NVB) and speech content of the liars and truth tellers were analyzed the later with the criteria based content analysis technique and reality monitoring technique. Results revealed several nonverbal and verbal indicators of deception. If only nonverbal behavior is considered 78% of the lies and truths could be correctly classified. An even the percentage of correct classification can be higher when all three detection techniques were taken into account. But this is completely hypothetical results based so is not liable. There are the basic ways to catch liars (A) By observing them how they behave their movements, whether they smile or steal gazes, pitch of their voice, rate of speech likewise. (B) By listening to them what they says analyzing there speech content, (C) By measuring physiological responses.[4][5] Deception detection method bases on verbal nonverbal behavior based on content-based criteria analysis (CBCA) and Reality monitoring(RM). Use of nonverbal cues for deceit detection accuracy rate is usually 45 and 60 percent. This method is not reliable because this is based on hypothetical assumptions. Some liars may act innocent during the test if they are skilled enough to deceive and some innocent may found guilty because of fear and nervousness.[1][6] This is not reliable method.

II.2. POLYGRAPH TEST

Anaother most widely used method lately is Polygraph Teste.The polygraph, which measures activity of the peripheral nervous system to detect deception .This method measure nonspecific peripheral emotional/autonomic arousal that might or might not be associated with lying. By their very nature, polygraph measurements provide an extremely limited and indirect view of complex underlying brain processes.

II.3. FIELD MAGNETIC RESPONSE IMAGING

Another emerging technique is FMRI. MRI is a medical imaging technique using high magnetic fields and non-ionizing electromagnetic radiation to produce high resolution, three-dimensional (3D) tomographic images of the body is distinguished from regular (structural) MRI by the speed of acquisition of each 3D image.[3] In fMRI, continuous images of the entire brain are acquired after every few seconds, which is fast enough to observe changes in the regional blood volume and flow that are associated with cognitive activity. Blood oxygenation level dependent (BOLD) imaging is now being used in the fMRI technique most commonly used in cognitive neuroscience. BOLD depends on the difference in the magnetic properties of the contents of the blood vessels and the surrounding brain tissue as well as the magnetic difference between oxygenated and deoxygenated hemoglobin. BOLD fMRI does not show absolute regional brain activity; rather, it indicates relative changes in regional activity over time. To make conclusions about the nature of the regional brain activity, BOLD FMRI task designs rely on a principle of “cognitive subtraction”. This principle assumes that the fMRI signal difference between two behavioral conditions that are identical in all but a single variable is due to this variable. We have presented a method for parallel spatial and temporal independent component analysis for concurrent multi-subject single-trial EEG-fMRI recordings that addresses the mixing problem in both modalities. The data are integrated via correlation of the trial-to-trial modulation of the recovered FMRI maps with EEG time-courses. The method afforded identification of an additional spatiotemporal process corresponding to the auditory onset response and subsequent low-level orienting/ change detection.[6][7]The discussion details the area where this method is applicable, and provides an account for the potential functional role of the reported component.

A researchable hypothesis is that by looking at brain function more directly, it might be possible to understand and ultimately detect deception. Based on this supposition a number of neurophysiologic signals have recently been investigated for the possible application to deception detection, including Functional Magnetic Resonance Imaging (fMRI) and event related potentials (ERP). ERPs are recorded from the central nervous system and are considered to be affected by the recognition of important events, which is more cognitively determined activity than autonomic responses. An endogenous ERP, which has been extensively studied, is the P300 (P3) wave. It is seen in response to rare, meaningful stimuli often called "oddball" stimuli.[8][9][10] The EEG is composed of electrical potentials arising from several sources. Each source (including separate neural clusters, blink artifact, or pulse artifact) projects a unique topography onto the scalp-'scalp maps'. These maps are mixed according to the principle of linear superposition. Independent component analysis (ICA) attempts to reverse the superposition by separating the EEG into mutually independent scalp maps, or components so that the method used is the study is independent component analysis (ICA).[11][12] After applying ICA and extracting required response features are extracted and then by using SVM classifier we can see the difference between truthful and deceptive responses.

III. PRPOSED METHOD

The brief idea about the method is that first acquiring the EEG recording of the person under test with the help of Concealed information test, then after signal acquisition performing some basic filtering operation on the acquired data so as to increase the SNR of signal and reduce some percent of noise. We know that EEG consist of many superimposed signal so by applying powerful Independent Component Analysis algorithm we will get refined and independent signals from mixed EEG signal. After applying ICA we can get the clear view of signal and then feature extraction can be performed. Various features can be extracted from the EEG signal such as Frequency , time, amplitude, Eigen values etc. After extracting the feature these features are applied to SVM classifier. SVM classifier will classify the features into two sets of value SVM classifier is one of the powerful classifier to classify two sets of value exactly.

III.1. CONCEALED INFORMATION TEST

An alternative technique, the concealed information test (CIT), also known as the guilty knowledge test, has recently drawn considerable attention among researchers. This test presents a set of question items to an examiner, which include one crime related item (critical item) and several control items (noncritical items). Items are selected so that an innocent examinee (i.e., one who does not possess the information) would be unable to distinguish the critical item from the noncritical items. In this study, we used the CIT technique which relied on contrasting brain waves evoked by relevant and control stimuli, and developed a novel efficient (i.e., accuracy/time) EEG-based CIT using machine learning algorithms. Through EEG signal processing, we automatically detected brain waves corresponding to different mental activity patterns to uncover the critical item from noncritical items. Indeed, numerous studies have previously demonstrated that CIT based on brain signals can be very accurate. Besides detection accuracy, it is important to develop fast algorithms that can be used in real-life CIT investigations, for a number of reasons.

Participants: The participants in this test are 5 healthy right handed person of age between. They had no previous history of neurological or mental abnormalities.

Protocol: Participants will be given a total 3 card out of which two will be face up on the computer screen Participants will be informed that the identities of these two face-up cards, as in some forms of poker, were known by the participants, as well as the researchers. Participants will then asked to choose a third card from among two sealed envelope, each of which contained a playing card which they kept in their hand ('target' card) and Rs50. Participants were informed that only they knew the identity of this card, and the experimenter would be attempting to learn the identity of this card by alternately presenting a series of cards, asking the question "Do you have this card?", and examining their brain responses. They were told that if they were successful in concealing the identity of the card, that would be able to keep Rs 50. Three categories of cards were presented to participants. The 'target' card was presented 10 times. The "correct" response to the question "Do you have this card?" for this card was "no." The 'truth' card was also presented 10 times with a correct response of "no." 'Control' cards consisted of 2 presentations each of the 2 'hand' cards, with a correct response of "yes." In this way the test is performed and EEG recording of 5 persons can be recorded.

III.2. EEG SYSTEM AND PREPROCESSING

The EEG recording will be made using Ag-AgCl electrode placed on the scalp .The EPR is mainly elicits in prefrontal lobe of brain. So the recording from the electrode placed in this area is taken that is recordings of electrode F3 F4 F8 F7 will be taken into consideration. Then the recorded EEG is to be processed for artifact correction and noise suppression. EOG and EMG removal is possible with the help of stem software. Then the principal of independent component analysis should be applied.

III.3. INDEPENDENT COMPONENT ANALYSIS

The EEG is composed of electrical potentials arising from several sources. Each source (including separate neural clusters, blink artifact, or pulse artifact) projects a unique topography onto the scalp-'scalp maps'. These maps are mixed according to the principle of linear superposition. Independent component analysis (ICA) attempts to reverse the superposition by separating the EEG into mutually independent scalp maps, or components so that the method used is the study is independent component analysis (ICA). [][]Independent component analysis (ICA) was used for the processing of the filtered EEG recordings. ICA is a signal processing technique that models a set of input data in terms of statistically independent variables: it is able to separate independent components produced by distinct sources from linearly mixed signals. The basic ICA model can be described as.

$$X = As(t)$$

Where $s(t) = [s_1(t) \ldots\ldots s_m(t)]^T$ is a source signal vector , x(t)=[x1(t),…,xn(t)] stands for the vector of mixtures, and A denotes the [n×m] mixing matrix . The minimal required apriori information is the independence of the source signals and the fact that at most one of the signals can have Gaussian distribution. The mutual independence of the sources is defined as:

$$f\left(s_1, s_2, \ldots s_m\right) = \prod_{i=1}^{m} f_i\left(s_i\right)$$

where s1, s2,…, sm are the source signals, fi is the probability density function of S_i, and f is the joint probability density
function of s1, s2,…, sm.

A solution for the ICA problem is possible if two additional conditions are met: the mixing matrix is full column rank and the number of recordings is at least equal to the number of source signals. In this case, the independent components (ICs) can be retrieved by determining a [m×n] matrix W, named unmixing matrix. Then, the m-dimensional vector

$$y(t) = Wx(t)$$

is the best estimate of the source vector s(t). In this way by applying ICA we will get different EEG signal sources.

The study proves that ICA is a powerful tool when the biomedical analysis involved more channels, which is the case of electroencephalogram and polysomnogram. In this case the important information can be obtained considering only the relevant signals, obtained after applying the Independent Component Analysis.

III.4. FEATURE EXTRACTION AND SVM CLASSIFIRE

A vast variety of approaches to the extraction of quantitative features from an EEG signal was introduced during more than 70 years of electroencephalography. As for any signal, it seems promising to elaborate a mathematical model of the EEG signal. However, mathematical models and physiological findings linking the EEG to electrical activities of single nerve cells remain problematic, and no single model of EEG dynamics has yet achieved the goal of integrating the wide variety of properties of an observed EEG and single-cell activities.

Successful attempts were limited to autoregressive modeling of short EEG segments. Further significant progress in this direction can hardly be expected, because the dynamics of EEG depends on brain activities related to a very complex dynamics of various types of information processing, which is related to repeatedly renewed internal and external information; thus stationary dynamic equations evidently cannot adequately describe an EEG signal. Support Vector Machines (SVM's) have become extremely successful discriminative approaches to pattern classification and regression problems. Excellent results have been reported in applying SVM's in multiple domains. However, the application of SVM's to data sets where each element has variable length remains problematic. Furthermore, for those data sets where the elements are represented by large sequences of vectors, such as speech, video or image recordings, the direct application of SVM's to the original vector space is typically unsuccessful. While most research in the SVM community has focused on the underlying learning algorithms the study of kernels has also gained importance recently. Standard kernels such as linear, Gaussian, or polynomial do not take full advantage of the nuances of specific data sets.

IV. CONCLUSION

The aim of this paper is to focus on all the previous researches took place in deception detection and there liability. Deception detection can play very important role in investigating crime and criminals. Real, fast decision making technique is required so the method can be developed using brain signals. The proposed method can be implemented successfully with high paradigm concealed information test and highly accurate discrimination and classification techniques for best results. The present study suggests that further development is worthwhile, and would provide assistance to forensic investigations in the future.

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