Review

LDM: A Systematic Review on Lie detection Methodologies

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Abstract :

In our day-to-day life, Lie detection has a significant concern. We human beings are very much inaccurate while detecting the liars and We believe in what we are told. Lie detection is important in today's life, because Concealing the information or faking it can sometimes take you to huge problems. In any areas like airport management[2], criminal investigations, counterterrorism, etc this concept has great importance. It is an evergreen challenging and changing topic. This paper presents the common technique which was followed up till now and why it was not considered effective and a review of Robust solutions to detection of deception. People generally do not[3] always believe on what someone says but also try to visualize their facial expressions. While in Robust solution these facial micro-expressions are identified, which are tiny, natural expressions seen on the individual's face, when they try to conceal or suppress emotions. In addition, the article also provides the year-wise assessment and analysis of research articles published in the area of Lie detection from 2011 to 2022.

In the end, our proposed framework for lie detection system is also presented. This paper cover up current issues as well as challenges that could be helpful to resolve in future research works. The review paper closes up by supporting future directions.

Keywords :- Expressions; Lie detection; Emotions; Micro expressions

1. Introduction :

Lie is a complex[5] social activity by someone to hide the truth to make someone else believe on that. In many areas for example Teaching, Medical, law enforcement offices, doctors, statutory organization etc. , lie detection has relevant impact. However people of these areas are trained regularly to differentiate liars and truth tellers, still it is very hard for human being to catch when someone is lying. Ekman [4] highlights five reasons to explain why it is so difficult for us: (1) during most of human history, there were smaller civilisations in which liars had more probabilities of being trapped with worse penalties than nowadays; (2) offspring are not trained how to distinguish lies, as even their parents sometimes want to fleece some things from them; (3) people wishes to belief in what they are said; (4) people do not prefer to expose the real truth; and (5) society is trained to be polite and for not to reveal the information which is not provided. However an average[5] exactness to identify a Lier by skilled police officer is 65% as stated by [2]Vrij,2004 and that [6]it does not depend on specific behavioural clues which are associated with lying, but instead of on subjective experience.

Also the current methods such as polygraph, sweat and respiratory rate measurement, heartbeat sensor and blood pressure monitor are highly inaccurate and dependent on physiological and behavioural patterns. The largest negative aspect of the polygraph is to obtain effective results without creating direct physical communication with the person who is under examination. While Robots[5] having capability to independently detect fraud which provide an important benefit to person to person and person to robot interactions. As lying requires more mental load as compared to telling a truth. For example, liars need to build a believable and articulate story, which would increase their cognitive load[5][11]and eye blinking and pupil

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dilation are usually associated to a higher cognitive load [5][12]The objective of this system is to demonstrate the possibility to develop a lie detection system that could be implemented on robots. To achieve this goal, we focus on human and human robot interaction to understand if there is a difference in the behaviour of the participants when lying to a robot or to a human.
This paper presents the work overview by various researchers and various methods used in lie detection system.

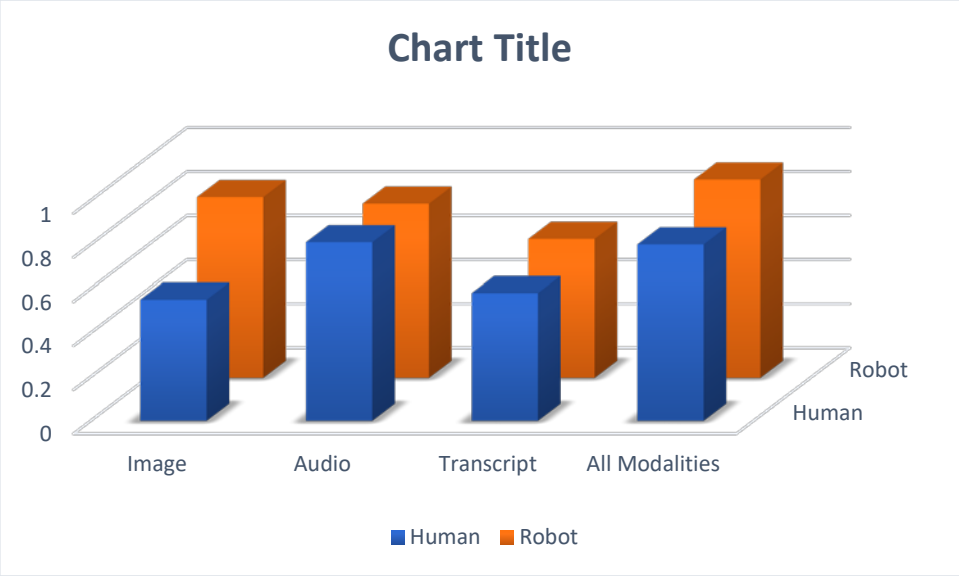

Fig.1 shows that How Computer vision based system is significantly better than human. While looking at the static face, machine learning produce better results. On the other hand, with only audio, human performance is good. But when only transcripts of videos are provided, the performance drops significantly both for humans and robotic system.
With all modalities, automated system is better compared to an average person.

Applications of Lie detection System :

- In Criminology field
- In the field of Defence
- In the field of Homeland Security
- Border Protection
- In Employee screening
- In the Testing for Sexual Offences
- For the authentication of Media Personnel

1.1 Motivation :

This work is conducted to discover the best methodology to detect the liars.
A comprehensive evaluation has been conducted to value many techniques used in deception testing based on their pros and cons and their accuracy and all are compared to find the best. The following mentioned facts particularly inspired me for this article :

1. Conventional techniques are not much susceptible to detect the liars.
2. Enthusiastic to give a complete review on the techniques used for lie detection till now.
3. Security is an important aspect of today's world

 doi:10.20944/preprints202212.0443.v1

4. Due to increase in crime, we need a system which can detect human activities, which motivates us to develop such system.
5. This paper will provide a brief comparison among all the methodologies, which was not prepared up yet to choose the best method.

1.2 Our Contribution :

Our significant contribution to this study is as follows:

- Existing research work is studied and techniques proposed by them are compared on the basis of cost, approach, advantages, disadvantages and results.
- Research findings by various researchers is compared.
- A methodology is provided to built a complete lie detector system.

1.3 Paper Organization :

The another segments of this paper covers the sections as: Section 2 covers the research strategy taken up to conduct this study. Related survey conducted by various researches in the deception detection system is covered in Section 3. Section4 describes the relation between expressions, emotions and lie. Section 5 provides a concise overview of various Lie detection methods. Section 6 illustrates the comparison chart where research opportunities and challenges are given. Section 7 concludes the article by providing future direction.

2. RESEARCH METHODOLOGY:

In this section Objective of the research article is given. The main reasons which encouraged towards this research, are discussed and the traditional and present technologies to review are presented.

2.1 Review Plan:

In this part of review, many research articles are reviewed, research queries was designed for searching and to find different databases. The procedure observed for this review is explored from several databases, i.e. IEEE explore, Google scholar, Elsevier science Direct, springer, Academia,. The peer review of research papers is conducted and mentioned in this article and which techniques will give the best results are also told at the end after reviewing all the techniques.

2.2 Search Criteria

Some keywords were used to find out the articles from database given in the review plan. Keywords, for example "Deception detection", "Methods of Lie detection", were used for searching. The method of searching from the databases is however common but a time consuming process. We also searched with various other common keywords used for lie detection; they are, " Models", "Methodologies", "Brain imaging", "Polygraph", "drawbacks", "Micro expressions for Lie detection" etc. We considered research papers from January2011 to July2022. We took only those research papers which we find met our evaluation criteria.

2.3 Objective

To compare various proposed techniques by various researchers and to find out the best chosen.

3. LITERATURE SURVEY

Payam Zarbakhsh and Hasan Demirel [7] proposed a paper "4D facial expression recognition using multimodal time series examination of geometric landmark-based deformations" in springer in 2019. They worked on how to catch temporal information in the dynamic facial expression recognition. Therefore they adapted a method of time series analysis, a novel approach to deal with this problem in which dynamic FER system composed of 4 steps: posture of head, correction and

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regulation, followed by feature extraction, feature selection and classification. To deal with large dimensions of features, types of time series features and choice of NCFS feature subset is utilized. NCFS is an efficient yet straightforward conducted embedded feature subset selection procedure which is applicable for large dimensions of data sets with a large amount of unrelated features. In conclusion, it finds out a smaller set of geometric deformations for categorization. Once the time series features are lowered, AC-DTW was used for classification of time series.

A research paper entitled "Construction the lie detection system with fuzzy reasoning approach" was published by Y.F Lai, M.Y.Chen, H.S.Chiang in 2017 in Springer. They[8]proposed a machine which can encourage real time lie detection by lessening the shortcomings of conventional lie detection methodologies. They employ electroencephalographic (EEG) variability and fuzzy theory in their study to create a deception recognition model and define a rule set which define vulnerable and valuable EEG frequency bands to correctly establish the state of lie on the basis of spectral analysis. The result indicates that the accuracy of proposed demonstration lie detection is of 89.5% and relates well with other data mining techniques. It gave a valuable source for upcoming exploration by correcting polygraph tests, the results however are influenced by human's physical and mental wellness, besides natural components.

X.Shen, G.Fan, C. Niu and Z. Chen published a paper in June2021 named, "Catching a Liar Through Facial Expression of Fear" in which to [9] test the speculation, they observed a game show , recorded its video & extracted video clips "The truth moments" are observed by Open confront (for yielding the AUs (Action Units) of fear & face) and it used WEKA (to categorize the visual clips where performers were lying or telling the truth with each other. The findings reveals that various procedures proceeded to the correctness of >80% by utilizing Action Units of fear. Action unit20 came up shorter than from the truth-telling condition. More investigation in this found the justification for the short length within the lying condition, which was because of the time window from peak to offset of AU20 was lesser than truth-telling condition. Findings too indicates that facial movements across the eye area was more unequal during lies. The whole outcomes from this recommended that such facial clues and fear could be utilized for identifying deception and recognizing liars. They use an objective measure of asymmetry. By using the above methods, they were able to differentiate among liars and truth tellers.

H. H. Thannoon, W. H. Ali and I. A. did [10] a study on **Design and Implementation of Deception Detection System Based on Reliable Facial Expression in 2019.** The purported method distinguishes lying subjects from the innocent on the basis of existence or lost facial AUs. They used 8 AUs as markers for lie detection and they are incorporated into a single facial behaviour pattern vector. They gathered Database from 43 subjects in which 20 males and 23 females were there and they were between the ages of 18-25 They collect 400 video clips after editing from collected database. Virtual Generalizing Random Access Memory Weightless Neural Network (VG-RAM WNN) is used as classifier is to take out conclusion in the final phase of DDS. The purported DDS was examined 3 times and achieve correctness of 84, 85 and 90% for identifying liars while used for both genders, male and female.

N.Rodriguez Diaz, D. Aspandi, F.Sukno, and X.Binefa[3], published work in 2015 named **Machine Learning-based Lie Detector applied to a Novel Annotated Game Dataset**, for their work they gathered dataset of facial images, which were combination of together 2D and 3D information of many participants during a card game , which urges players to lie. With the use of collected dataset, they examined various lie detectors in terms of generalization, person-specific and cross-domain tests. Their results depicts deep learning models reaches the best accuracy up to 57% on the whole and 63% when dealt with only single participant.

J. Gu Xiaodong Yang Shalini De Mello Jan Kautz in their paper published in 2017 named "Dynamic Facial Analysis: From Bayesian Filtering to Recurrent Neural Network", recurrent neural network (RNN) used for collective assessment & tracing of facial features from videos. RNN has similarity to Bayesian filters for performing the computation, which was followed up in many earlier approaches of facial analysis from videos. The RNN-based methods when used with Post-RNN and

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RNN, helpful to enhance the performance [14] of per-frame evaluation. RNN substantially lessens the failure rate compared to other approaches.

Brandon S. Perelman in their paper named Detecting deception via eyeblink frequency modulation published in 2014 used[26] eye blinking rate to detect lie. During the research he collected eye blink frequency with the help of electromyography and from the video recorded. Liars control on their eye blink rate while lying, on the other hand truth teller shows more eyeblink frequency in the questioning time. A discriminant function used to find lying correctly with sensitivity of 88.2% and with the specificity of 73.3%. This method exposes the ability for future testing different from polygraph. This technique is consistent with distance technology.

4. EXPRESSIONS, EMOTIONS, AND LIE

4.1 Expression

Expression are the outer manifestation of inner thoughts or views or internal behavioural changes. Expressions are the sign of changes in the state of mind. All the living things have inherent ability of representation of expressions when they feels their emotions, feeling , thoughts or views are changed. These are visible in face. In many conditions people try to hide their inner feelings with some other expressions.

For example, if A little baby do some funny mischief, a mother internally might laugh on his act, but on the outer side she shows anger to him, so that he do not repeat same mischiefs again. Hence it concludes that face is a multi signal system[24]. A face can be mixture of two emotions at the same time, for example a person can be happy and surprise at the same time or sadly angry and many more.

For an expression Emotions are not always needed.

Example of simply an expression is, A boy and a Girl waiting for a bus on bus stand and smiling each other. There is not any emotion at that time.

Paul Ekman developed a comprehensive facial expression scoring technique called the Facial Action Coding System (FACS) [25]. FACS classifies every expression in the group of thousand expressions which are generated from the mixture of one or more facial muscle(s). Expressions are commonly categorized into three types.

1. Macro Expressions: The type of expressions which occur in 4 to 5 seconds of time period.
2. Micro Expressions: Unintentional expressions which occur in a blink of an eye. The length of such expressions are from 1/fifth of a second to 1/twenty-fifth of a second.
3. Understated Expressions: the expression which depends upon the strength of expression not on the duration is called Unintentional expressions.

4.2 Emotions

We know that Emotions play a vital role in our daily life. They reveal our true nature. We have seen many times in our lives people pretend to be happy or anger sometimes, however in real they are not happy at that moment or in anger, which

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is basically be catches up reading their emotions. There are 6 Universally accepted emotions which are Happy, sad, Surprise, Disgust, Anger, fear. However a new emotion is added in the universal emotion called Contempt. As discussed above the old techniques to detect deception is somewhat not appropriate. This new approach using Machine learning overcome the drawbacks of traditional techniques and provide a better version to detect lies by avoiding direct physical contact.

4.2.1 Happy :

Happiness is a state of mind when you feel satisfied. And it is peace of mind and a joy which reflects by expressions on your face. A Happiness is a positive experience.

An example of happiness: When someone gets a good job, first salary, when a wish fullfills, when someone rewarded, Meeting with old friends or family members.

Fig.2: Happy Facial emotion

4.2.2Anger:

Anger is the feeling when we realized something is happened wrong or something happens which is against you. It is a basic human emotion, which may happened due to many reasons. For example : Loss of job, when your efforts are not appreciated, when someone do an activity to show you down, when you did not get what you want etc.

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Fig. 3: Angry Facial Emotion

4.2.3 Sadness:

This emotion comes up when someone feels low or the feeling of unhappiness is called sadness. It may happen due to many reasons : upon loss of something, when he didn't get good results as per his efforts.

Fig.4 : Sadness Facial Emotion

4.2.4 Disgust :

Disgust is an emotion which come into existence when someone feels offensive or happening of something unpleasant event or action.

Fig.5 : Disgust Facial Emotion

4.2.5 FEAR:

Fear comes one something dangerous happens or someone feels threatened, in pain or harm. Fear can be real or imagined.

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Fig.6: Fear Facial Emotion

4.2.6 Surprise

When an unexpected event occur whether it is positive or negative, a surprise expression can be seen on someone's face at the time.

A positive Example could be, When a Lady offered a Gold ring on her birthday by her husband.

Fig.7: Surprise Facial Emotion

4.2.7 Neutral : Neutral Facial expression is a stable human expression. Many reasons could be behind it. For example relaxed, depressed, boredom or due to any confusion.

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Fig.8 : Neutral Facial Emotion

4.2.8 Contempt : It is a feeling when someone feels of superior from other or dislikes others.

Example : When an employee feels contempt from her colleague. Or When a student got lower marks than her friend.

Fig. 9: A Contempt emotion

Many other types of expressions are also available with the combination of these expressions. These are listed below :

1. Happily Surprised
2. Happily Disgusted
3. Disgustedly Surprised
4. Fearfully Disgusted
5. Fearfully Surprised
6. Sadly Fearful
7. Sadly Angry
8. Sadly surprised
9. Hatred

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10. Awed

etc.

these emotions are called compound emotions.

4.3 LIE

Lie is a very common phenomenon in human being. It is well to say, deception is a popular part in human communication. Verbal and non verbal features both are important in detecting deception. In Verbal features voice is extracted and facial features, head movement, body movement are extracted in Non Verbal. Non verbal features provides efficiency in lie detection process due to its simplicity and robustness. Decades of research proved that three principal ways of deception detection: physiological responses, behavioural analysis, and verbal analysis. Physiological responses assume that when a human feels uneasiness, fear, angst, etc., the physiological factors like blood pressure, galvanic skin resistance increases significantly. This methodology comprises of primarily 3 techniques: Polygraph [1], interview, and guilty knowledge test [2]. While On the other hand, behaviour analysis [3] is based on the analysis of faces, facial expressions, etc., However these two approaches require trained experts and it is a time-consuming process

5. Existing Lie detection Models :

5.1 Polygraph Test:

It is an apparatus in which on a single strip of moving paper several signals from the sensors are recorded. This sensor records : Breathing rate of a person, Pulse rate, blood pressure and the person's respiration. Several Polygraph also track record arms and leg movement. A person is asked for many questions, and these measures are checked by polygraph examiner and a significant faster heart rate, high blood pressure , increased perspiration indicated that person is lying. Certain findings show that polygraphs are worse on detecting if people are true than detecting if they are lying, This can be particularly problematic to deal with in probation situations, where an reprobate may don't have an opportunity to verify that they were not lying even when the polygraph signifies they are.

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Fig.10: Polygraph equipment attached to an examinee

5.2 Voice stress analysis:

The only species which have lot of real and virtual behaviour are Human beings. The tone and pitch of a person is an effective measure to express feelings and emotions. Speech is an effective measure to determine mental changes of human beings. Many researchers works on voice changes to detect lie and other emotional changes . investigators concentrated their focus on the vocal analysis of speech. This Technique has the benefit[28] over others: it doesn't need any direct relation among the person and apparatus. Three procedures are used in this: Reality monitoring, scientific content analysis, and criteria-based content analysis. Now a days detection via use of computers are popular, because of the ability to analyse complex datasets without having direct content. However there is a main difficulty with computer-based techniques that the requirement of much distinct elements to categorize truth or lie.

Overview of voice stress analysis of lie detection system:

We expresses our inner state via voice. As we discussed above that voice stress analysis is useful lie detection technique which involve only recording of speech statements. And machine learning-based methodologies are utilized to evaluate the performance from the real-life dataset, which have honest and fraudulent speeches statements which are taken from the video clips of used dataset. Then SVM classifier is used for lie detection.

In speech classification, the first stage (Fig. 11) is speech acquisition. Then it is refined using Pre-processing of the speech which is done to achieve the correct prediction of the lie. To remove the Noise STFT based thresholding technique is used in this stage. Features extraction is also done at this stage from pre-processed signals. Once the features are extracted , MFCCs is used to inspect relevant features. Then extracted features supplied to classifiers for improved prejudice of lie from the truth and on the basis of it decision is made.

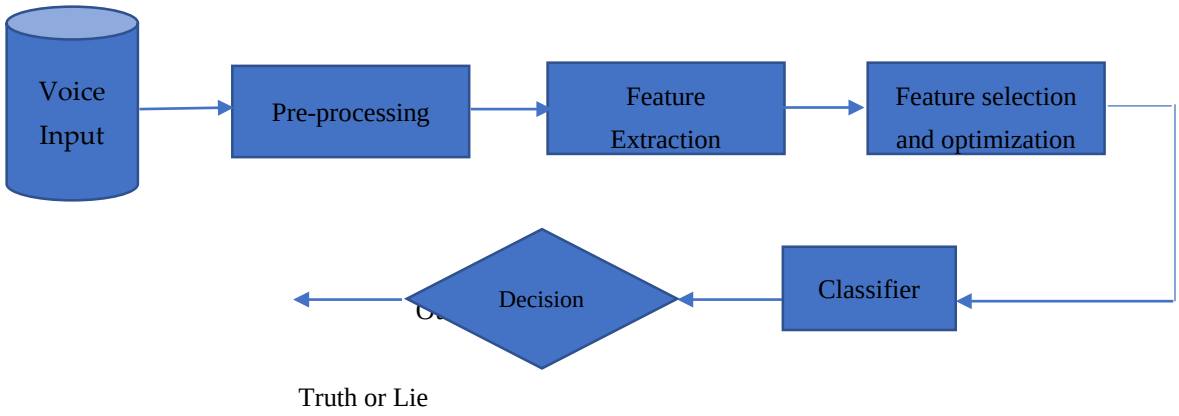

Fig. 11: Block diagram of lie detection technique using Voice

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5.3 Eye tracking:

Eye-tracking technique is a concept under intellectual load theory for detection of deception. The main hypothesis is that extra cognitive load which is related to the lying lead to pupil stretching, extended fixation and reduces the rate of eye blinking. Generally eye-tracing is assessed by cameras from a remote which makes this techniques is appropriate to examine.

Key metrices in eye tracking : a) ***Pupillary size***
b)Fixation duration
c) Blinking
a) Pupillary size pupillary size, pupil dilation and deception can be considered as a main factor during the processing load or enhanced attention.

b) One more factor of eye-tracking is an **eye fixation**. These Fixation interval exposes face recognition.[50] Schwedes and Wentura (2012) [51]expanded the outcomes in a lab study and conclude about the that extended fixation duration for masked faces in comparison to neutral faces.
And the advantage is, eye fixation recorded from distance with no knowledge of the person.

c) The Next factor is to detect is eye blinking rate in eye-tracking which can be measured with a distant camera. Researches has shown that eye blinks change to lessen when there is an increase in the mental load (e.g., Goldstein, Bauer & Stern, 1992). Leal and Vrij (2008) in their study shows that when liars undergo through a situation where cognitive load is more, then they found that there is a reduction in eye blinking rate which is vice versa of the above if when the load reduces after the lie there is an increase in eye blinking.

5.4 Brain Imaging

Another more techniques is to detect a lie is a functional magnetic resonance imaging (fMRI)[30], that evaluates brain activity of people via using mental countermeasures.

An fMRI device tracks flow of blood to activate brain areas. The principle behind it is that the brain show signals of identification when concealed elements are presented however extra effort required to hide signals of such recognition. The brain region which do more work, get more blood flow. These regions are lighted up in the scans. Such areas directs the attention and helpful to make the decision. A medical imaging method MRI uses high magnetic fields & nonionizing electromagnetic radiation[27] to generate high resolution, 3-dimensional (3D) tomographic photos of the body. In this technique of fMRI, the images of the whole brain are taken serially after each few seconds, this process is speedy enough[30] to examine variations of amount of blood and flow of blood in the region which is related with mental activity.

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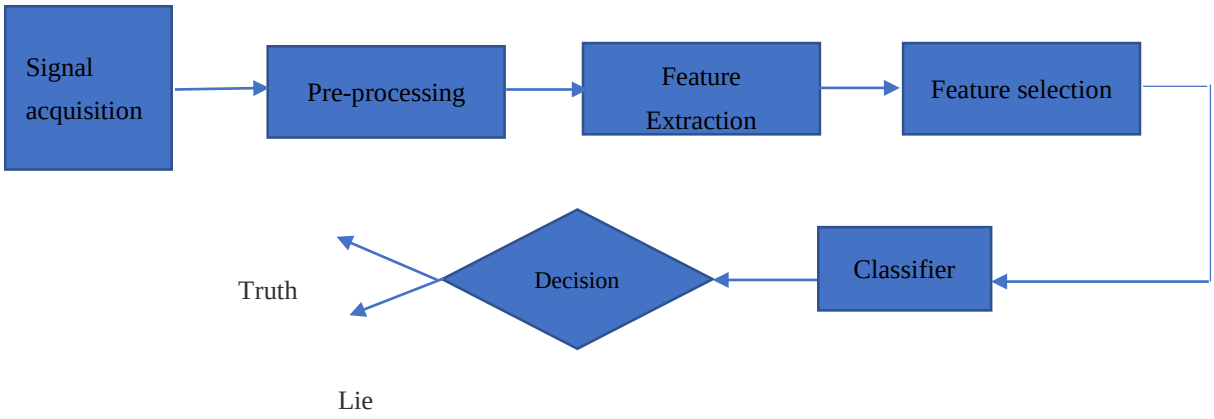

Fig. 12: Block diagram of lie detection technique using Brain Imaging

5.5 **Thermal Imaging :** The next Technique is thermal imaging or thermography. It is a technique which based on the concept that variations in facial temperature is related with variations in the blood flow and this is identified by special camera. The concept behind is that the liars found more increase in blood flow on the face than the truth tellers and by so they are detected. This operates by using a **thermal imaging camera** which takes variations in **facial temperature** in response to inquiring. Whenever somebody answers a lie the brain activity changes and this rise up the facial temperature. The Most sensitive spots are the areas across the eye and the **cheeks** where temperature rise can be easily detected. The thermal imaging camera tracks face gestures frame-by-frame which are then analysed using **Facial Action Units**. FAU is a procedure of differentiating facial expressions.

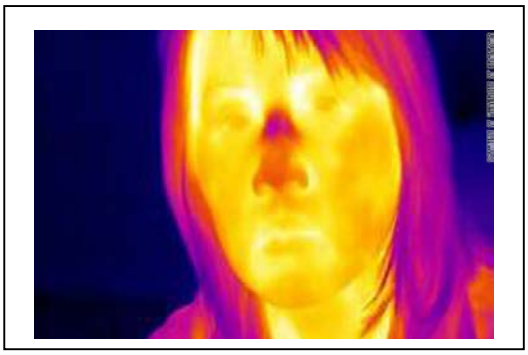

Fig. 13: Sample photo of Thermal Imaging showing body temperature.

5.6 Facial Emotion Recognition :

Facial Micro expressions are automatic responses which are impossible to hide. Liars when experiences stress manifests their body language, signs and verbal signs. Facial Micro expressions are recognized and distinguished based upon the theory presented by Paul Ekman's Research using Principle Component Analysis.

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Approach and implementation:

The abbreviation FER has many meanings, such as Facial Emotion Recognition and Facial Expression Recognition. In our review article this abbreviation FER is described as Facial Expression Recognition.

FER is generally categorized into 3 stages :

Face Detection, Feature Extraction and Emotion Classification.

The first stage consists of pre-processing stage, in which face is detected from an image and then facial components of the face areas are identified. These facial elements could be eyes, brows, nose, and mouth.

The second stage is an edifying feature in which features will be extracted from the several parts of the face.

The last stage uses classifier to train and to produce results for the Emotions using the trained dataset.

Implementation of Deception Detection system :

The Deception Detection system consist of three phases.

1. Data Collection and Pre-Processing
2. Features Extraction
3. Classifier

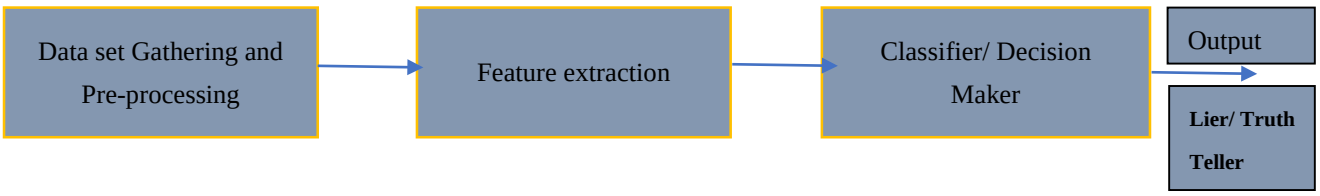

Fig. 14: Stages of Deception Detection

6. Comparison Of various Techniques used for Lie detection :

Techniques	Working	Accuracy	Advantages	Problems
Polygraph Method	It identifies stress-related reactions such as increase in skin conductivity, heart rate, breathing rate	Studies in this field vary considerably, which shows 60 to more than 90 percent accuracy.	Cost of the system has decreased due to competition in the market.	Human can experience stress for many reasons: Tension, annoyance, pain, fear, surprise. 2.

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	and BP (blood pressure).			An expertise need to read the graphs
Voice-Stress Analysis Method	This needs a computer program which determines variations in speech patterns, such as tone, pitch and intensity, stress, which may imply deception.	Uncertain	*Not required any direct contact with the subject. * Ease of use, only a microphone required to attached to the subject. .	*Found stress better , than a lie but if it is a good lie detector it remains unclear.
Micro -Expressions	Popularly working on facial movements which can reveal range of emotions, including however a person is trying to hide	Highly Accurate	*Not required any intervention with the subject. *Could be used secretively by videotaping *High precision	Availability of Datasets *Compound Expressions
Functional MRI	fMRI signifies changes in the brain activity based on the concept that when people lie, they shows greater changes in blood flow rate.	Unclear	*FMRI has no risk, as it does not use radiations like X-Rays. *It can evaluate brain function safely	* It is expensive * fMRI scan difficult to interpret. *Researchers still don't completely understand how it works
Thermal Imaging	It measures the surface skin temperature accurately.	Accurate for measuring surface skin temperature.	*Works well without Physical interaction. * It can act as a cue to detect deceit.	*High Initial Cost. *High Temperature may be the reason of many other causes which may produce wrong results. * Environment sensitive

7. **Conclusion:** In this paper we reviewed various research paper to find put the best possible technique for lie detection**.** Various techniques are discussed and the way by which they detect liars. All the techniques are ended up with some pros and cons which are highlighted in the chart. And it is clear that deception detection using micro expression has more advantages over other techniques, in terms of accuracy and results. However the results can be improved more if we add voice stress analysis and Thermal Imaging techniques with Facial expressions, to decrease the error and to get more truthful results.

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