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Analysis of EEG Signals for Deception Detection

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ABSTRACT: Progress in the use of EEG to differentiate lying from truth telling has created an expectation of a break in a search for objective methods of lie detection. In the past few years, litigants have attempted to introduce EEG based deception detection evidence in the courts. Both the science and its possible use as courtroom evidence have spawned much scholarly discussions. This article contributes to the interdisciplinary debate by identifying the missing pieces of the scientific puzzle that needs to be completed if EEG based deception detection is to meet the standards of either legal reliability or general acceptance. The article provides a balanced analysis of the current science and the cases in which the litigants have sought to introduce EEG based deception detection. Identifying the key limitations of the science as expert evidence, the article explores the problems that arise from using scientific evidence before it is proven valid and reliable.

KEYWORDS: Electroencephalogram (EEG), guilty knowledge test (GIT),polygraph, deception, lie, ultra-wideband(UWB), functional magnetic resonance imaging(FMRI)

I. INTRODUCTION

Deception detection is one of the most emotive and hotly debated of all human technological endeavors. With long and some would say chequered history. Prominent deception detection approaches include the standard polygraph which monitors the signature changes in autonomic responses and the cognitively more central EEG, and in the last few years FMRI methods. Amongst the applications of these approaches statistical signal processing is particularly important .Deception detection is the practice of attempting to determine whether someone is lying. Usually this involves asking the subject to control questions where the answers are known to the examiner and comparing them to questions where the answers are not known. The reason why deception detection is important is that it can be used in interrogating crime and to find the truthfulness of the evidence. It may prove very useful when hiring the potential employees and dealing with the stock broker, sales, lawyer, ex wife, car dealer, mechanic etc. A large number of stimuli were often used for identify the guilty subjects in deception detection. Liu.Y.Sourina.O.ngyen M.K." real time EEG based human emotion recognition and visualization. In proc.2010. International conference on cyber world.singapore. (2010)

Common Signs of Deception

The common signs of deceptive behavior have been reported in the literature[www.blifaloo.com/info/lies.php (last update: April 10, 2013)] such as body language, emotional gestures and contradiction, interactions and reactions, verbal context and content,facial micro-expressions, change of topic etc. These deception techniques are used by police, forensic psychologists, security experts and other investigators to help prevent them from being victim of fraud or scams and other deceptions. Of course, these signs don't strictly indicate that someone is lying, but that they are more likely to be lying. Just because some exhibits one or more of these sign does not make them a liar.

a)Body Language:

Liars have a typical body language as they avoid making eye contacts, move the hands on their face, throat, mouth, touch or scratch the nose or behind the ear, take up less space by having hand, arm and leg movements toward their own body.

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b)Reactions During Interactions:
It is not uncommon that an innocent person goes on offensive whereas the guilty behaves defensive. Mostly it is found that a person telling a lie feels uncomfortable to face the investigator and often turns the head or body away while being interrogated. Another peculiar behavior is that the guilty might unconsciously keep some object like a water bottle, anote book between him and the interrogator.

c)Emotional Gestures and Contradiction:
It is found that the gestures or expressions of a liar do not match the verbal statement. There is no timing and duration between emotional gestures and words of expressions. Expressions are limited to mouth movements and not the whole face.

d) Verbal Context and Content:
The liars use the words of the interrogator to make the answer of the question asked to them, speak more than natural, and add unnecessarily more details to convince the questioner as they are uncomfortable with silence or pauses in the conversation. They speak in a monotonous tone and the pronouns of their statements are not emphasized. The words may be garbled and spoken softly with no usage of grammar. Sentences will be muddled instead of having emphasized. One of the verbal signs of lying is that the liar tries to invent the answer and hence spends more time for searching a right word while speaking, doesn't use contractions and takes long time to provide an answer.

e) Change of Topic:
When someone is guessed for lying, then the theme of the conversation should be changed quickly. By doing so, it is found that the liar follows the change and feels more relaxed. In contrast, an innocent subject gets confused by such a sudden change of topic under interrogation and may try to go back to the previous topic. The liar may try to use humor or sarcasm to avoid the subject of issue.

f)Facial Micro-expressions:
Sometimes a momentary involuntary facial expressions such as anger, disgust, fear, sadness, surprise and contempt known as micro expressions are unconsciously displayed when the person attempts to hide an emotion. These actions are quick (even sometimes not easily noticeable), intense expressions of concealed emotion, appear and suddenly disappear off the face in a fraction of second. [Haggard, E. A., & Isaacs, K. S. (1966). Micromomentary facial expressions as indicators of ego mechanisms in psychotherapy. In L. A. Gottschalk & A. H. Auerbach (Eds.), Methods of Research in Psychotherapy (pp. 154-165). New York: Appleton- Century-Crofts.] These micro expressions betray the person while lying as the one will be trying to cover his feelings with fake smiles, but involuntary face muscles reveal the hidden emotions. Like micro expressions, forced smile (that involves only the muscles of the mouth and not the rest of the face), increased blinking, scratching the face or nose, placing the hand over the mouth while speaking are also other good indicators of change of a person's normal behavior and known as the non-verbal signs of lying [How Lying Works by Tom Scheve (http://people.howstuffworks.com)].

g) Statement Analysis:
This is also known as linguistic text analysis and detecting anomalies and was developed in 1970s [Susan H. Adams, "Statement analysis: What do suspects' words really reveal?" FBI Law Enforcement Journal, October 1996]. The method involves studying the language, grammar and syntax of a person's event description. Text analysis represents the subject's verbal behavior i.e. usage of words (written and oral statements). Text analysis or statement analysis is a two-part process according to Susan Adams, senior instructor at FBI Academy [Susan H. Adams, "Statement analysis: What do suspects' words really reveal?" FBI Law Enforcement Journal, October 1996]. Sometimes police and other investigators adopt this technique to indicate the presence of lies by analyzing the subject's words, because, people always phrase a statement according to their knowledge and therefore their statement may even include the information which they really did not intend to share. It is nearly impossible to give a long deceptive statement with an idea of protecting it from revealing it as a lie.

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

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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 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. 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.["Recent advances in lie detection" Department of Forensic Medicine, Postgraduate Institute of Medical Education and Research, Chandigarh.IAFM, 2004; 26(1). ISSN 0971-0973].

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. [F.A.Kozel .F .A .Jhonson .Q .Mu. E .L .Grenesko. S .J .Laken. and M,S.George ."detecting deception using functionl magnetic resonance imaging." boil psychiatry, .vol 58 no 8 pp 605-613.oct 2005]

3) ***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.

4)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

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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 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. ["Radar Based Lie Detection Technique" By Kedar Nath Sahu, Dr. Challa Dhanunjay Naidu & Dr. K Jaya Sankar Volume 14 Issue 5 Version 1.0 Year 2014 : Global Journals Inc. (USA)]

III. 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.

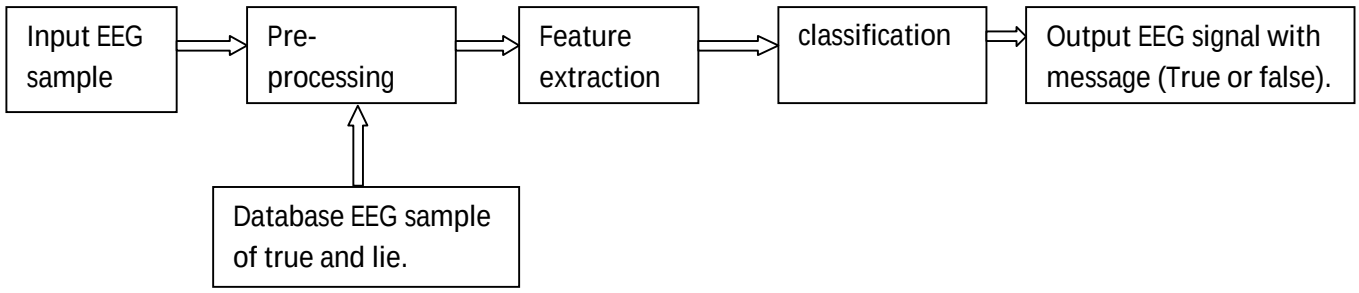

FIG.1 Block diagram of Analysis of EEG Signals for Deception Detection.

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

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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)

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.[Anna Caterina Merzagora, Scott Bunce, Meltem Izzetoglu and Banu Onaral. Wavelet analysis for EEG feature extraction in deception detection. IEEE EMBS Annual International Conference New York City, USA, Aug 30-Sept 2006]

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".

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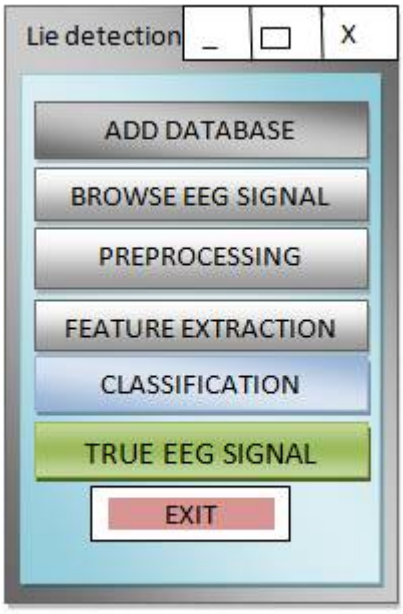

FIG.2 Flow Chart of Proposed Work

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.

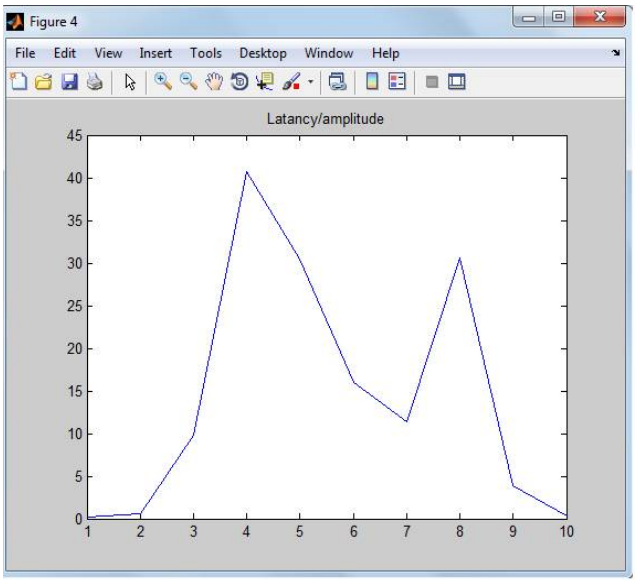

FIG: 3 Latency/amplitude Graph

Figure 3 indicates the highest latency / amplitude ratio indicating it a false signal i.e of deceptive person.

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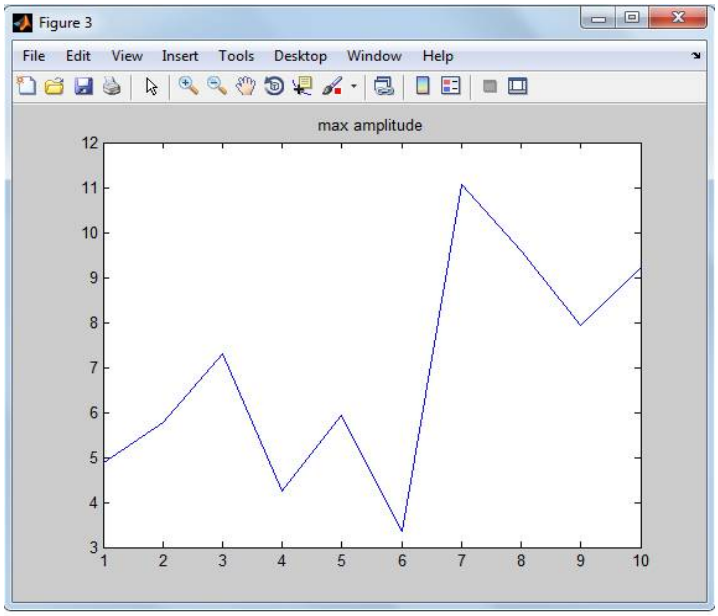

FIG. 4 Amplitude Graph

Figure 4 indicates the highest amplitude indicating it a false signal i.e of gilty person.

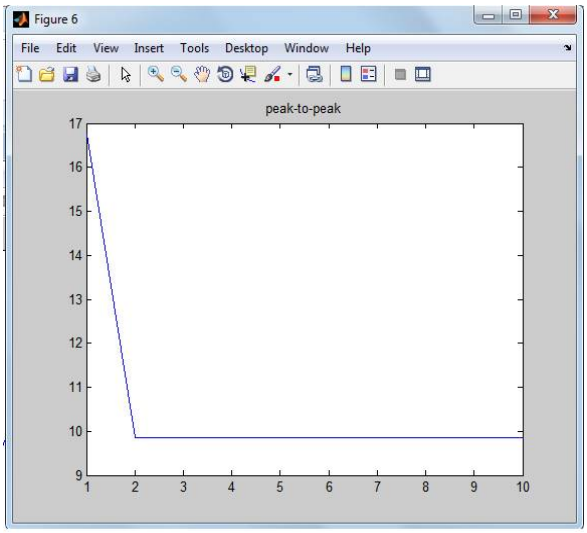

FIG.5 Peak to Peak Graph.

Figure 5 indicates the highest peak for guilty person and for innocent person it does not exist.

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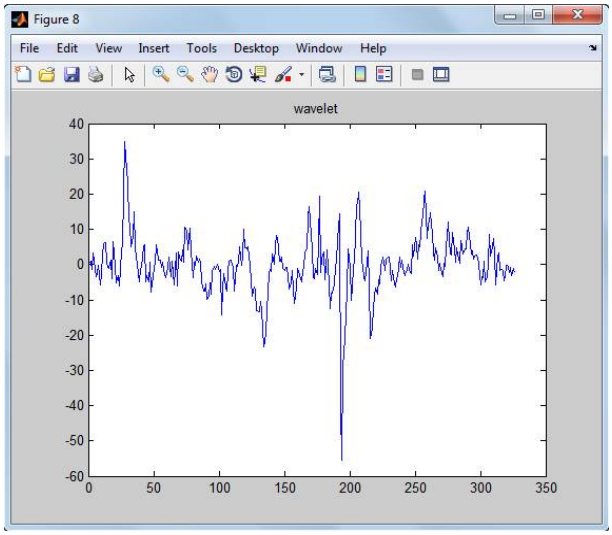

FIG.6 Wavelet Transform Graph

Figure 6 shows the highest ERP indicating that the person is telling a lie and the other flat signals are obtained for innocent persons.

IV.CONCLUSION

In this project, a detail study on EEG based lie detection is presented. The conceptual study indicates that it is feasible to identify the basic lie detection.EEG signals will be used for the lie detection because this is non invasive, cheap, and are the direct results of the electric activity inside the brain. Various parameters are to be used to judge the features for the effective lie detection. The system can be used for a wide range of purpose. This project has a very vast scope and advancement in this model can lead to more accurate models that can have a huge number of applications.

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