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Integrated Image Processing and Gas Sensing for Enhanced Hazard Detection

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Abstract
In industrial and public safety applications, the timely detection of hazardous environments is crucial for preventing accidents and ensuring the well-being of individuals. This paper presents an innovative approach to hazardous environment detection leveraging advanced image processing techniques. The methodology involves the use of advanced image processing algorithms to extract relevant features from visual data captured through cameras or sensors. Simultaneously, gas sensors are deployed to monitor the chemical composition of the environment, particularly focusing on gases indicative of potential hazards. The combination of visual and gas sensor data enables a more comprehensive analysis, improving the system's ability to detect and classify hazardous conditions accurately.

Keywords: Image processing, Gas sensors, multi-sensor integration, Safety monitoring.

1. Introduction

Today's business and public safety situations require new solutions to quickly and accurately detect potential hazards. Events such as gas pollution, chemical leaks and uncontrollable fires pose serious risks to human life and infrastructure, and advanced technology is required to reduce this risk. The purpose of this article is to raise awareness about environmental safety and increase the effectiveness and accuracy of hazard identification using image processing tools and gas sensors. Traditional hazard detection methods often rely on single methods such as smoke detectors or visual inspection methods. However, this approach may not provide a full understanding of the complexity of hazardous situations. This research aims to fill this gap by integrating data visualization and technology into an integrated process, providing multiple pathways to provide greater information and accurate representation of the environment. Image processing holds great promise for extracting useful information from data captured by cameras or sensors. Using image segmentation, object recognition and anomaly detection, the system can analyze the situation and detect unusual patterns that indicate danger. This visual information is then supported by gas sensors that monitor the chemical composition of the environment, especially those associated with various hazardous situations.

2. Literature Review

- Prof. Vijaya Nilesh Kamble in [1] discusses about the presented paper introduces a computer vision-based system for the simultaneous detection of fire and smoke using conventional cameras, aiming to enhance the limitations of traditional heat-sensing fire detectors. By leveraging image processing techniques, the proposed system operates on video input and employs colour models such as RGB, YCbCr, and HSV for effective fire and smoke pixel identification. The key features include a reduction in false alarms, monitoring capabilities for large open areas, simultaneous fire and smoke detection through gray cycle pixel identification, and scalability options. The RGB, YCbCr, and HSV colour models are employed to differentiate pixels and determine fire and smoke regions. The method is highlighted for its potential in real-time fire detection, reducing false alarms, and providing a robust system for surveillance. Future developments could include the integration of artificial intelligence algorithms for noise reduction and self-learning capabilities, enhancing system efficiency and adaptability to varying smoke characteristics.

- V.Ramyaet al. in [2] discusses about the project focused on enhancing safety through the implementation of a microcontroller-based toxic gas detection and alerting system. The system utilizes gas sensors, specifically MQ-2 for combustible gases and MQ-6 for LPG, connected to a PIC16F877 microcontroller. When gas levels exceed predefined thresholds, an alarm is triggered, and an alert message is sent via GSM to an authorized user. The proposed system aims to address the shortcomings of existing gas detection systems by providing a portable, affordable, and real-time solution suitable for both industrial and residential settings. The abstract also references related work on intelligent security systems, remote monitoring, and gas sensors. The importance of air quality monitoring, particularly in the context of increasing pollution, is highlighted. Overall, the abstract outlines a practical approach to mitigating the risks associated with hazardous gas exposure.
- Hasan Demireland et al. in [3] discusses about the novel models for fire and smoke detection using image processing, introducing improvements to a previous fire detection model through the incorporation of fuzzy logic and proposing a new model for smoke detection. The fire detection model utilizes the YCbCr colour space, employing fuzzy logic to enhance discrimination between fire and fire-like coloured objects, achieving a 99.00% correct detection rate with a 4.50% false alarm rate. Smoke detection relies on an RGB colour space model considering intensity and saturation characteristics, with additional motion detection to reduce false positives. Comparative analysis demonstrates the superior performance of the proposed models, providing potential applications as pre-processing stages for fire and smoke detection systems. The conclusion emphasizes the efficacy of the models, while suggesting future work in region-based fire and smoke recognition. The literature survey is expected to cover related works, key contributors, methodological comparisons, and recent trends in fire and smoke detection through image processing.
- Mobasshir Mahbub in [4] discusses about the design and implementation of a gas detection and measurement system using MQ2 gas sensor, nRF24L01P Wireless Transceiver Module, and Arduino as a microcontroller. The system is designed to detect and measure toxic gases in environments such as homes and industrial areas, providing a wireless monitoring solution. The paper covers the system architecture, design, and working principles, detailing the components used in both the detection/transmitting unit and the receiver/monitoring unit. It also describes the gas measurement approaches, including the analysis of the MQ2 gas sensor graph and the calculation of gas concentrations in parts per million (PPM) and percentage. The results and discussions section provides examples of gas measurements under various conditions, such as steady room atmosphere, burning of a match, burning of a match with smoke, and gas pressure variations near a gas stove.

3. Methodology

A. Components used:

1. Arduino UNO

Arduino Uno is a popular open-source microcontroller board with 6 analog input pins and 14 digital I/O pins. It has 32 KB flash memory and runs at a clock speed of 16 MHz

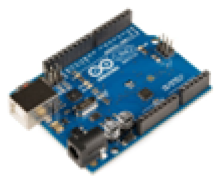


Fig 1- Arduino UNO

2. 16x2 LCD

Commonly used alphanumeric display modules with 16 columns and 2 rows that can display 16 characters per row are called 16x2 LCDs (Liquid Crystal Displays).

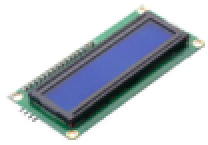


Fig 2- 16x2 LCD

3. MQ4 sensor

Among the MQ sensor series, the MQ4 sensor is one of the most often utilised. A MOS (Metal Oxide Semiconductor) sensor is what it is. It's employed to find LPG.

Fig 3- MQ4 sensor

4. MQ7

Another member of the MQ gas sensor family is the MQ7 gas sensor, which is a metal oxide semiconductor (MOS) type gas sensor. Its main purpose is to find carbon monoxide.

Fig 4- MQ7 sensor

5. DHT11 Sensor

The DHT11 is a famous temperature and humidity sensor with an 8-bit microprocessor to output the temperature and humidity measurements as serial information and a specialized NTC to discover temperature.

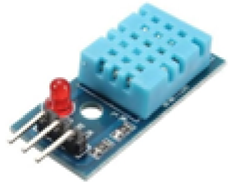


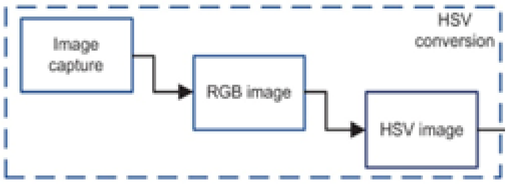
Fig 5- DHT11 sensor

B. Image Processing - HSV Model

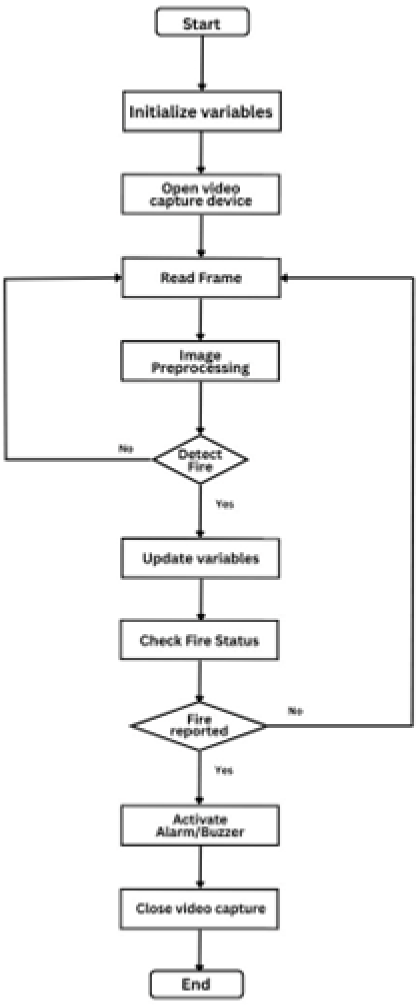
- Colours are described by the hue, saturation, and value (brightness) components of the HSV model.
- Hue: hue is a symbol for colour. Hue is represented in this model as an angle ranging from 0 to 360 degrees.
- Saturation: Saturation shows the colour space's range of grey. It has a range of 0% to 100%. A primary colour is present when the value 1, and grey is present when the value is 0. Lower saturation levels result in faded colours since they contain more grey tones.
- Value: - Value, which changes with colour saturation, is the color's brightness. It has a range of 0% to 100%. The colour space will be completely black when the value is 0. The value increases, brightening the colour space and displaying a range of hues.
- Human perception can distinguish the colours used in HSV quite well, although RGB does not always allow for this. The following formulas can be used to convert an RGB colour model to an HSV colour model:
  $V = \max(R, G, B)(4)$
  $S = 255 \times (V - \min(R, G, B)) / V(5)$
  $60\times(G-B)/ S\ V = R$
  $H= 180 + 60\times(B-R) / S\ V = G$
  $240 + 60\times(B-R) / S\ V = B$
- Core input data are RGB values that represent a pixel in an image. Using well-known formulas, the RGB data are transformed into HSL (Hue, Saturation, Lightness) values.
  Red (R) = 255 (red is supposed to have the maximum intensity).
  Green (G) = 100.
  Blue (B) = 20.
- Hue (H), Saturation (S), and Value (V) are the appropriate HSL values that are obtained by substituting these values into the conversion formulae.
- To compute value (V), the maximum RGB value must be found and scaled by four: Max(R, G, B) * 4 = max(255, 100, 20) * 4 = 255 * 4 = 1020 is the value of V.
- The difference between the maximum and minimum RGB values, normalized against the maximum RGB value, is used to calculate saturation (S): The formula for S is S = 255 * (V - min(R, G, B)) / V = 255 * (1020 - 20) / 1020 = 255 * 1000 / 1020 ≈ 249.02
- A complicated computation based on the relative proportions of the RGB components is required to determine hue (H):

S = 180 + 60 * (20 - 255) / 249.02 = 180 + 60 * (-235) / 249.02 ≈ 95.95 H = 180 + 60 * (B - R) / S

- These computed HSL values—H = 95.95, S ≈ 249.02, and V ≈ 1020—act as numerical indicators of the colour characteristics of the pixel in question.



Flowchart 1- HSV conversion



Flowchart 2- image processing flow

C. Gas Detection

- The system is intended to monitor the surrounding environment by gathering and presenting data on temperature, humidity, and gas concentrations. The laptop acts as an interface for more sophisticated control and data analysis.

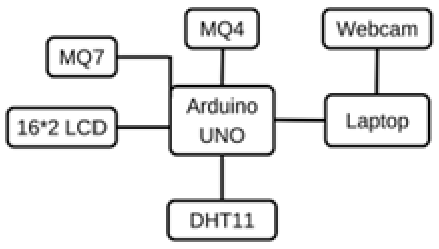


Fig 9- Block diagram

- If the value detected by the sensor is more than mentioned in the table, the buzzer will turn on and give alarm. Given below are the range values of each sensor and the type of gas they detect.

Sensor type	Detection gas
MQ4	Methane, CNG gas 300 -10,000 ppm
MQ7	LPG, butane gas 300-10,000 ppm
DHT11	Humidity (-20 – 60 degree C)

Table 1- type of sensor and the gas they detect

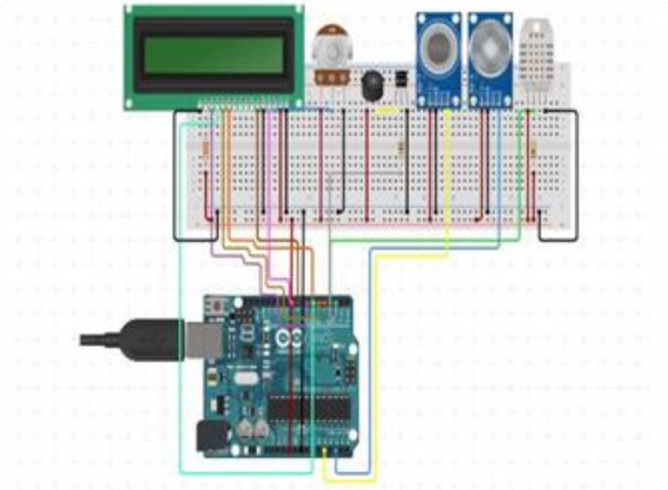


Fig 8- circuit diagram

4. Results

- The performance metrics for the fire detection system are as follows:

Accuracy	91.9%
Precision	90.2%
Recall	93.2%

F1 Score	91.7%
Average Response Time	1.08 seconds

- This project successfully detects fire using image processing and detects gas using sensors (MQ4, MQ7, DHT11), here are some images of the result obtained.

Fig 10- result 1

Fig 11- result 2

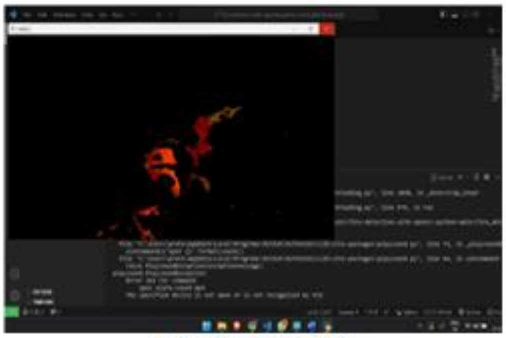


Fig 12- result 3

5. Conclusion

In conclusion, the integration of image processing and gas sensors for hazardous environment detection stands at the forefront of safety technology. The system's ability to fuse visual and chemical data enables a comprehensive understanding of potential hazards, making it adaptable to diverse environments.

6. Future Enhancements

- Integration with IoT platforms can enable real-time data sharing, remote monitoring, and centralized control, enhancing the scalability and connectivity of hazardous environment detection systems.
- Incorporate Bluetooth or Wi-Fi modules (such as the ESP8266 and HC-05) to facilitate remote control and monitoring.
- For machine learning applications and long-term data patterns, use cloud-based data analysis and storage.
- Create automated reactions that, when sensor thresholds are surpassed, can activate ventilation systems, set off alarms, or send out SMS or email warnings.

7. References

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