Lie Detection Using Facial Analysis, Electrodermal Activity, Pulse and Temperature

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ABSTRACT

The paper describes a system based on lie detection named "Lie Detection Using Facial Analysis, Electrodermal Activity, Pulse and Temperature". Detecting lies plays a vital role in many areas, such as airport security, police investigations, counter-terrorism, etc. The system uses four parameters for detecting a lie such as facial gestures using the 68 point facial landmark, pulse and temperature sensing and electrodermal activity using the galvanic skin response i.e. GSR. The traditional method of lie detection is by using heart pulse of the convict which is not that reliable as the convict might be able to manipulate his heart pulse to avoid lie detection. The other technique to detect lies is through the identification of facial micro-expressions, which are brief, involuntary expressions shown on the face of humans when they are trying to conceal or repress emotions. Along with the pulse detection and facial analysis, the system also includes the electrodermal activity which helps to get more accuracy while testing the convict. When a set of targeted question in line with the investigation are asked to the suspect, the liars experience stress which manifests itself as body language cues. The system uses these cues to determine if the convict is telling the truth or not.

Keywords: Lie Detection , Electrodermal activity, EDA, GSR, Galvanic skin response, Lie Detection using facial analysis, Lie Detection using heart beat analysis, Lie Detection using Galvanic skin response, lie detector using facial analysis, heartbeat sensing and Galvanic skin response, Ear value, Facial 68 landmark points, HOG, Histogram oriented gradients.

INTRODUCTION

For as long as human beings have deceived one another, people have tried to develop techniques to detect deception and find the truth. Lie detection took on aspects of modern science with the development in the twentieth century of techniques intended for the psycho physiological detection of deception, most prominently, polygraph testing. The polygraph instrument measures several physiological processes and changes in those processes. For using polygraph test on the suspect, many countries require special permission from the court which makes it difficult to execute. Although the traditional polygraph test is good and is been used from a long time, it becomes unreliable as the person on which the test is being performed might be able to manipulate the parameters used in polygraph test. As in a polygraph test, the examiners observe the charts of the above measures in response to questions, and then infer whether a person is lying or telling the truth.

Researchers are developing several techniques to detect lying individuals. British airport authorities are testing one system based on the Facial Action Coding System. One of the human behavior measurements is sign judgment, which aims to describe the visually discernible facial movement, rather than the meaning underlies a displayed behavior. The human face is a sign vehicle that sends messages using not only its basic structure and muscle tone, but also changes in the face conveying expressions, such as smiles, frowns, etc. The person's mood and intentions can be read from the facial expressions. These facial gestures can be determined based on the concept of 68 point face landmark which is a Histogram oriented gradients (hog) based approach.

Galvanic skin response refers to the changes in the skin conductance i.e. it refers to the changes in the activity of sweat glands which are reflected as per the intensity of the emotional state of a person. Electrodermal activity (EDA) is referred as to the changes in electrical conductance of the skin that is it measures or collects the data from the response that is generated whenever there are psychological movements in the body.

The system is developed by using these parameters of facial analysis, pulse, temperature and electrodermal activity. The system uses the data coming from these parameters and feeds it to the logic which then determines if the person on which the test being performed is telling the truth or lies.

LITERATURE REVIEW

This section comprises the study of existing work done related to our system. It contains the review of papers related to the parameters that are used in the system.

The paper is based on polygraph test which works on the principles of bio signals. In polygraph test the multimodal bio signal data is used by a trained inspector with the objective of detecting whether a person is telling the truth or not. In this paper, the authors are focused on the performing the lie detection using the heartbeat readings of the convict. The authors used the heartbeat reading of the convict while question was asked and provided the data to a supervised classification algorithm. It is known that emotional situations, such as stress, anger, amusement, lead to variations in the heart rate, which can be obtained through blood volume pulse signals based on which the algorithm evaluates the input[2].

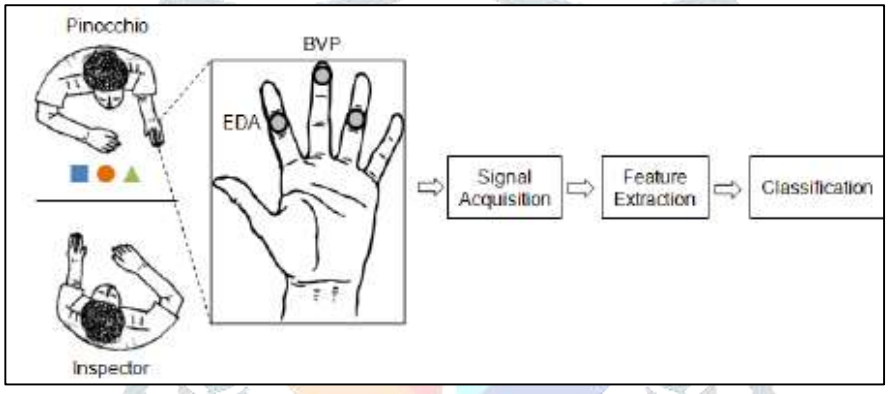

Fig 1: working of author's setup

Figure 1 shows the author's setup that he used for his system. The Blood Volume Pulse (BVP) measures the variation of the blood flow within the vessels surrounding the sensor region, by emitting a light onto the surface of the skin and measuring the amount of light reflected to the sensor. When the blood is pumped through the capillaries, it increases the opacity of the finger, resulting in a higher amount of light reflected to the sensor, which decreases until a new hear beat occurs [2].

The paper describes how facial landmark points detection in important in image processing as face identifies, face re-construct, face corners alignment, face detect different head pose and facial expression analysis. In this paper the authors have use Haar cascading face detection technique for face detection and tracking. Histogram of Oriented Gradients (hog) was used for 68 facial landmark points detection in case of human tracking and detection. The SVM classifier was used to classify the detected 68 landmark points such as corners of mouth, eyes, nose tips and left-right eyebrows, chin, cheek and lips midpoints [3].

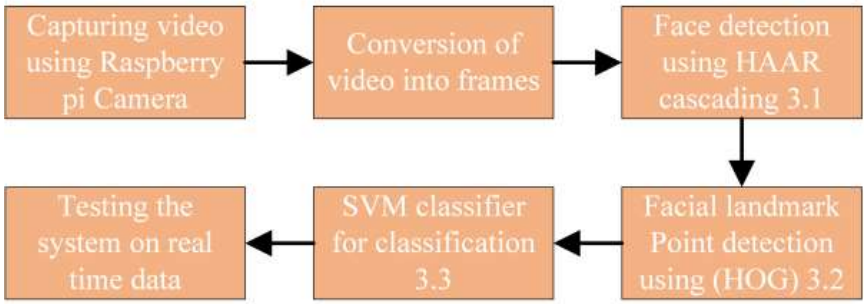

Fig 2: Work flow of the author's system

The efficacy of the SVM algorithm was tested on 580 real-time images and videos overextended Multi-PIE database. The experimental results proved that the proposed system was successful in detection and tracking of real-time facial landmark points over 580 images and just 9 images which are extremely high and side faces are not able to detect [3].

The paper is based on electrodermal activity (EDA), which is referred to the changes in electrical conductance of the skin. Physical signal activity is commonly used parameter. However, body movement has great impact on physiological signals because of the changes in autonomic arousal caused by energy expenditure. It is difficult for the recognition of emotion and the record of physiological signals. In the paper, the authors developed a wrist-type multi-physiological parameters acquisition device, which records the electrodermal activity, acceleration, skin temperature and angular velocity signals, to study the variation of physiological signals. The authors stated that EDA was positively correlated with energy expenditure under different physical motion states. The more intense the motion is, the faster the EDA changes and vice versa [4].

Table 1: Summary of paper

SR NO.	YEAR	Name of Paper	Author	Content
1	2013	Uncovering Lying Detection using Blood Volume Pulse and Electrodermal Activity	Ana Priscila Alves, Hugo Plácido da Silva, Andre Lourenco, Ana L. N. Fred	The paper focuses on the performing the lie detection using the heartbeat fluctuation of the person. The authors used heartbeat of the person while question was asked and provided the data to a supervised classification algorithm.
2	2016	Lie Detection based on Facial Micro Expression, Body Language and Speech Analysis	Soumya Barathi C	This paper discusses the various body cues Exhibited by a liar and proposes a method to identify a subject's body language using the SURF (Speeded Up Robust Features) approach to see if the subject exhibits the body language of a liar.
3	2018	Detection of Deception Using Facial Expressions Based on Different Classification Algorithms	Harith H. Thannoon, Wissam H. Ali, Ivan A. Hashim	The paper proposed a system that uses Facial Expression as a parameter to detect deception by using different classification algorithm. This paper provides us with the accurate information for implementation of facial gesture to detect a lie that can be combined with the Heartbeat and Electrodermal activity to provide a system with better accuracy.
4	2018	A Review on Facial Micro-Expressions Analysis: Datasets, Features and Metrics	Walied Merghani, Adrian K. Davison, Member, IEEE, Moi Hoon Yap	The aim of this paper is to provide the insights of automatic micro-expressions analysis and recommendations for future research. Paper proposes some promising future directions to advancing micro-expressions research.
5	2019	Research on the Electrodermal Activity during Walking and Running	Xiaoyong Ji, Heng Li, Zhuofan Lu, Zifeng Wang and Xinyu Chai	In this paper the author has used the Electrodermal Activity in actual system of walking and running to obtain the results. We referred to this paper so that Electrodermal activity (EDA), referred to the term for changes in electrical conductance of the skin, is a significant physiological signal in health.
6	2019	Facial Representation for Automatic Facial Action Unit Analysis System	Ruicong Zhi, Mengyi Liu, Dezheng Zhang	In this Paper the authors have presented Facial Representation for analyzing the human facial expression. This paper provided as a base guideline to utilize facial recognition as parameter to increase the accuracy of our project.

In Table 1 we have described the summary of existing papers related to the parameters such as facial gesture, heart pulse, and Galvanic skin response.

PROPOSED SYSTEM

In the system, we start by obtaining information from the human body using parameters like pulse rate, temperature, skin response, facial analysis. Then these parameters are used to create a lie detector system. The information about heart rate and temperature is acquired from sensors like pulse sensor and body temperature sensor and are analyzed them in the system. The system makes effective use of Open CV library and DLIB library for feature extraction. It uses concept of 68 point face landmark which is a Histogram oriented gradients (hog) based approach to obtain the information about the facial gestures. System also uses the concept of electrodermal activity (EDA) which has also been known as skin conductance or the galvanic skin response (GSR). The galvanic skin response refers to changes in skin's sweat gland activities that are reflective of the intensity of our emotional state. Once all these data are obtained and tuned as per the system it is fed to the system which will help to determine whether the person on which the system is tested is telling the truth or not.

IMPLEMENTATION

The implementation of the system is divided in the following sections

A) Facial Analysis

The system is based on a real-time method to perform face detection using Haar cascade technique. The system uses the Open CV library for image processing and DLIB library for feature extraction.

Haar Cascade is an Object Detection Algorithm used to identify faces in an image or a real time video. The algorithm uses edge or line detection features proposed by Viola and Jones in their research paper "Rapid Object Detection using a Boosted Cascade of Simple Features" published in 2001. It is a machine learning based approach in which a cascade function has trained a lot of positive images consisting of faces, and a lot of negative images not consisting of any face to on them. It is then used to detect objects in other images.

Histogram oriented gradients (hog) approach is applied to detect and track the 68 facial landmark points. The system is based on to detect the facial parameters like right-left eyebrow, left-right eye, nose, lips, chin, and jaw for extracting landmark points. The system measures the euclidean distances between landmark points.

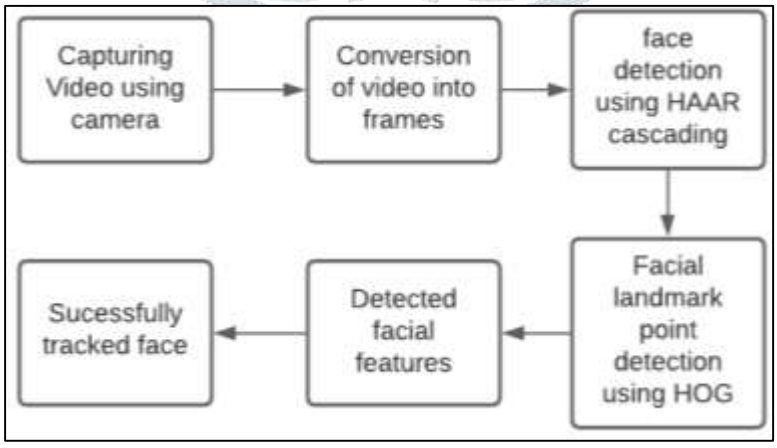

Fig 3: Flow Diagram for Facial features Detection and tracking

Figure 1 shows the flow of working in the proposed system. The system follows the following step to operate facial landmark points tracking and detection.

Step 1: A real-time video is captured using camera.

Step 2: The video is then converted into frames.

Step 3: Haar cascade algorithm is used for face detection. The algorithm identifies whether a face is existing in an image, if a face does not exist in the image, then it searches the face in subsequent images.

Step 4: It then converts the image into a series of histograms based on the orientation and magnitude of pixel gradients within the image using the Histogram oriented gradients (hog) approach.

Step 5: Facial features are detected using facial landmarks.

Step 6: Successfully tracking a face.

There are two steps to detect facial landmark points through DLIB'S 68 Model in the image as given below:

1. Face Detection

The Haar Cascading method is used to identify whether a face is in the images or not. If the algorithm finds a face in the image then it continues or it again starts with finding the face in image. Face localization process is used for finding whether a face is included in an image, and its location and size. The moving object detection window and an image pyramid are used in DLIB library. The DLIB library is based on face detector performance of the Open CV variants with good accuracy and detection error is low positives when capture the real-time images and videos in uncontrolled environments, like facial feelings, head position, different changes in head pose, high gender and face interpersonal variation, and from control conditions such as lighting and image resolution.

2. Facial Landmarks Detection

The second step is to detect facial landmarks. The main aim is to find automatically face and 68 facial landmark points. To find the landmarks on face, a shape estimator implemented in the DLIB library is used. The 68 facial landmark points are as shown in Figure 2.

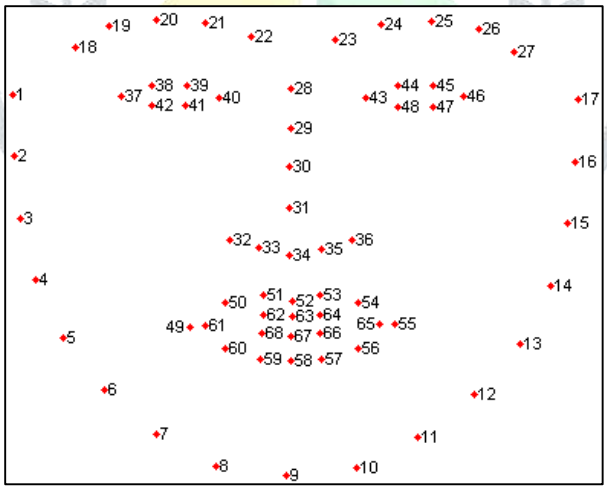

Fig 4: 68 facial landmark points

The facial landmark points are arranged in two classes primary and secondary. The first landmarks i.e. the primary classes are directly detected landmarks, such as eyes, eyebrows, nose and mouth. They play an important role in facial identification from low-level image. The secondary class landmarks points are cheeks, left-right eyebrow, chin and lips, non-extremity points and nose. These are important in identifying the facial expression and for face tracking.

B) Eye aspect ratio

Eye aspect ratio (EAR) is another parameter that is used in the facial analysis module. The EAR value is used as the baseline for stating the person's eyes are open closed or wide open or drowsiness based on the EAR threshold value. The EAR value obtained is used as the additional parameter to determine whether the person is telling the truth or not. EAR is calculated based on the landmark coordinates on the face especially the eyes. The EAR value of the right and left value is calculated as average.

C) Pulse and Temperature

The second section of the system is the pulse and temperature. This module is based on the traditional polygraph system. Polygraph test is method which is based on parameters like blood pressure and heart rate. This system uses the heart beat and temperature parameters in addition to the facial analysis and galvanic skin response. This module of the system is completely IoT based. It consists of hardware parts such as heart rate pulse sensor and human body infrared temperature measurement module (MLX90614) which collects the required data from the object or the person on which test is taken on and sends to the system for implementation in further modules. The working of the pulse and temperature module starts by collecting data of pulse rate and body temperature from the person. The data is then analyzed to remove the noise from data, and then the data is send serially to the main python module from Arduino. After analyzing the data it calculates the upper and lower bound for the given data.

D) Galvanic Skin Response (GSR)

The third section of the system is the galvanic skin response (GSR). This is an added parameter which will help the system to get more accurate results. Galvanic skin response refers to the changes in the skin conductance i.e. it refers to the changes in the activity of sweat glands which are reflected as per the intensity of the emotional state of a person. This module also follows an IoT based approach. It consists of a GSR sensor connected to the Arduino with other sensors.

To measure the GSR value the individual needs to insert any two fingers into the straps, which has electrodes attached to it and then the test will be conducted and data about the skin response or the conductance will be sent to the system through the serial port along with the other data.

E) Implementation

The system's pulse and temperature module is IoT-enabled. It consists of sensors like pulse sensor and human body infrared temperature measurement module (MLX90614) which are connected to the Arduino which acts as the main part of this module. Data is collected from these sensors with the help of Arduino which is then sent through the serial port.

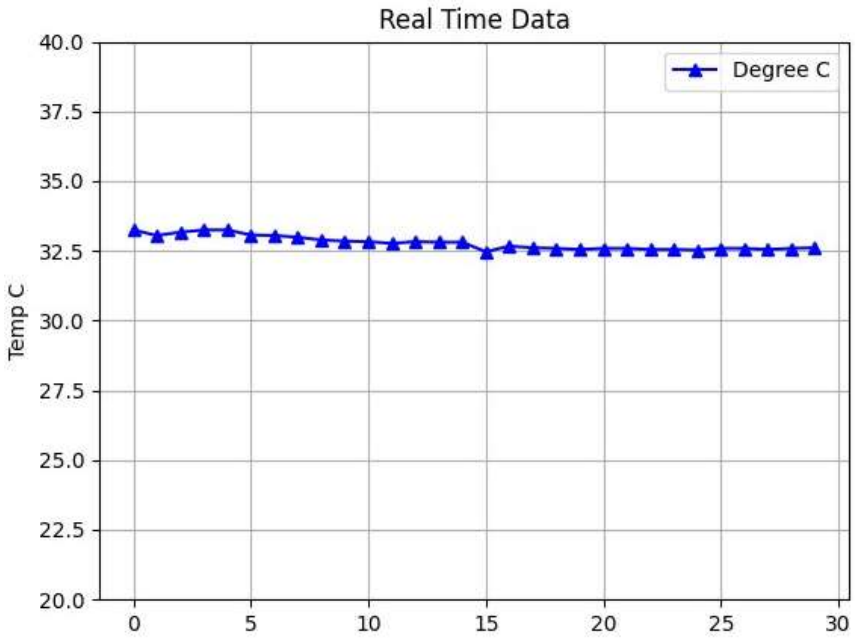

Fig 5: Temperature readings

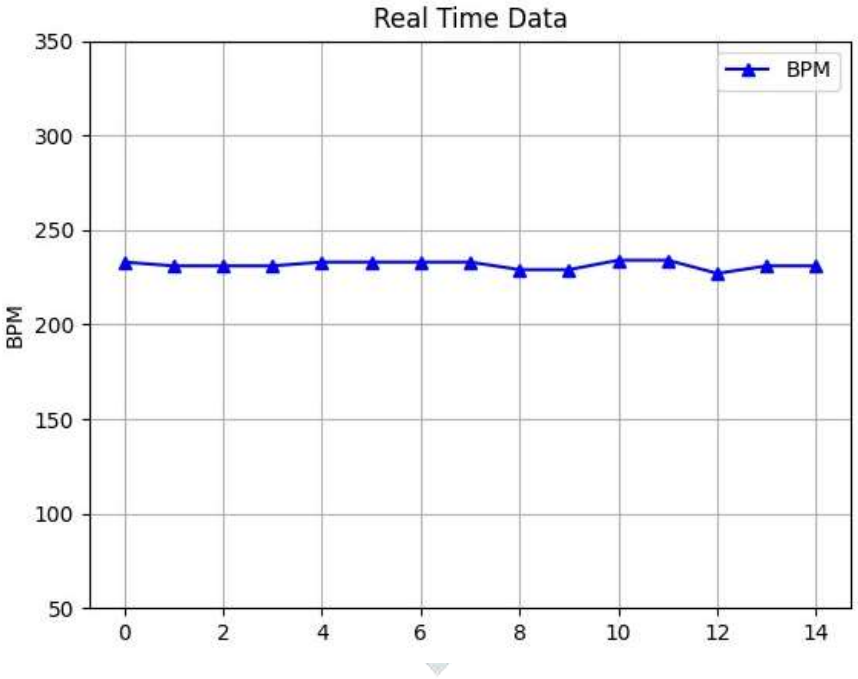

Fig 6: Pulse readings

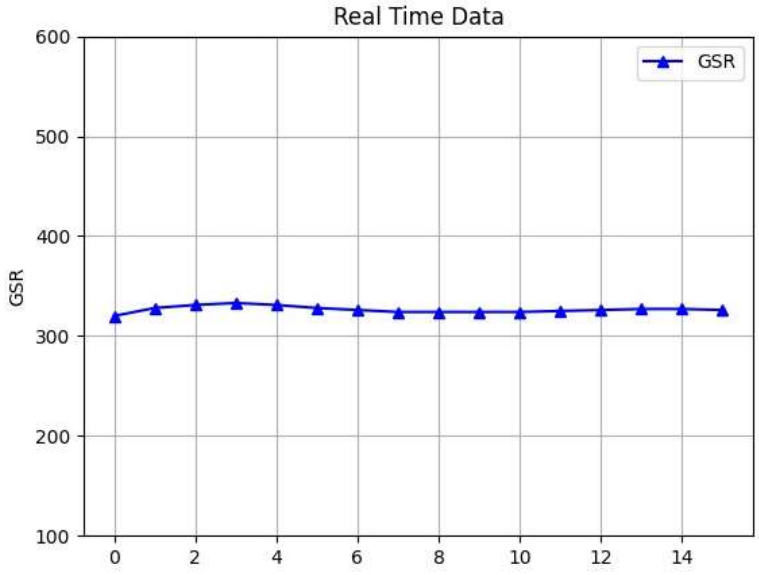

Fig 7: GSR readings

The figure shows data that is obtained from the sensors which is then sent through the serial port to the main system. The data is tuned as such that it will get the maximum and minimum pulse and temperature data of the person on which the system will be tested.

The EDA module of the system is also IoT-enabled. Galvanic skin response (GSR) sensor is used to collect the skin response of the person undergoing the test. It works same as the pulse and temperature module. The Arduino serves as the module's heart, and the data collected by the sensor is sent to the device via serial port. The GSR data will be tuned to get the maximum and minimum value from the data.

The facial analysis module is based on a real-time method to perform face detection using Haar cascade technique. Feature extraction of the 68 pints is performed using Open CV library and DLIB library.

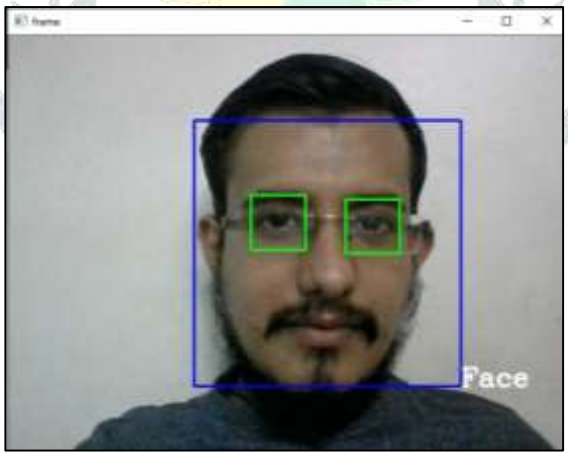

Fig 8: open CV output with required landmark points

Open CV is used to capture the real time video of the person undergoing the test. The video captured from the open CV is then divided into frames on which the Haar cascade algorithm is used for face detection. Once the face is detected by the Haar cascade technique facial landmark points are detected through DLIB'S Model. Total 68 facial landmark points are detected which consists of facial parameters like right-left eyebrow, left-right eye, nose, lips, chin, and jaw. These 68 points are then used to calculate the EAR value. The system measures the Euclidean distances between these landmark points to determine the EAR value.

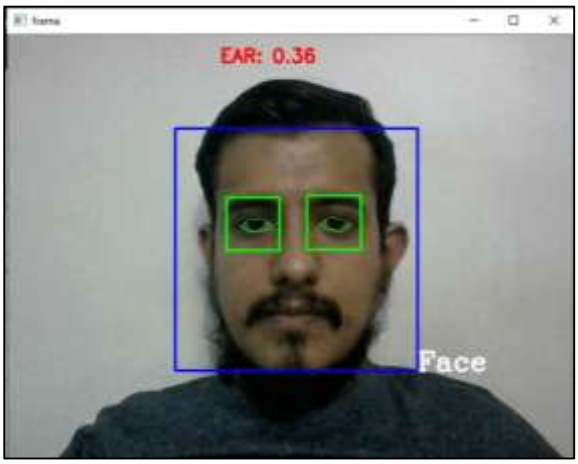

Fig 9: EAR value

Above diagram shows the EAR value based on the landmark points of the user. This EAR value is then fed to the logic in the system.

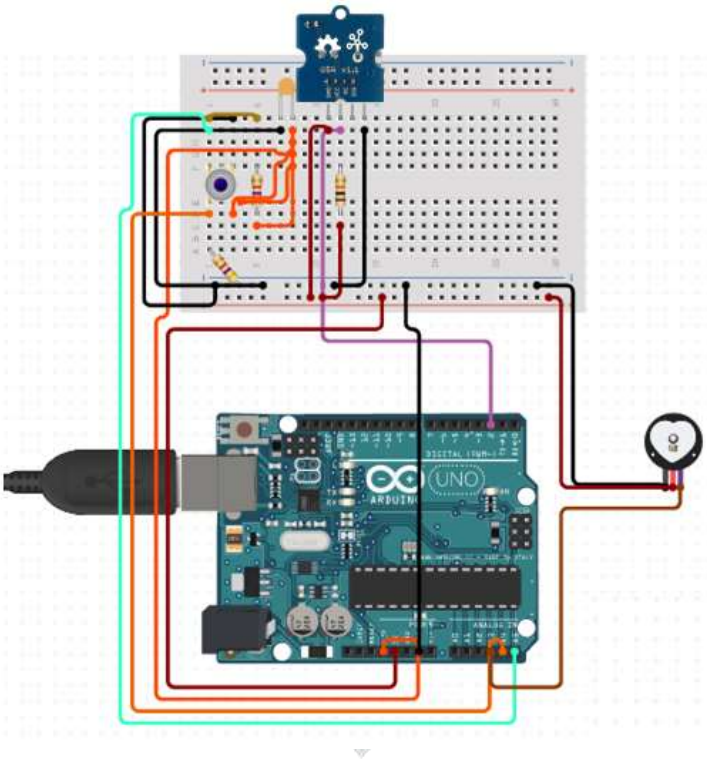

Fig 10: Circuit Diagram

The diagram above shows the complete connection setup of the system. Sensors such as pulse sensor, human body infrared temperature measurement module (MLX90614) and Galvanic skin response (GSR) are connected to the breadboard which is then finally connected to Arduino. Arduino then transfers this data serially to the system via serial port.

Individual data from the above modules i.e. Pulse, Temperature, GSR and Facial i.e. EAR values are received. This data is then fed to the logic through which the decision is taken if the final state is true or false. The logic then calculates the upper and lower bound from the readings that is generated. Once the bounds are calculated then it moves to the next phase which is explained in the next section after logic table. In next phase the system will check if the new value generated in phase two falls within the bound or exceeds the bound and based on that the system will give the final output. The logic of the second phase can easily be explained in the form of truth table as shown below.

Table 2: Logic truth table

Pulse	GSR	Facial	Temperature	Results
0	0	0	0	F
0	0	0	1	F
0	0	1	0	F
0	0	1	1	F
0	1	0	0	F
0	1	0	1	F
0	1	1	0	T
0	1	1	1	T
1	0	0	0	F
1	0	0	1	F
1	0	1	0	T
1	0	1	1	T
1	1	0	0	T
1	1	0	1	T
1	1	1	0	T
1	1	1	1	T

The above table shows the truth table for the logic where, 0 represents that the current state has exceeded the bound value and 1 represents that the current state is within the bounds. Due to the restricted amount of trials performed during the testing phase we summed up the percentage of individual parameters according to the reliability and usability of the values obtained during the testing phase. Based on the trials we have assumed the percentage of individual parameters as 30% for pulse, 30% for GSR, 25% for facial and 15% for temperature to determine the final result.

The final working of the system goes as follows

The working of the system is divided in to 2 phases where first phase is used to collect data about the person undergoing the test and the second phase is where the logic comes into picture to determine truth or false.

In first phase of the project the sensors are attached to the convict's body and the data is collected. During this phase the convict is asked a set of question which answers are known to the observer. This phase is active for few minutes and all the readings are recorded. Once this timer is expired, the system stops recording data, then the upper and lower bounds are calculated based on the readings obtained. These bounds are then stored so that it can be used in second phase.

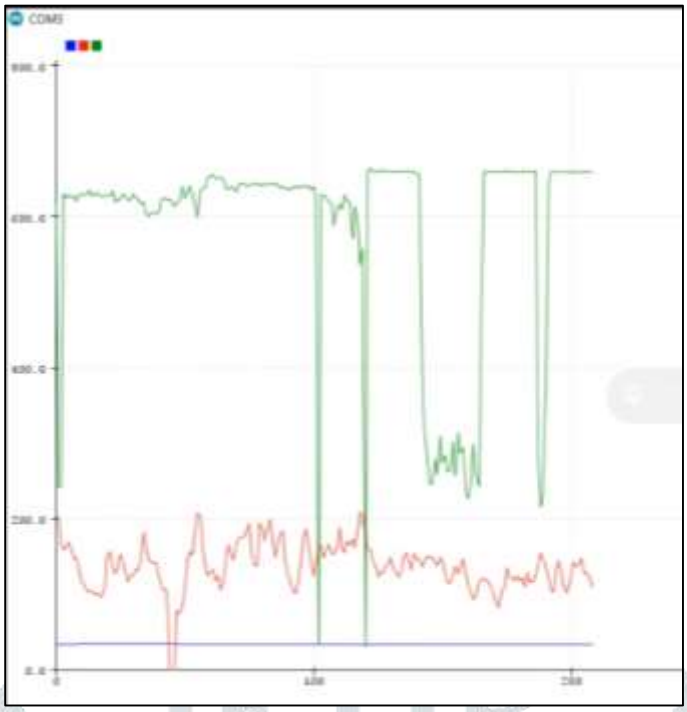

Fig 11: Data obtained during initial phase

The above figure shows the data of individual parameters that is obtained during the first phase i.e. when the timer is running. Here blue, red and green lines represent the readings for temperature, pulse and GSR respectively.

The second phase starts by retrieving the stored data. Then the interviewer starts asking questions to the culprit and new data is recorded, then the new data is compared with the bound values as per the logic table and if the new reading exceeds the upper or lower bounds then we can determine that the convict is telling a lie and if the new readings are within the bounds then the convict is telling the truth.

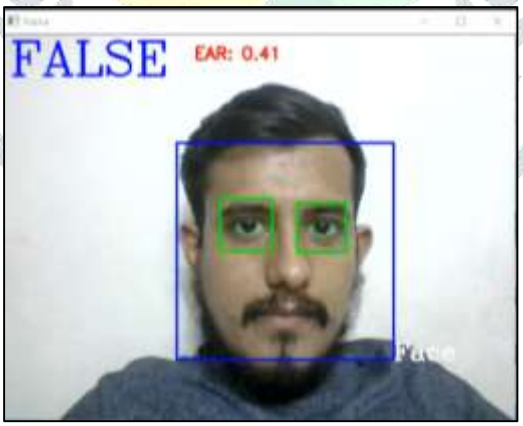

Fig 12: False Output

As shown in the figure above when the convict is asked a serious crime related question, his readings are exceeding the bounds thus the system determines that the convict is telling a lie.

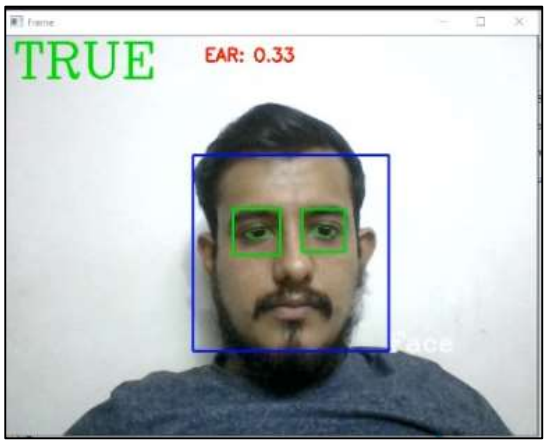

Fig 13: True Output

As shown in the figure above the data obtained is within the range thus the system determines the convict is telling the truth.

CONCLUSION

The paper gives an insight about the project which represents a solution for the challenging task that is to predict whether a person is speaking truth or a lie which can help in an on-going investigation. The system uses Haar cascade technique for face detection which is an object detection algorithm. Pulse, Temperature and GSR are IoT-enabled modules. The key aspect of this project is the combined use of various technical aspects such as Heartbeat, Temperature fluctuation, Electrodermal Activity and Facial gestures. The actual experiment of the combined system provides a reliable result as compared to other existing systems. We also would be eager to add more parameters to the system without drastically increasing the complexity but reliably and consistently increasing the accuracy of the system.

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