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A Review on Statistical Signal Processing of EEG Signals for Lie Detection

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ABSTRACT: The need for lie detection is to resolve disputes that arise over inheritance, forgery, impersonation as well as in forensic science which deals with application of science to law aiding to deliver justice by eliciting truth, scientific evaluation of physical evidence usually encountered in many civil,criminal regulatory and statutory cases. All the methods for lie detection including the most popular polygraph test depend on the measurement of variation of physiological conditions like heart beat rate, respiratory rate (breath rate), etc. by establishing physical contact of some medical device with the person's body and thus are invasive and obtrusive. But this leads to an ambiguous and/or inaccurate decision about the person telling lies. Recently newer methods of recording electromagnetic signals from the brain show promise in permitting the detection of deception of truth telling. Forensic electroencephalogram (EEG) based lie detection has recently begun using the guilty knowledge test (GIT) as a potentially more robust alternative to the classical comparative question test. For the evaluation of this method, several participants were gone through the designed guilty knowledge test paradigm and their respective brain signals were recorded. P3 and p4 electrodes signal were selected and then a group of features based on time, frequency and amplitude were extracted from the reconstructed p3 waveforms. Finally based on some features a statistical classifier was implemented. The optimal feature including some morphological, frequency and wavelet features and was used for the classification of the data. The method proposed in this paper improves the efficiency of lie detection as compared to the previous reported methods.

KEYWORDS: Electroencephalogram (EEG), guilty knowledge test (GIT),polygraph, classifier

I.INTRODUCTION

Human beings are the only creation of the nature, bestowed with the ability to think, analyze and act accordingly, but few unscrupulous creatures have utilized these capabilities for the wrong purposes. Therefore the society is always on the lookout to develop measures to curb these criminal activities. There are always new frontiers and novel techniques to combat crime. Recent advances in DNA research Dactylography Cheiloscopy, help the investigators to the great extent to crack the case, but their availability is the major limit.The ability to detect deception has important legal, moral and clinical implications, and has recently received revived interest from the scientific community. Currently, the polygraphic tests are the most widely used technique for the quantitative discrimination between deceptive and truthful responses []. Polygraphy relies on some measures of autonomic nervous system response such as respiration pattern, cardiovascular measures and electrodermal response.

In the recent times, f-MRI and Brain Fingerprinting are the much talked about techniques which have revolutionized Forensic investigations. By their very nature, polygraph measurements provide an extremely limited and indirect view of complex underlying brain processes. 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 . For example, if a subject is viewing a Bernoulli (random) series of names, one every three seconds, and occasionally, one of these is the subject's name, a P3 wave is evoked in response to this rarely presented, recognized, meaningful (autobiographical) stimulus. In this proposed method, whenever the guilty was being questioned about the crime such as mock steal scenario, a strong p3 wave

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evoked in response. P3 is a positive-going wave with a scalp amplitude distribution in which it is largest parietally (at Pz) and smallest frontally (Fz), taking intermediate values centrally (Cz). (Fz, Cz, and Pz are scalp sites along the midline of the head.) Its peak has a typical latency of 300–1000ms from stimulus onset. The size or amplitude of P3 at a given recording site is inversely proportional to the rareness of presentation; in practice, probabilities<0.3 are typically used.The meaningfulness of the stimulus is also extremely influential in determining P3 size. The P300-based GKT is a "Guilty Knowledge Test (GKT)" which utilizes P300 amplitude as an index of actual recognition of concealed information. GKT is a method of polygraph interrogation that facilitates psychophysiological detection of prior knowledge of crime details that would be known only by the suspect involved in the crime.The GKT rests upon the assumption that familiar items will elicit different responses when presented in the context of a large number of homogeneous unfamiliar items.

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 potentials can be used to determine concealed knowledge that only a crime would know. By placing details of the crime randomly among a list of non relevant items, one can distinguish criminal from citizen. If an indivisual recognizes a detail of the crime, it produce a P300 EPR and is likely guilty of, or at least familiar with the crime.

II. LIE DETECTION TECHNIQUES

Lie detection has recently become a topic of discussion once more. Courts of law were interested in it for a long time, but the unreliability of the polygraph prevented any serious use of it. Now a new technology of mind-reading has been developed, using different devices that are deemed to be able to detect deception. It meets at least with various kinds of obstacles: technical, methodological, conceptual and legal. Technical obstacles are linked with the state problems tied to what lying consists of, and legal ones with the effects of brain imaging on lawsuit. Let us take a review on several of these lie detection methods. The obstacles examined may not be insuperable, but a lot more research is needed.

2.1 POLYGRAPH

Throughout history, it has often been assumed that lying is accompanied by a change in the body's physiological activity. The polygraph is a set of equipment that accurately measures various sorts of bodily activity such as heart rate, blood pressure, respiration, and palmar sweating. In recent years brain activity has also begun to be measured in this setting. This bodily (and brain) activity can be displayed via ink writing pens on to charts or via a computer's visual display unit. In lie detection situations its use is based on the premise that lying is accompanied by changes in the activity measured by the polygraph. One of the major topics that psychologists and others have focused on across the decades is how best to determine if a testing procedure can be relied upon. Obviously, many issues are involved in this, but the most important ones include validity and reliability. Four polygraphic test are mentioned. The Relevant/Irrelevant Technique the oldest polygraph procedures developed by Larson in 1932. In the RIT, two types of questions are asked, crime-relevant questions and crime irrelevant questions. The Control Question Test (CQT, also labelled the Comparison Question Test) compares responses to relevant questions with responses to control questions. In a directed lie test, the control questions are standarised and can be asked in all situations. Typical examples of such control questions are 'During the first 27 years of your life, did you ever tell even one lie?' the aim of the Guilty Knowledge Test (GKT) (sometimes known as the concealed information test) is to examine whether examinees possess knowledge about a particular crime that they do not want to reveal. Polygraph test outcomes will often have serious negative consequences for guilty examinees, and they might, therefore, try to influence polygraph outcomes and try to produce physiological responses that may lead the examiner to conclude that they are telling the truth. Methods to achieve this are called 'countermeasures'. Countermeasures are deliberate techniques that some guilty people use in order to beat the polygraph test. It is possible that innocent subjects may sometimes also use deliberate countermeasures to influence the outcome of the test.

2.2FUNCTIONAL MAGNETIC RESONANCE IMAGING

Lying causes a conflict between lie and the truth within the brain. The increased activity can be detected by fMRI which records brain activity by identifying changes in brain blood flow and the metabolic rate. This discovery is a step

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closer to developing a lie detector which doesn't depend on nonspecific physiological vectors that can be induced by conditions other than lying.

This technique maps the brain activity by means of powerful magnets. This measures the usage of oxygen throughout the brain. Different parts of the brain of a person are activated while telling a lie than telling the truth. As active parts of the brain involve increased blood flow, more oxygen usage than the inactive parts this increases the intensity of magnetic resonance signal. This feature is exploited in the functional MRI technique. Though this technology has tremendous potential for lie detection but still not trustworthy due to its own drawbacks such as invasiveness, inaccuracy etc. Moreover this technology finds it tough for the real time application as the f-MRI machines are bulky, highly expensive and sensitive to motion. The responses of multiple voxels in the brain are evoked by stimulus and then detected by fMRI in order to decode the original stimulus during brain-reading.

2.3 EVENT RELATED POTENTIALS

This method involves the measurement of positive and negative change of potentials corresponding to information processing of brain but suffers from the disadvantage that the signal averaging eliminates all the complex patterns which lead to loss of meaningful signals. This led to the development of another lie detection technique known as multifaceted EEG response analysis (MERA).

2.4 BRAIN FINGERPRINTING

In the event of a crime, a lot of physical evidences related to the crime may be unavailable but the sequence of the events is silently recorded by the subject's brain. This makes a difference between a criminal and an innocent person that the criminal has the details of the crime stored in his brain whereas the innocent does not possess any such record. Brain fingerprinting or uses EEG to determine if the subject is familiar to an image. In this technique three types of stimuli viz. targets, irrelevant and probes are attached to the subject's headband to measure electrical brain responses. For any reason if the techniques mentioned above do match with the crime scene evidences then even innocent will be proved guilty. Moreover, all of the above lie detection techniques to some or all extent whether justifiable or not but, invade the privacy of someone's mind and thus are invasive. Hence, this gave rise to the need for some non-invasive, non-obtrusive method of lie-detection that takes care of the subject's privacy.

2.5 RADAR BASED LE DETECTION

The radar based procedure which could perform remote, unobtrusive, non-invasive and stealthy lie detection is when an UWB radar pulse passes through the human thorax it gets echoed back by the cardiac structure i.e. the heart wall. This characteristic was exploited to design and build the UWB radar based lie detector. The most incredible feature is that it is a stealth detecting device as it is not physically connected and is invisible to the subject under test. Hence it bears no physiological and psychological discomforts, prevents the breathing and cardio countermeasures of the subject unlike the polygraph lie detector. In its experimental setup comprising of a UWB radar device and an ECG amplifier heartbeat rate could be detected from a distance of 15 to 20 cm from the heart. Both ECG and UWB radar methods yield the same heartbeat related data from the heart-rate-variability (HRV) characteristics. In the event of human heartbeat detection, the parasympathetic and sympathetic sections of the autonomic nervous system play a major role and hence the time interval between successive heartbeats known as the Heart Rate Variability (HRV) is measured. The heart rhythm fluctuates around the mean heart beat rate due to continuous alteration in sympathetic and parasympathetic balance of the autonomic nervous system. The heartbeat rate decreases due to parasympathetic activity and increases due to sympathetic activation.The strength of UWB radar based lie detection is that the subject under test can be maintained unaware of being monitored and thus psychological discomfort can be avoided. Moreover the operation of this lie detector machine in a stealthy mode is a bonus of avoiding countermeasures. This factor adds to the strength to the legal aspects in delivering justice.

2.6 HEART RATE VARIABILITY:

This is the physiological phenomenon of variation in the time interval between heartbeats i.e. the variation in the beat-to-beat interval. HRV is also an indicator of the emotional arousal. The main inputs received by the sinoatrial node (SA node) viz. the sympathetic nervous system (SNS), parasympathetic nervous system (PSNS) and humoral factors are affected due to thermoregulation, hormones, sleep wake cycle, meals, physical activity, stress etc. HRV reduces due to decreased PSNS activity or increased SNS activity.

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III. PROPOSED WORK

The basic flow of the proposed method starts from acquisition of the EEG signals. EEG signals were captured by performing the guilty knowledge test. This guilty knowledge test was peformed on students between the age groups of 13-15 years. It was a just like a mock steal sceniario. This EEG signals contains various artifacts including EMG and EOG. It becomes difficult to extract the required signals information due to such presence of the noise. For this purpose filtering operation is performed to remove noise. Proceeding to filtering operation features are extracted in order to know about the various parameters of the signals. This feature extraction can be done with the help of wavelet transform, correlation dimension etc. feature extraction help us to know about the latency, eigen values, amplitude, peak to peak value, absolute amplitude and so on. Finally classification is done to produce the results. We could easily differentiate between the guilty and suspect.

IV. GUILTY KNOWLEDGE TEST

Guilty knowledge test present a set of question items to an examinee,which include one crime related item(critical item) and several control items (non critical items). Items are selected so that innocent examinee (i.e.one who oes not possess the information) would be unable to distinguish the critical item from the non critical item. In this study we used the GKT techniques which relied on the contrasting brain waves evoked bu the relevant and control stimuli, and developed a novel efficient EEG based GKT using machine learning algorithms. Through EEG signal processing, we automatically detected brain waves corresponding to different mental activity patterns to uncover the critical items from the non critical ones.

V. DATA ACQUISITION

4 subjects (4 students, girls) participated in the stydy. Students were between the age group of 13 to 15 years. They had normal and corrected vision. All the subjects were present in the hall and then actual GKT test was performed. The examiner informed the students in the hall about the mathematics test which was to be held on the next day. After the class got over,4 of the students returned in the hall since they had left their few important books in the hall. To their surprise they found the question papers of the test to be held next in the drawer. 2 of the students saw the questions(suspect), while the other two didn't (innocent). Then P300 based GKT test was performed about the knowledge of the scenario. The electroencephalogram (EEG) was recorded using Ag/AgCl electrodes placed at the Fz (Frontal), Cz (Central) and Pz (Parietal) sites (10–20 international system). All sites were referenced to linked mastoids. Only the results from Pz will be reported here. Electrooculogram(EOG) was recorded from sub and supraorbital electrodes (above and below the right eye). The subjects were grounded at the forehead. Brain electrical activities were amplified and digitized at a rate of 256 samples per second. Digitized data were subsequently analyzed offline using MATLAB software. Prior to data analysis, all data were digitally filtered in the 0.3–30Hz range.This is the frequency range which is used typically in P300-based GKT studies. After the attachment of the electrodes and starting the recording, questions were asked to the students regarding the question paper. Students replies yes and no respectively. EEG readings were recorded. The guilties were trying to hide the information and were behaving mentally innocent. Thus, guilties and innocents, both replied honestly to targets and irrelevants; but for probes, the guilty subjects replied falsely while the innocents answered honestly.

VI. MORPHOLOGICAL FEATURES

Several morphological features were extracted to distinguish truth from lie telling.
(1) Latency (LAT, tsmax)—the ERP's latency time, i.e. the time where the maximum signal value appears:
tSmax ={ t|s(t)=smax},……..(1)
where s(t) is the ERP single trial during 400–800ms after stimulus and smax is the maximum signal value in this time interval.
2)Peak-to-peak (PP, pp):
pp=smax –smin…….. (2)
where Smax andsmin are the maximum and the minimum signal values, respectively:
smax =max{s(t)},s min =min{s(t)}

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3) Amplitude (AMP, smax)—the maximum signal value:
smax =max{s(t)}.
4)Wavelet feature:
For the extraction of wavelet features, each single trial was decomposed into five-octaves using the wavelet transform. Six sets of coefficients (including residual scale) within the following frequency bands were obtained: 0–4Hz, 4–8Hz, 8–16Hz, 16–32Hz, 32–64Hz and 64–128Hz.The coefficients in each set are concerned with sequential time bands between 0ms and 1000ms. Because of previous filtering of the signal, coefficients within 30–128Hz and 0–0.3Hz ranges had not any useful information. But other coefficients represent the signal information in four frequency bands: (A) 0.3–4Hz, (B) 4–8Hz, (C) 8–16Hz and (D) 16–30Hz. Fig. 1 shows the decomposition and reconstruction of a single trial ERP into five octaves, using the quadratic B-Spline wavelet.

VII. CONCLUSION

From a practical viewpoint it is clear that any kind of criminal investigation accounts for the act of determination of innocence or guilt and this act is more a legal entity than just a scientific determination. The aim of this preliminary study is to investigate the ability of the wavelet domin feature obtained from the EEG to differentiate the truth from lie during a low anxiety task. This method has the highest potential to detect lie using EEG.

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