

Autonomous Gas Detection Robot for Industrial Environment and Disaster Response

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Abstract – Industrial gas accidents take place when early detection doesn't take place, leading to a disaster. These kinds of accidents expose the rescue team to toxic gases and limited visibility. This paper presents an autonomous gas detection rover specifically designed for industrial environments and disaster response operations. Our proposed system integrates embedded systems, machine learning models, robotics, and edge computing to operate efficiently in hazardous environments. A Raspberry Pi is used to process inexpensive gas sensors as they sense smoke, carbon monoxide and other poisonous gases, temperature, and humidity sensors in real time this rover. Furthermore, it is equipped with ultrasonic sensors that allow it to detect obstacles. It also has a camera module with machine learning capability. This camera is capable of detecting humans who are present on the device. This rover is flexible and can be operated either autonomously or by remote control. If the gas concentration exceeds the pre-set safety limits, the alarm system will trigger alert messages to the mobile IoT platform. It also sends live video and environmental information.

Keywords – Disaster Response Robotics, Gas Detection, Autonomous Rover, Industrial Safety, Edge AI

I. INTRODUCTION

Heavy rains inundate the town as well as the city streets where we reside. Also, this brings about a dilemma. Floods caused by heavy rains or other reasons complicate the situation further. The floods can also be the cause of an earthquake or a similar occurrence. Moreover, if

there is excessive rainfall over the span of time, any area will get flooded. Heavy rains later create a dirty situation in the regions.

Earlier, in great extent, they relied heavily on manual inspections for monitoring such situations. Additionally, manual inspections also increase the possibility of human exposure to such situations. This also restricts the ability to identify the risk at an increased speed. According to the current scenario, one can see the increasing demand for intelligent robotic system that can monitor the ongoing changes in the environment. Additionally, they must have the capability to assist rescue teams in dangerous regions.

Gradual improvements in robotics, embedded systems, and artificial intelligence have enabled a few interesting things to happen. We now have self-carrying equipment able to function in environments that are nasty with low or zero human involvement. In effect, these mobile robotic systems are outfitted with an assortment of devices such as gas sensors, cameras, wireless communication devices, etc. These systems allow for ongoing monitoring, can detect risky situations in a fast timeframe, and share awareness of the situation in real time. Most importantly, these applications are useful in disaster response applications.

This paper proposes an AI-enabled autonomous gas detection rover designed for industrial safety monitoring and disaster response applications. The system integrates multi-sensor data acquisition, embedded processing on a Raspberry Pi, autonomous navigation, and IoT-based communication to detect hazardous gases and support remote monitoring. The proposed platform aims to reduce human exposure to dangerous environments while enhancing rescue efficiency and environmental hazard detection.

II. LITERATURE REVIEW

Jiho Chang et al. [1] proposed a flexible and scalable system for industrial monitoring using Boston Dynamics' SPOT robot. The system allows operators to modify or create scripts for specialized tasks like anomaly detection and real time surveillance, integrating AI-driven data processing for analyzing multimodal sensor data. This approach enhances operational safety and efficiency by enabling dynamic adaptation of the robot's behavior and early detection of abnormalities. The research highlights the system's robustness through extensive field testing, bridging the gap between commercial robots and specialized industrial applications.

Pavith Ashwin G K et al. [2] introduced "MineGuard," a manually controlled surveillance robot designed to enhance mine safety through real-time video monitoring and methane gas detection. Equipped with an ESP32-CAM module and an MQ-4 gas sensor, the robot can navigate rugged terrain, detect hazards, and provide continuous surveillance via Wi Fi. This system aims to reduce human exposure to dangerous underground conditions and offers a proactive approach to monitoring environmental conditions in mines.

Kunto Aji Wibisono et al. [3] developed a mobile robot equipped with a thermal camera and the YoloV5 algorithm to detect gas leakage sources. This system addresses the challenge of gas dispersion by using thermal imaging to identify gas leaks, with YoloV5 performing real-time object detection based on thermal characteristics. The mobile robot achieved a 91.25% success rate in accurately locating gas leak sources, demonstrating its potential to improve efficiency and safety in hazardous environments by minimizing human intervention.

Victor Hernandez Bennetts et al. [4] introduced "Gasbot," a mobile robotic platform for methane leak detection and emission monitoring in landfills and biogas production sites. This platform utilizes a Tunable Laser Absorption Spectroscopy (TDLAS) sensor and a novel gas distribution algorithm to generate methane concentration maps. The research demonstrates Gasbot's effectiveness in both indoor and outdoor scenarios, highlighting its ability to automate measurements and provide valuable gas distribution maps for identifying high methane concentration areas.

Dani Martinez et al. [5] presented an autonomous mobile robot for gas leak detection in indoor environments, focusing on localizing toxic gas leak sources. The robot employs a SLAM method with a LIDAR sensor for auto-localization and mapping, and a photoionization detector to measure gas concentrations. The study demonstrates the robot's ability to autonomously explore areas and estimate gas leak locations with high accuracy, even detecting unexpected gas sources, thus automating human-risky operations.

M. A. Abu Bakar et al. [6] designed a prototype mobile robot system for the early detection of explosive and flammable gas leaks in confined spaces. This system aims to replace human workers in hazardous environments by using MQ-2, MQ-4, and MQ-5 gas sensors to detect smoke, methane, and LPG, respectively. The robot can be maneuvered via a mobile phone, sending real-time gas readings

wirelessly to a PC and activating an alarm when safety limits are exceeded, thereby improving worker safety.

III. PROPOSED SYSTEM

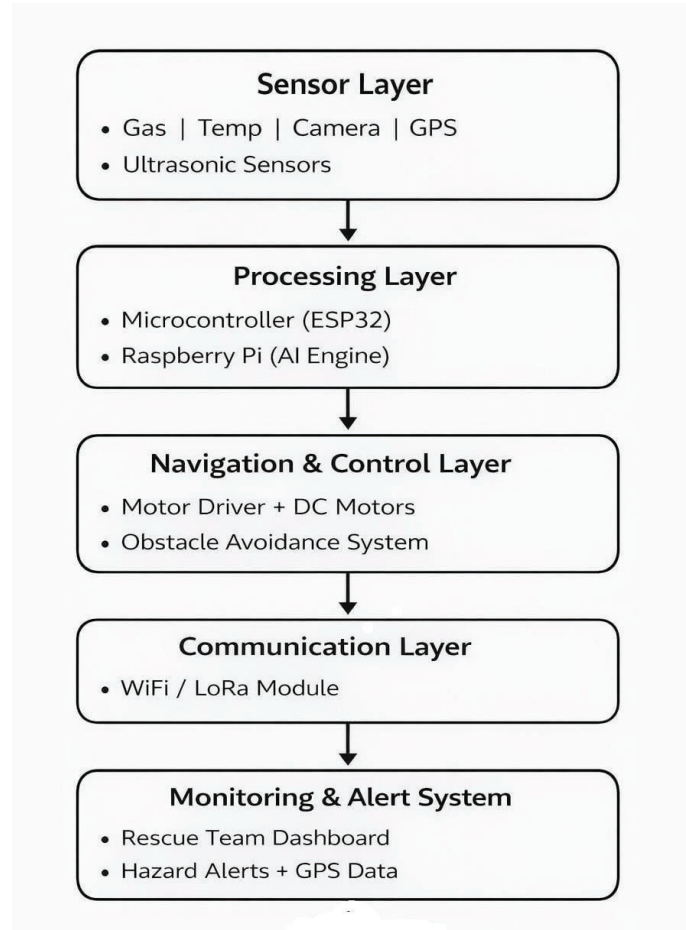


Fig 1. Proposed System

Fig. 1 illustrates the proposed architecture of the autonomous gas detection rover designed for industrial safety and disaster response applications. The system is organized into multiple functional layers to enable efficient sensing, processing, navigation, and communication. The sensing layer has gas sensors, temperature sensors, ultrasonic sensors, a camera module, and a GPS unit. The processing is carried out through the processing layer as the sensor data is received and sent to a microcontroller like ESP32, to control sensors and motors.

Raspberry Pi has been used in the proposed system because it is used for processing higher-level data and using AI to analyze the situation and locate people. The control layer comprises components like motor drivers and DC motors, which help control the movement of the rover and its locomotion. The communication layer uses wireless technology such as Wi-Fi or LoRa and is used to send real-time information about the environment to the user's dashboard.

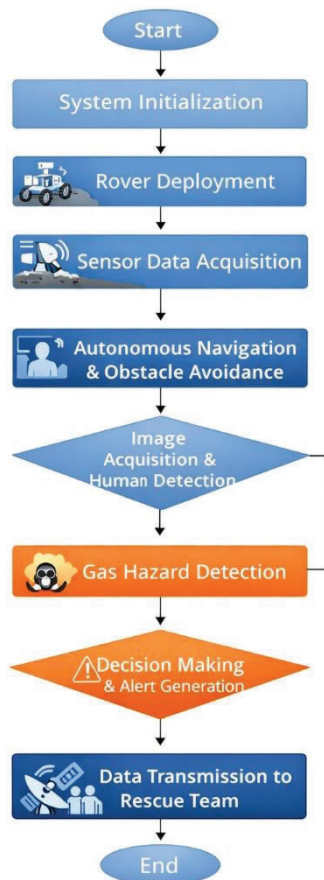


Fig 2. Flowchart for Rover

Fig. 2 illustrates the operational workflow of the proposed autonomous gas detection rover designed for industrial monitoring and disaster response scenarios. System initialization is the first step of the process, where the control sensors on the rover are turned on along with its communication models. The next stage is environmental sensing, where the information will be collected by the gas sensors, temperature sensors and other mounted components. Using the data from these components, the rover uses ultrasonic sensors to navigate through obstacles and any type of terrain.

Simultaneously, the mounted camera module in the rover takes pictures for AI-based human detection, which helps with finding people in the disaster regions without human intervention for the rescue missions.

IV. HARDWARE REQUIREMENTS

Hardware parts used to build the rover:

Raspberry Pi and Raspberry Pi Camera Module: Raspberry Pi 4 is the main processing unit for the proposed system, as it can drive tasks

such as sensor processing, communication, and computer vision simultaneously. It is attached to the Raspberry Pi camera module, which helps to get pictures and videos of the environment in real time without any delay. The captured visual data is processed to buy the rover component for applications such as observing and monitoring the environment, locating humans in disaster and industrial scenarios. This helps the remote user to get visual feedback remotely and understand the disaster situation without having to go to the actual disaster zone.

ESP32: The low-power microcontroller ESP32 has been used for the proposed system as it has a built-in Wi-Fi and Bluetooth, making it great for talking to sensors and processing and controlling things in real time without any delay. This microcontroller gathers data from the environment and sensors, and the driver motors and interfaces the same with temperature, gas, and ultrasonic sensors to understand its environment and surroundings. This data is forwarded to the primary processing unit for further interpretation. ESP 32 also facilitates communication and interaction between the sensors and navigation system of the rover to ensure smooth working.

MQ-2 Gas Sensor, MQ-7 Gas Sensor, MQ-135 Gas Sensor, DHT22 Temperature and Humidity Sensor, Flame Sensor: The rover consists of a multisensor gas reduction module, such as the MQ2 gas sensor, the MQ7 gas sensor, and the MQ135 gas sensor, all of which monitor various toxic gases commonly detected in industrial environments that can cause disasters. The MQ-2 sensor is used to detect smoke and flammable gases like LPG and methane, and on the other hand, the MQ7 sensor is useful for detecting carbon monoxide in the environment. The MQ-135 sensor detects the air quality and measures gases such as ammonia, benzene, and other harmful gases present in the environment. The temperature and humidity of the environment will be monitored using the DHT 22 sensor, and a flame sensor module is integrated to take care of the environment for potential fire hazards. All of these modules are integrated and optimised to work together so the rover can monitor the environment in real time without any delay.

HC-SR04: The sensor used to determine distance and avoid obstacles is the HC-SR04 ultrasonic sensor. It emits ultrasonic sound waves and measures how long it takes for the echo to return after hitting the objects in its surroundings. The proposed system also uses the same type of ultrasonic sensors and process to detect obstacles in its environment during motion by assessing the distance to everything around it in real time. The rover avoids crashing into things and navigates safely across all terrains, even in the disaster area.

4WD Rover Chassis: The framework of this robotic platform is derived from the four-wheel-drive (4WD) rover chassis. It provides a mounting point for electronic components such as sensors, controllers, motors, and power systems. All this work is to prepare the chassis to operate on rough and uneven terrain, such as that found at an industrial site or disaster zone. That four-wheel-drive configuration is better able to provide stability and traction, allowing the rover to be mobile over debris, uneven ground, and through cramped quarters. The chassis also allows for sensors and cameras to be positioned in different places for optimal environmental coverage. This ensures that monitoring and

navigation are constantly accurate through hazard detection and rescue operations.

DC Motors: DC motors are the core component that enables the rover to move, are responsible for driving the wheels of the rover. The motor alters electric energy from the battery to mechanical energy to move the robot forward/backward and make different steer adjustments. The proposed system enables motor-driving modules and connections made between the microcontroller to control the motors. You can precisely control both the speed and the direction of the motor with the setup. A rover can move with ease on account of the addition of more than one DC motors in a 4wd chassis. The rover can navigate rough terrain because of it. The rover's ability to move is essential for successful areal navigation hazardous environment as used in industrial inspection and disaster response operations.

LoRa SX1278 Module: The LoRa SX1278 module is a wireless communication device that can send and receive data over long distances. It uses Low Power Wide-Area Network (LPWAN) technology. It is made for long-distance communication with low power, so it can be used in places where regular wireless networks might not work. In the suggested system, the LoRa module lets the rover send environmental data, hazard alerts, and location information to a remote monitoring station. This makes sure that communication stays open even in big factories or disaster areas where the network infrastructure might be broken. LoRa technology makes the system more reliable and helps with real-time monitoring and decision-making.

Li-Ion Batteries: The autonomous gas detection rover uses lithium-ion battery systems to operate mostly on battery energy. Due to their high energy density, low weight, and long life, they are widely used in portable electronic devices. The proposed system's Raspberry Pi, battery pack, microcontroller, sensors, communication modules, and motor driver all get their power from the battery pack. In order for long-term monitoring or rescue operations to take place, an uninterrupted power supply is required to keep the system running. Because there is no power supply in the remote areas, the rover uses rechargeable Li-ion batteries.

V. SOFTWARE REQUIREMENTS

Raspberry Pi OS: Raspberry Pi OS is a Linux-based operating system for Raspberry Pi devices. This operating system gives apps a stable place to run and lets the user manage hardware resources. It also lets the user connect to the peripherals. It supports tasks like gathering data from sensors, running cameras, and communicating. Apart from that, it also allows the user to run computer vision algorithms and ML models that are needed for finding people and keeping an eye on the environment. The hardware and software integration in this operating system is great, which ensures that the system runs smoothly and efficiently.

Python and C++: Python and C++ have been used in the proposed system for high-level tasks on microcontrollers like the Raspberry Pi. These languages have been chosen considering the library support it

has, making them good for development with software frameworks. The languages used ensure the simultaneous working of the sensing, processing, and control layers of the rover.

OpenCV + TensorFlow Lite: OpenCV is a computer vision library. It has been used in the proposed system, considering its flexible process of image capturing, processing, and finding objects. Along with the computer vision, AI features have also been integrated into the system using OpenCV and TensorFlow, making the process easier and more sophisticated. TensorFlow Lite is a lightweight machine learning framework. The proposed system has been trained using these lightweight ML models, so people can be identified and rescued during a disaster.

Arduino IDE + Visual Studio Code: Arduino IDE and Visual Studio Code have been used in the proposed system to write and manage the system software. The Arduino IDE is used to write and upload firmware to the ESP32 microcontroller, which helps in getting data from sensors and controlling motors. On the other hand, Visual Studio Code is a flexible development platform that runs Python scripts, organizes project files, and fixes bugs in apps.

VI. EXPECTED PERFORMANCE & APPLICATIONS

The application of our proposed system is the sustainable Information and Communication Technology (ICT) for integrated long-range communication and data processing. As our gas rover is proposed to enhance industrial safety, our system should be simple yet sophisticated enough to accomplish that. Through the use of various environmental sensing components and data processing techniques, our system will ensure that the expected performance is met.

The toxic gases, whose leakage can lead to industrial disasters, will be detected by our rover, which consists of multiple sensors working together simultaneously for efficient detection of any abnormalities in the environmental gas composition in industries. The MQ2 gas sensor, the MQ7 gas sensor, and the MQ135 gas sensors have been used in the rover to accomplish the same.

Apart from the gas sensors, the DHT 22 sensor and the flame sensing module have also been integrated into the proposed system. This helps with the monitoring of the temperature and humidity of the industrial environment and alerts the users or admins when abnormal temperatures are detected in the region avoiding fire accidents in industrial regions.

The proposed system has been designed to make people more aware of what's happening around them and to alert them before disasters can take place in the industrial regions where the rover is used. This initiative is believed to save lives and avoid property loss. During disasters, the rover also locates people who are trapped and in need of help by using A form of ML computer vision algorithms is employed by the system. This way, the proposed system plays a huge role in saving lives and disaster management.

VII. CONCLU

This paper details the design and conceptual evolution of an autonomous gas detection rover aimed at industrial safety monitoring and disaster response scenarios. The suggested system combines several environmental sensing technologies, such as the MQ-2 Gas Sensor, MQ-7 Gas Sensor, MQ-135 Gas Sensor, and DHT22 Temperature and Humidity Sensor. It also has a flame detection module to allow for full monitoring of dangerous situations. The system can find toxic gas leaks, strange weather conditions, and possible fire hazards in real time by combining multi-gas detection with environmental sensing.

The rover platform is made to work in dangerous places where it might not be safe or possible for people to go. By combining computer vision and machine learning, the system can find people in disaster areas, which helps rescue teams find people who are trapped more quickly. Also, wireless communication and the ability to monitor from a distance keep you aware of what's going on at all times and let you respond quickly in an emergency.

The proposed architecture shows how combining embedded systems, robotics, and AI could make industrial safety and disaster management better. The system can make industrial operations safer and emergency response plans more effective by lowering the risk of people being exposed to toxic environments and making it easier to find hazards early on. The next steps will be to work on prototypes, put the system together, and test how it works in the real world.

VIII. REFE

[1] Ji o Chang and Jeongho Park, "Design of a Robot System for Surveillance and Anomaly Detection in Industrial Environments", in *Electronics and Telecommunications Research Institute*, Deajeon, Republic of Korea.

[2] Pavith Ashwin G K, Manikandan M, Hari Hara Ramasamy A, Praveen Raj P, and Kumar K, "Mine Guard: Manually Controlled Surveillance Robot with Gas Detection for Mine Safety", in *Proceedings of the Fourth International Conference on Ubiquitous Computing and Intelligent Information Systems (ICUIS-2024)*, IEEE Xplore Part Number: CFP24UG3-ART; ISBN: 979-8-3315-2963-5.

[3] Kunto Aji Wibisono, Dava Aulia, Muhammad Rivai, Djoko Purwanto, and Sheva Aulia, "Mobile Robot Equipped with Thermal Camera and YoloV5 to Detect Gas Leakage Source", in *Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember*, Surabaya, Indonesia.

[4] Victor Hernandez Bennetts, Achim J. Lilienthal, Ali Abdul Khaliq, Víctor Pomareda Sesé, and Marco Trincavelli, "Gasbot: A mobile robotic platform for methane leak detection and emission monitoring", in *AASS Research Centre, Örebro University*, Örebro, Sweden.

[5] D ni Martinez, Javier Moreno, Marcel Tresanchez, Mercè Teixidó, Davinia Font, Antonio Pardo, Santiago Marco, and Jordi Palacin,

"Experimental application of an autonomous mobile robot for gas leak detection in indoor environments", in *Department of Computer Science and Industrial Engineering, University of Lleida*, Spain.

[6] M A Abu Bakar, M R Manan, R M Kawi, and L J Yunn, "System Design for Early Detection of Explosive and Flammable Gas Leaks Using Mobile Robot in Confined Space", in *J. Phys.: Conf. Ser.* 2107 012028, 2021