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Statistical Signal Processing of EEG Signals for Lie Detection

Sheeba.S.Kazi[1], Bhavana.P. Harne[2]

Assistant Professor, Dept of ECE, Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra, India [2]

PG Student [DIGITAL ELECTRONICS], Dept. of ECE, Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra, India [1]

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 (GKT) as a potentially more robust alternative to the classical comparative question test. For the evaluation of this method, we have used P300 wave of EEG. This method of using EEG to differentiate lying from truth telling will create an expectation of a break in search of objective methods of lie detection. 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

For centuries, philosophers have pondered on the nature of human lie. However, the scientific approach to human deception is far younger. For some decades, psychologists and scholars within the domain of communication have studied lie as a phenomenon of interpersonal relations. Researchers have also focused on the nature of lie in applied contexts, such as in a forensic one. In the legal system, professionals such as police officers and judges frequently face the task of having to judge the veracity of a person, be it a witness, alleged crime victim or a suspect. These judgments can be of utmost importance in the legal process, and the outcome of the judgments can have far reaching consequences for the person being judged. Detection of lie using EEG in the legal system is the focus of the present work. More specifically, I will examine the detection of lie in the context of interrogations, with a special focus on the effects of strategic use of the available evidence. The ability to detect lie 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 lie and truthful responses [6]. Polygraphy relies on some measures of autonomic nervous system response such as respiration pattern, cardiovascular measures and electro-dermal response [6]. Polygraphy relies on some measures of autonomic nervous system response such as respiration pattern, cardiovascular measures and electro dermal response.[6].

We have used MATLAB 7.0 for our work. It is high performance language for technical computing. It simplifies the analysis of mathematical models. It saves a lot of time. It provides inextensible programming environment, provides professional looking graphs. It is a technical language to ease scientific computations. 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

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system and are considered to be affected by the recognition of important events, which is more cognitively determined activity than autonomic responses.

Fig: F-MRI machine.

Fig: polygraph machine.

An endogenous ERP, which has been extensively studied, is the P300 (P3) wave. In this proposed method, whenever the guilty was being questioned about the crime such as mock steal scenario, a strong p3 wave evoked in response. P3 is a positive-going wave with a scalp amplitude distribution in which it is largest parietal (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 has also extreme influence 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 psycho-physiological 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. In 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.

II. LITERATURE REVIEW

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.

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 palm 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 is 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

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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.[5].

2)*Functional magnetic resonance imaging :* Lying causes a conflict between lie and the truth within the brain. The increased activity can be detected by F- MRI which records brain activity by identifying changes in brain blood flow and the metabolic rate. This discovery is a step 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 F-MRI 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). [5]

4) *Radar based lie 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. [4].

5)*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 sino-atrial node (SA node) viz. the sympathetic nervous system (SNS), parasympathetic nervous system (PSNS) and humor 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. However, 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

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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. [4]

Proposed work: our proposed work is completely related to brain waves i.e EEG signals. The reason for adopting EEG in our work is that it measures electrical activity that your brain makes. Moreover it does not send any electricity into your brain. It measures the voltage fluctuations resulting from ionic currents that flows within the neurons of the brain. The block diagram of proposed work is as given below.

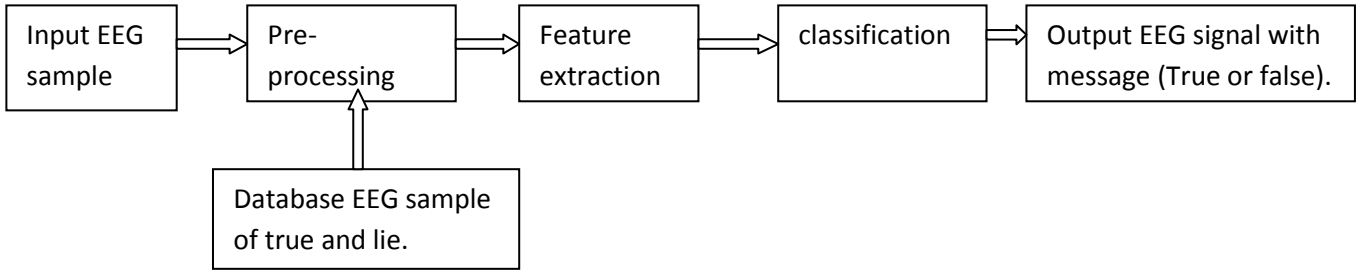

Figure: block diagram of statistical signal processing of EEG signals for lie detection.

III. RESULT AND DISCUSSION

1.input EEG sample: The main work of the proposed work is to collect EEG sample which is done by GKT(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 does 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 but 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.

2. Database EEG sample: 4 subjects (4 students, girls) participated in the study. 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. The examiner sent 4 girls to bring the question paper. 2 of the students saw the questions (suspect) and noted it down, while the other two didn't (innocent). Then P300 based GKT test was performed about the knowledge of the scenario. The P300 is a specific electrical brain wave that is triggered whenever a person sees a object familiar to him. 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 ERP and is likely guilty of, or at least familiar with the crime.

3 .Pre-processing: 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 P3 and P4 will be reported here. 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. 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.

4. Feature extraction: Several morphological features were extracted to know the various parameters and distinguish truth from lie telling.

(1) Latency (LAT, Ts(max)—the ERP's latency time, i.e. the time where the maximum signal value appears:

$Ts(max) = \{ t|s(t)=Smax\},$……..(1)

where s(t) is the ERP single trial during 400–800ms after stimulus and S(max) is the maximum signal value in this time interval.

2) Peak-to-peak (PP, pp):

$pp=S(max) –S(min)$…….. (2)

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where S(max) and S(min) are the maximum and the minimum signal values, respectively:
S(max) =max{s(t)},S(min) =min{s(t)}
3) Amplitude (AMP, S(max)—the maximum signal value:
S(max) =max{s(t)}.
4) Wavelet Transform:
For the extraction of wavelet features, each single input signal was decomposed into five octaves using the wavelet transform. Six sets of co-efficients (including residual scale) within the following frequency bands were obtained. The co-efficients in each set are concerned with sequential time bands. The signals obtained after decomposition contain high frequency component and low frequency component. Out of which the noise is removed in high frequency component, and hence actual information retains in low frequency component. Inverse wavelet transform is performed on the constructed signal to produce reconstructed signal. Hence the difference of input and output which gives minimum value would identify the signal as lie or true.[8]
5. classification: Classification is done by Euclidean distance method, which will calculate the minimum value between the vectors to display the output.
6. Output: The output is generally displayed with a message as "lie EEG signal" or "true EEG signal".

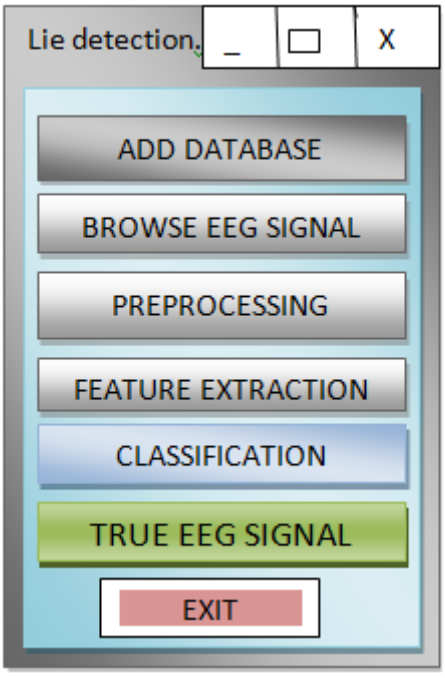

FIG: FLOW CHART OF PROPOSED WORK.

Readings of EEG signals were plotted on the excel sheet. Ten signal i.e train database were chosen out of which first five were lie signals and next were true signals. Five test signals were chosen. Loading of the train signals will compare with the test signals on the basis of the Euclidean distance method. Before classification it will extract features using wavelet transform. The graphs are plotted down of the various features. Minimum distance(less than 5) will give the output as lie and maximum distance(more than 5) will give the output as true after classification.

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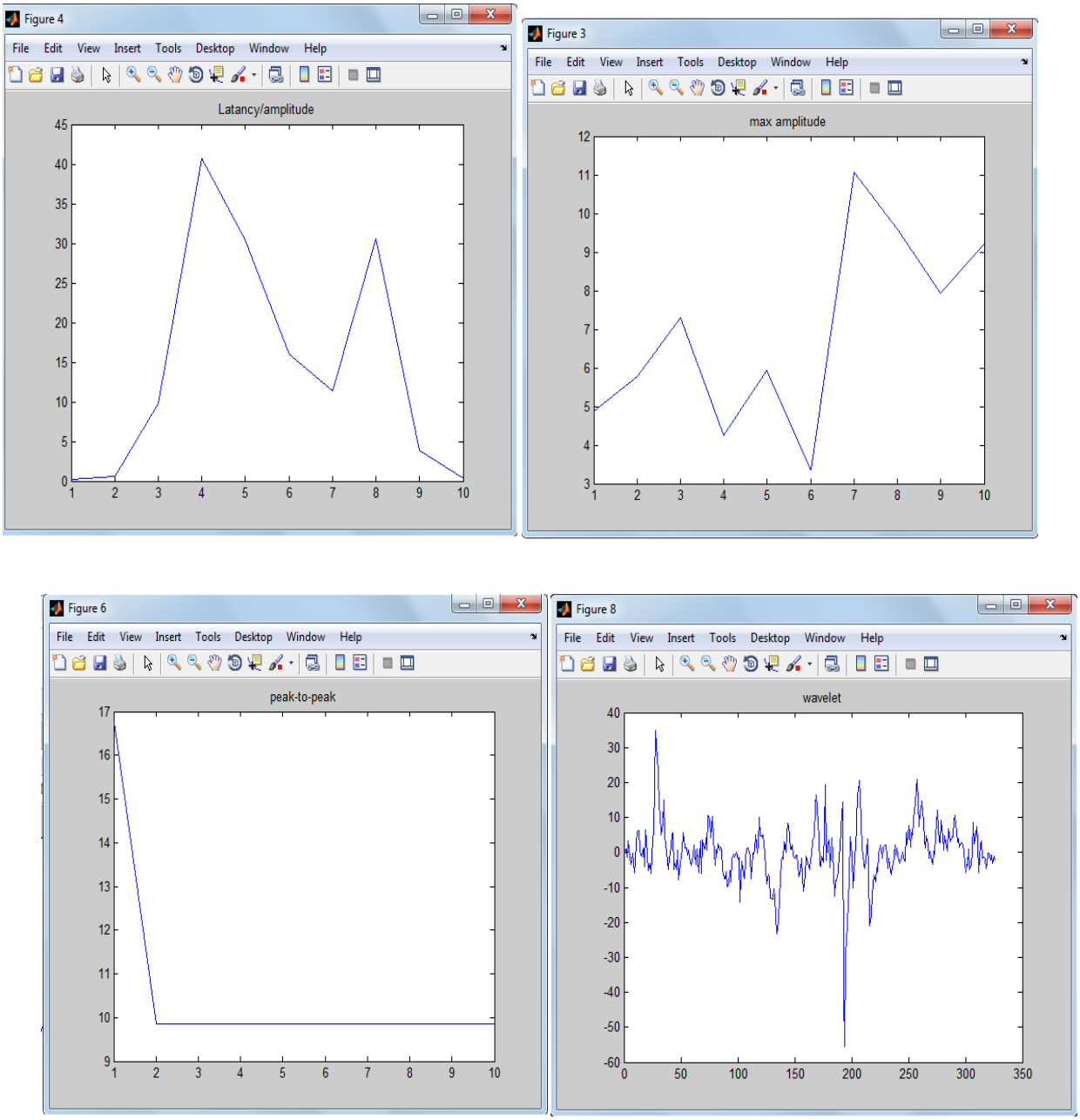

FIG: 1) latency/amplitude graph. 2) amplitude graph. 3) peak to peak graph. 4) wavelet transform graph.

IV. 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 domain feature and also all the features mentioned above 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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