Lie Detector System

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Abstract- **In an era where information authenticity is critical, the development of reliable lie detection systems has garnered significant interest across various domains, including security, forensics, and psychological evaluation. This project presents the design and development of an advanced lie detection system that integrates biomedical sensing with artificial intelligence to improve the accuracy and reliability of deception detection. The system utilizes a combination of physiological signals—Galvanic Skin Response (GSR), body temperature (via a piezoelectric sensor), and blood oxygen levels (SpO_2 through an oximeter)—to monitor stress-induced changes in the human body. In addition to these standard biometric parameters, the system also incorporates behavioral cues such as eye blink frequency. The key innovation introduced in this project is the integration of AI-based pupil dilation analysis, which enhances the system's ability to detect deceptive behaviour. Using computer vision techniques, the system captures and analyzes real-time changes in pupil size, a physiological indicator often linked to cognitive load and emotional stress. This data is processed by a machine learning model trained to differentiate between truthful and deceptive responses based on multi-modal input.**

***Keywords:** Lie Detection, Pupil Dilation, Artificial Intelligence, Galvanic Skin Response (GSR), Biomedical Sensors, Eye Blink Detection, Computer Vision, Machine Learning, Deception Detection, Physiological Signals, Oximeter, Temperature Sensor, Cognitive Stress, Real-Time Monitoring ,Haar cascade classifiers, Blink detection*

INTRODUCTION

Correct identification of lies is essential in areas like security, law enforcement, and psychology. Conventional polygraph-based systems, based mainly on physiological signals like heart rate and skin conductivity, suffer from reliability issues and are restricted by their invasive nature. With the advancement in sensor technology and artificial intelligence, more

Interest has been observed in the design of non-invasive, intelligent, lie detection systems with improved accuracy and versatility. The project indicators are augmented using artificial intelligence. The system tracks Galvanic Skin Galvanic Skin Response (GSR), body temperature (with piezoelectric sensor), oxygen saturation in blood (with oximeter), and eye blink frequency to detect signs of deception and stress. The paper outlines the design and implementation of an intelligent lie detection system based on both biomedical signals and computer vision-assisted visual analysis. The system utilizes a combination of Galvanic Skin Response (GSR), body temperature (with a piezoelectric sensor), and oxygen saturation (SpO_2) using an oximeter to detect physiological changes related to emotional stress. At the same time, behavioral signals like eye blink frequency are detected as indicators of mental load. The contribution of this work is the use of computer vision-assisted pupil dilation analysis—a new idea that detects subtle visual signals not typically monitored by conventional systems. Through the assistance of computer vision and machine learning, the system analyzes real-time variation of pupil size to improve deception detection accuracy. The contribution of this work is the use of pupil dilation analysis using computer vision and AI. Pupil dilation, which is usually related to mental effort and emotional arousal, is another signal not detected by conventional systems. With image processing algorithms, the system detects real-time pupil size change. Visual signals and sensor signals are analyzed by a machine learning algorithm designed to detect responses as true or false**.**

In lie detection, monitoring pupil size can provide valuable insights into the subject's emotional state. Research shows that individuals tend to exhibit **larger and prolonged pupil dilation** when telling lies compared to when they tell the truth. This response is controlled by the autonomic nervous system and is difficult to consciously manipulate, making it a reliable parameter in deception analysis.

LITERATURE REVIEW

The pursuit of reliable lie detection methods has intrigued researchers for decades, driven by applications in security, law enforcement, and psychological studies. Traditional tests have served as a foundation, relying on physiological signals such as heart rate, skin conductivity, and respiration patterns to infer deception. However, these systems often require bulky equipment, trained personnel, and are prone to inaccuracies due to emotional variability in individuals. With advancements in sensor technology, embedded systems, and artificial intelligence, there has been a shift towards developing more compact, cost-effective, and intelligent lie detection systems.

This shift has been particularly notable in the use of microcontroller-based platforms, such as Arduino, which allow for the integration of multiple physiological sensors to monitor heart rate, skin conductance, body temperature, and other signals in real time.[1] Intentional-Deception Detection Based on Facial Muscle Movements in an Interactive Social Context. Micro-expression, which is generated by facial muscle movements, could be a crucial cue for deception detection. Addressing this issue, this paper proposes an experimental paradigm with high ecological validity that uses electromyography (EMG) signals to precisely examine the role of facial muscle movements in deception detection. [2] Lie Detector using MATLAB, Arduino and Biomedical Sensors. Here we are using two sensors first one is a blood pressure monitor sensor (B.P.M) and the other one is the temperature sensor and we sample the output data from the two sensors. The LM35 temperature sensor will measure the body temperature of the individual by the help of skin contact. The second sensor is the BPM sensor which will measure the beats per minute of the individual and display he output on the LCD. These two sensors will be used to assemble the lie detector. After the assembling we will initially gather data from a group of volunteers. We will also design a Simulink model and a Simulink program so that we can serially communicate to the lie detector with the MATLAB and then digitally acquire the Real-time readings on the MATLAB Simulink model.[3] A Survey for Lie Detection Methodology Using EEG Signal Processing. Electroencephalography (EEG) is a hot topic all around the world. EEG signals, a series of measurements taken using electrodes on the scalp, can indicate brain activity. They are more private, sensitive, and difficult to steal and recreate. EEG data are increasingly commonly employed in diagnosing brain illnesses and the field of Brain-Computer interfaces, thanks to advancements in biomedical signal processing techniques (BCI). BCI is a brain-computer

The interface that uses electrical impulses from the brain to communicate. EEG signals are used to interpret the electrical activity of the brain.[4] Pupil Size Changes for Lie Detection in a Biofeedback Scenario. The eyes are the window to the soul," attributed to Shakespeare, suggests that our eyes reveal individual emotions and thoughts. And indeed, previous research indicates that pupil diameter increases with cognitive load, including memory recall, mathematical problems, and attention tracking. Kahneman and Beatty [4] observe the magnitude of pupil dilation to be proportional to task difficulty. In addition, pupil size has been shown to be sensitive to affective load, suggesting an increase in diameter during emotional processing. Partala and Surakka report larger pupil sizes during emotionally negative and positive stimulus processing compared to neutral conditions.[5] Implementation of Heart Rate System using AD8232 and Arduino Microcontrollers. The prevalence of heart disease as a leading global cause of mortality underscores the utmost importance of prioritizing cardiac health. Electrocardiography (ECG) stands as a cornerstone in evaluating cardiac conditions, capturing intricate electrical signals generated during each heartbeat and aiding in diagnosing irregularities.

METHODOLOGY

This project focuses on designing and implementing a lie detector system using Arduino and sensor-based AI logic. The idea is to detect lies by monitoring physiological parameters that typically change under stress or anxiety, such as skin resistance, body temperature, and body movement. Traditional lie detectors (polygraphs) need sophisticated equipment and human judgment, whereas this system employs simple hardware elements and embedded logic to simulate intelligent behaviour

A. Pre-requirement

Knowledge of Microcontroller programming language (Arduino). Awareness about the usage of heart sensors and temperature sensors.

B. Components Required

Component Name	**Specification**	**Quantity**
Arduino UNO	ATmega328P	1
Heartrate and spO2 Sensor	MAX30102	1
Temperature Sensor	LM 35	1
GSR Sensor	Aluminium based	1
Piezoelectric Sensor	Round Shaped	1
Resistors	50KΩ 22kΩ	2 1
Capacitor	0.1uF	1
Power Supply	5V regulated	1
Jumper Wires	(Fe)Male-to-(Fe)male	25-30
Breadboard	-	1

C. Process Detail

The lie detector mainly comprises an

Arduino, two aluminium electrodes, heart rate sensor, and temperature sensor. The sensors are fixed on the subject's fingers to measure his/her respective signals. The Arduino will be instructed to measure all three signals in a sequence with a specified delay. Electrode reading is first done followed by heart rate and then temperature. Electrode readings are taken by measuring the difference in potential between the electrodes.

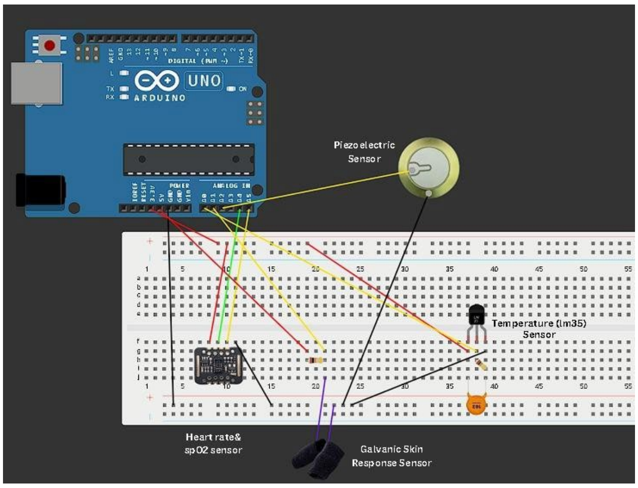
According to the condition, both the potential between the electrodes and the conductivity of the skin change. Arduino's analogue pins are utilized for reading this in, and inferences are drawn based on them. The observed values are graphed for visual inspection. The values are compared with the threshold values on Arduino to make the initial prediction. Fig. 1 illustrates the block diagram of the working approach of the lie detector. Lie detection starts with easy questions for obtaining a normalized reading of the subject in the relaxed state and then hard questions to which the subject might hesitate to answer correctly thereby resulting in a change of sensor readings that can be utilized to predict a lie.

D. Design and development

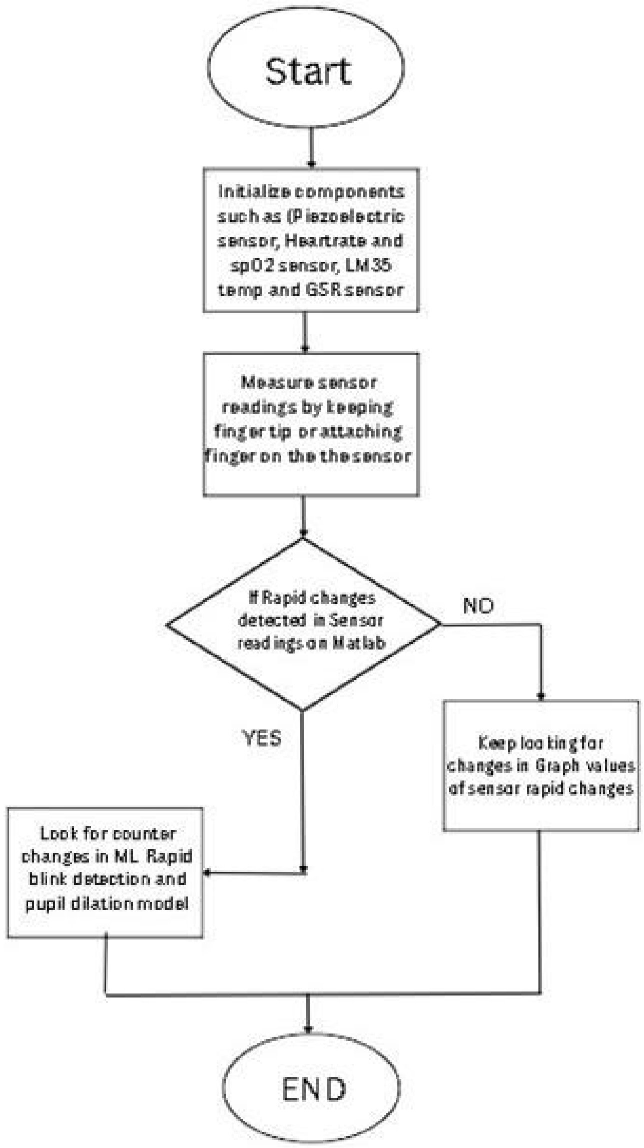
In the creation of a lie detector system using Arduino, some physiological sensors are integrated to check for stress or deception indicators. The LM35 temperature sensor is interfaced with the Arduino using its VCC and GND pins connected to 5V and GND, respectively, and the output pin connected to analog pin A0. This sensor provides an analog voltage proportional to body temperature, with minimal increments showing nervousness. The GSR (Galvanic Skin Response) sensor, on analog pin A1, is interfaced to measure electrical skin conductivity, increasing with increased sweating levels — a normal reaction to stress or lying. The heart rate sensor (e.g., a KY-039 or pulse sensor) is interfaced through its signal pin to analog pin A3 and detects variations in blood volume through an infrared sensor, allowing the system to monitor heart rate variation that is typically increased during stress or lying. Lastly, a piezoelectric sensor, connected to analog pin A2 (with a pull-down resistor), detects minor vibrations or body movement, which may also be an indicator of stress or discomfort. All sensors are powered via the 5V and GND lines of the Arduino.

By continuously monitoring these parameters, the system can identify physiological changes potentially associated with lying, and further process this data for decision-making or classification using artificial intelligence models.

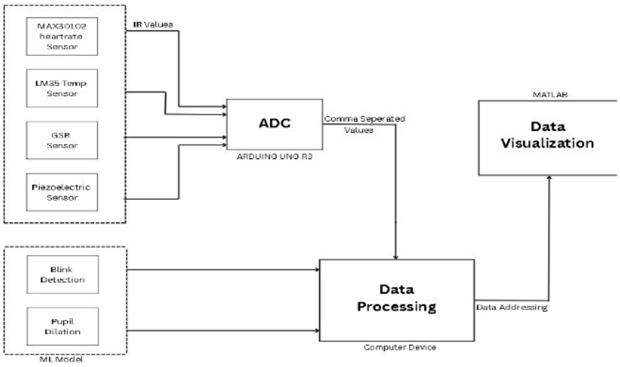
The lie detector machine works on the concept of tracking natural physiological responses one experiences when in a state of stress or not being truthful. The operation starts by supplying voltage to the Arduino microcontroller, which activates all the sensors wired to it. They can be a GSR (Galvanic Skin Response) sensor, heart rate sensor, temperature sensor, and additionally a piezoelectric sensor to measure the tension in muscle or minor movement of the body.



Circuit Design of the lie detector model



Block diagram – Methodology for Lie Detector Development



Block Diagram

IMPLEMENTATION AND DISCUSSION

The lie detection system that developed subsequently was then tested on a group of participants under controlled conditions, where subjects were given a list of questions, both of which were known to be facts and where lies were deliberately made. Sensors — GSR, heart rate, temperature, and piezoelectric — gave real-time readings, which were recorded and processed to detect physiological differences between truth and falsehood responses.

The GSR sensor values of a relaxed subject varied between 300–500 units (analog reading between 0–1023 scale). But under suspected lies, these values increased significantly to 600–750, reflecting heightened skin conductivity due to stress sweating. This GSR peak is a good indicator of emotional arousal. The heart rate sensor generally recorded 60–80 beats per minute (BPM) under normal conditions. Under deceptive responses, the heart rate increased to 85–100 BPM, as expected under the physiological response of heightened pulse rate due to anxiety or stress. The temperature sensor (LM35) provided stable readings between 36.5–37°C (normal human skin temperature). A slight increase was noted under deception, with readings reaching 37.5–38°C in certain instances, possibly due to peripheral vasodilation or stress-induced metabolic response. The piezoelectric sensor recorded negligible signal activity under truthful responses, reflecting little or no abnormal body movement. But under lies, micro-movements and body fidgeting were noted, with analog readings reaching sporadically between 200–400 units, compared to less than 100 units under normal conditions

This simple yet effective process makes the system a helpful tool for experimenting with biometric responses and understanding how the human body reacts under different emotional conditions. For more advanced versions, features like pupil dilation detection or machine learning-based decision-making can be added to enhance accuracy.

Parameter	Traditional Model	Your Model
Sensor Types	MAX30100, LM35, GSR	MAX30105, LM35, GSR, Piezo, Webcam
Behavioral Input	–	(Eye tracking & blinks)
Visualization	Serial Plot/LEDs	Real-time graph (MATLAB), live feed
ML Integration Ready	–	(ML-ready via Python pipeline)
Accuracy Enhancement	Threshold-only	Continuous tracking customizable logic
Portability	Compact but rigid	Modular (3-part, scalable setup)

COMPARISON

The Lie Detector System in this project combines an Heartrate and spO2 sensor, Arduino UNO, LM35 Sensor, GSR Sensor, and LM35 temperature Sensor with an ML model for instant blink detection and pupil dilation as cues to evaluate stress in real-time. Other previous studies and designs have applied the same sensor technologies in lie detection. This section contrasts our proposed system with conventional and existing lie detection models, with the major differences and advantages of the combined ML model for instant blink detection and pupil dilation.1. Traditional Arduino-Based Lie Detector System

This system utilizes basic physiological sensors connected to an Arduino Uno to detect lies based on threshold comparison logic.

Core Features:

- Uses MAX30100 for heart rate, temperature using LM35, and GSR sensors.
- Generates results using LEDs (depending on how many thresholds have been met)
- Serial monitor and plotter data processed.
- Simple threshold-based binary decision model.

Limitations:

- No machine learning or dynamic data interpretation.
- No visual graphs beyond serial plotter.
- Limited to pre-set thresholds; can't adapt to individual baselines.
- No real-time visualization or trend analysis.
- No eye-based metrics or behavioral cues.

2. ML-Based Multimodal Lie Detection System

The system extends the detection functionality with machine learning reasoning, eye-tracking, real-time graphing, and multimodal data capture on three platforms: Python (behavioural features)

Arduino (physiological), and MATLAB (visualization). The model uses quick blink detection and pupil dilation monitoring using computer vision techniques with OpenCV and Dlib. The model begins by locating face landmarks using a 68-point model from Dlib. Left and right eye positions are then obtained from landmarks. For blink detection, the model calculates the Eye Aspect Ratio (EAR), which is a metric of the openness of an when the distance between some eye landmark .

The formula used is:

$$EAR = \frac{||p_2 - p_6|| + ||p_3 - p_5||}{2 \times ||p_1 - p_4||}$$

where p1 to p6 represent specific points around the eye. When a person blinks, the EAR drops significantly. If the EAR falls below a threshold (e.g., 0.2) for a few consecutive frames (e.g., 2 frames), the model registers a blink and increments a sudden_blink_counter. This logic allows the system to track rapid or frequent blinking, which can be associated with increased cognitive load or stress during deception.

For pupil dilation detection, the system uses Haar cascade classifiers to locate the eye region, then isolates the pupil by converting the image to grayscale, applying histogram equalization, and Gaussian blurring. Adaptive thresholding is then applied to segment the pupil region:

$$\text{Thresholded Image} = \begin{cases} 255, & \text{if } I(x,y) < T(x,y) \\ 0, & \text{otherwise} \end{cases}$$

Contours are extracted from the binary image, and the largest appropriate contour is assumed to be the pupil. The pupil size is estimated by fitting a circle around the contour and measuring its radius, which is converted into millimeters using a fixed scale factor:

$$\text{Pupil Size (mm)} = \frac{\text{Radius (pixels)}}{\text{Pixels per mm}}$$

To detect dilation events, the system maintains a sliding buffer of past pupil sizes. When two consecutive pupil size readings have a disparity of more than some threshold value (e.g., 2.2 mm), it will increase a sudden pupil counter. This permits real-time monitoring of sudden changes in pupil size, which has a physiological association with arousal, stress, or lying. The model also plots pupil size data in real time with matplotlib to supply live visual feedback, allowing the detection system to be better understood.

Together, these methods provide a robust multi-modal behaviour monitoring system that can enhance lie detection from simple physiological signals by adding fine-grained micro-expressions to the analysis process.

Key Improvements:

- Behavioral Features: Detects blinks and pupil dilation using OpenCV + Dlib (Python).
- Multimodal Sensors: Heart rate (MAX30105), temperature (LM35),Aluminium based GSR, and piezo sensor integrated via Arduino.
- Live Visualization: MATLAB provides animated real-time graphs for all sensor data.
- Smart Alerting**:** Blink rate and pupil changes are logged for cognitive load insights.
- Machine Learning Compatibility: System designed to support future classification via eye patterns or time-series data.
- Extended Interpretation: Graph-based interpretation allows deeper insight beyond fixed thresholds.

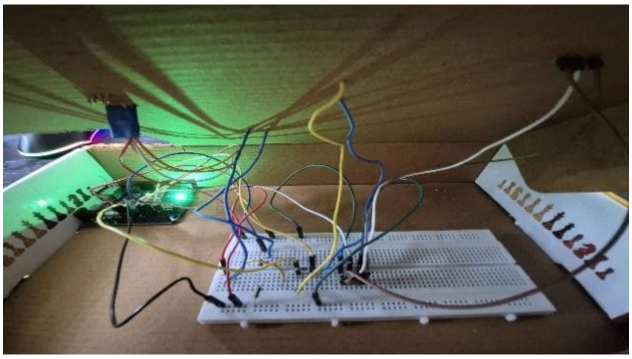
3) Discussion on Limitations

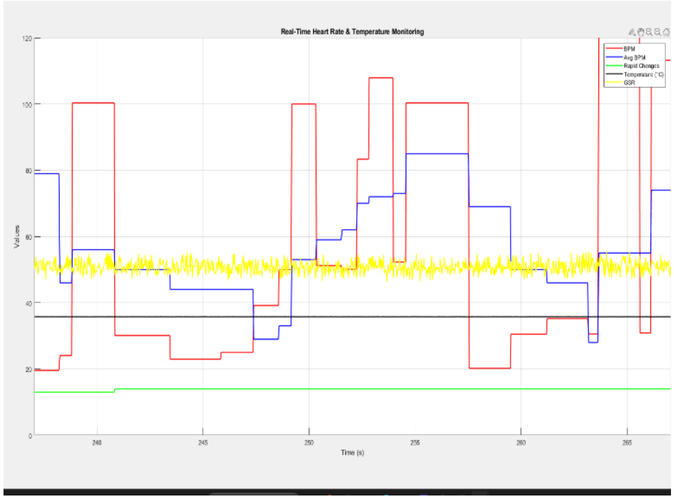
Traditional System**:**

- Rigid threshold-based decision-making.
- No behavioral metric inclusion.
- Limited visualization and adaptability.

ML based System:

- Higher computational requirement.
- Eye tracking needs proper lighting and stable input.
- Requires calibration and baseline data for accurate classification (ML training phase)





Conclusion

This project constructed a lie detection system using physiological sensors (piezoelectric sensors, heart rate, temperature, and GSR) using an Arduino. The system was able to detect physiological reactions to stress and deception and had the potential to detect lies using heart rate, skin conductivity, and body temperature. False positives because of anxiety, however, require more precise analysis.

AI would additionally enhance the system by using machine learning algorithms to better interpret data from sensors. Large data set model training would allow the system to learn how to detect variation between individuals, minimize false positives, and make overall truth versus deception classification stronger. Future research can be targeted towards using AI for real-time feedback and learning continuously, which could make the system more resilient and accurate across different situations.

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