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Gas Leak Detection And Monitoring Drone

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Abstract: Gas leaks pose significant risks in industrial, residential, and natural gas pipeline sectors, leading to injuries, property damage, and even loss of life. Addressing these challenges requires robust monitoring systems that can detect and respond to gas leaks in a timely and effective manner. This research paper presents the development of a gas monitoring and detection system that integrates an unmanned aerial vehicle (UAV) with an array of MQ series gas sensors. The proposed system leverages the accessibility and continuous monitoring capabilities of a drone platform to address the limitations of fixed instrumentation. The integration of the gas sensing system with the UAV allows for autonomous, wide-area surveillance of volatile gases, minimizing the risks to human personnel. The system utilizes an Arduino Nano microcontroller, MQ series gas sensors, and an NRF24L01 transceiver module to acquire and transmit real-time gas concentration data to a ground station.

I. Introduction

Gas leaks are a major problem that pose serious risks to life in the industrial sector, residential areas, and other sectors such as Natural Gas pipelines, where the processing of gases is at an all-time high with the rise in gas powered vehicles. Catastrophic leakage of gases at various industries has resulted in injuries, loss of property and in some cases death [1][15]. In today's fast evolving industrial landscape its essential to not only have alert systems in place, but to also have continuous monitoring systems that can provide accurate historic readings of the surroundings. With rise in global warming gas emissions are coming under even closer environmental scrutiny

There are 2 types of leak detection systems, fixed and mobile. In the former, a sensor or an array of sensors are installed around the equipment handling the gases. They can be used to monitor and raise alarms in case of a disaster, but it is not enough to just have fixed sensors. In areas such as gas pipelines which are usually offshore a mobile sensing unit that can sweep a large area and continuously monitor the parameters becomes essential. Also, an aerial perspective can be of benefit to first responders who would want an overview of an incident be it a chemical spill, a gas leak or a warehouse fire spewing toxic gases into the atmosphere. There are also areas wherein it would be near impossible to send human beings to conduct a survey of the impact zone simply because of the risk of exposure as well as inhalation [2].

This is where mobile sensing units come in. The Gas monitoring and detection system proposed here makes use of an unmanned aerial vehicle, or simply a drone fitted with an array of sensors that can detect the concentration of volatile gases and relay them to the ground station in real time. For this prototype we are making use of the MQ series gas sensors which are metal-oxide based sensors that can measure concentration of gases based on the changes in the value of resistance of semiconductor material

The applications of this prototype are twofold we can achieve continuous monitoring of the airborne chemical compounds placed on a use-case specific drone and also, since the gas detection system is separate from the rest of the drone, we can add it to other pre-existing drones.

II. LITERATURE REVIEW

There have been major losses of life and property due to gas leak disasters. Most of the afflicted regions did not have appropriate systems in place to have ensured peoples safety [1].
Detecting and identifying volatile chemical concentrations and gas leaks is essential for environmental risk assessment. Employing Unmanned Aerial Vehicles (UAVs) to measure gas levels across different locations is highly advantageous due to their capacity for Simultaneous Localization And Mapping (SLAM), enabling comprehensive spatial analysis of volatile substances [3].
In recent years with the advancement of drone technology, they have been used in various scenarios, including but not limited to aerial mapping, agriculture and others. Drones have also been used for gas concentration mapping in areas wherein concern for the environment is a major talking point [4].
Periodic testing of critical areas in industrial sites which were previously being done by a single person with multiple detectors or a group of people, can be done using an autonomous drone with a suite of onboard sensors continuously relaying data.
Many gases are lighter than air, because of which within an indoor environment, the gas will rise towards the ceiling. A ground-based system might not get the most accurate of results, but a drone can cover multiple areas while maintaining 360-degree awareness of its surroundings. A tool that can easily navigate in and around dangerous or otherwise inaccessible places under the context of inspections and monitoring, is always one of the main benefits of any aerial solution.
The EPA estimates that power plants in the United States alone release nearly one billion m^3 of methane, without considering any other gases emitted.
Most of these losses (around 80%) seem to come from leaky compressors, valves, seals, and connectors [5]. Each year, refineries typically investigate approximately 800,000 to 900,000 leaks. Among these, roughly 200 to 300 incidents directly lead to fatalities, injuries, equipment damage, or operational setbacks. [7].
With respect to areas that emit volatile gases and need continuous monitoring of the same, for example, landfills, oil and gas plants etc need continuous monitoring of gases such as methane. Drone based monitoring improves safety of the operators in these situations with added precision and automation of the process [8].
There are already a few gas detection systems already out there namely, chemo optical sensors [9], chemo resistive sensors [10], Electrochemical sensors, metal oxide sensors [11]. Metal oxide sensors are used in this prototype.
The MQ series sensors are all metal oxide semiconductor sensors. They can be of P type or N type and the change in resistance due to the presence of a reducing or an oxidizing gas depends on the type and the majority charge carrier of the sensor [13].

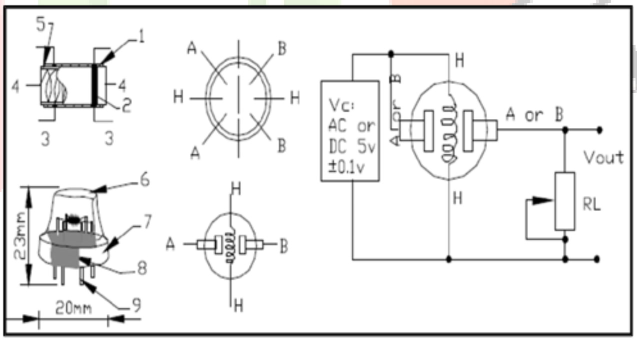

Fig 1. Diagram of MQ 7 Sensor

III. PROPOSED SYSTEM

(A) UAV

A drone with the capability of lifting 1 kilograms of load was developed for this application. The DJI 920KV propellors combined with the 9443 propellors together are capable of producing 2 kilograms of total thrust. The motors were paired with a 30A Electronic Speed Controller (ESC). The 3300 mAH battery provided flight for 18-20 minutes. The DJI F450 quadcopter frame was chosen for its light weight and the accompanying landing gear. In total the drone without the payload weighed close to 900 grams with a total thrust capacity of 2 kilograms. With the Pixhawk flight controller onboard coupled with the GPS module and telemetry kit, it is possible to achieve autonomous flight. This can be done using the Mission Planner software, in which we can set waypoints we need the drone to fly to and back from. This can allow us to continuously monitor a given area with no human intervention required to fly the UAV.

(B) Flight Path

Currently there are multiple route planning schemes that have been researched and implemented, proving their viability. Various routes can suit different terrain and flight objectives. While basic horizontal and vertical line setups are simple, they may lack coverage and overlap, impacting data quality. Diagonal layouts are sometimes vital for irregular areas or intricate terrain. Refinement of crisscross patterns, building on initial layouts, enhances both efficiency and accuracy by ensuring proper overlap. These patterns enable autonomous drone flights over designated areas. [14].

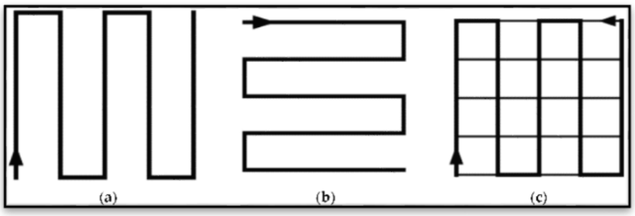

Fig 2. Flight Path Examples

(C) Gas Leak Detection System

The proposed system is based on combining an Arduino Nano, MQ series gas sensors for data acquisition and NRF24L01 transceiver module for sending over data to the ground station. The Arduino Nano is a breadboard friendly microcontroller board based on the ATMEGA 328 MCU, with 8 analog and 14 digital pins. For powering the board, we use a 5V DC power supply that is fixed on the drone.

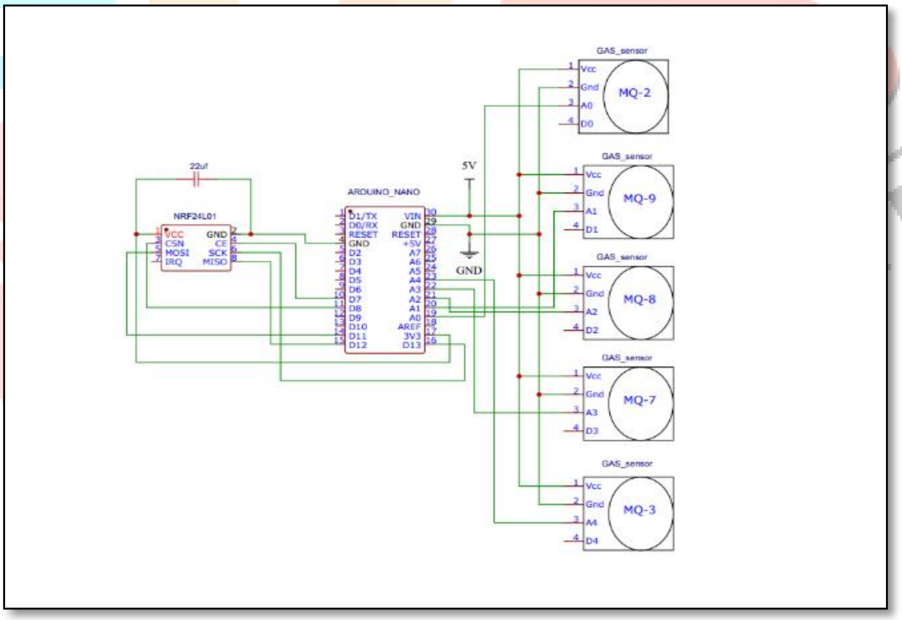

Fig 3. Transmitter Schematic

The NRF24L01 transmitter and receiver are used in conjunction with the Arduino Nano for sending data towards the ground station. It operates on the 2.4 GHz frequency band.

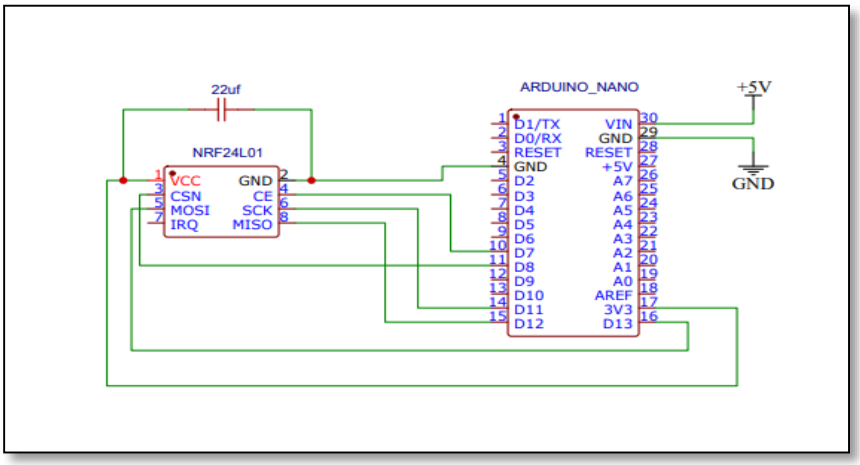

Fig 4. Receiver Schematic

We propose on using the MQ 2,5,7,8 and 9 sensors for this project. These sensors measure concentration of gases such as Methane, Natural Gas, LPG, Butane, Smoke in ppm[16].

The MQ series sensors are all metal oxide semiconductor sensors. They can be of P type or N type and the change in resistance due to the presence of a reducing or an oxidizing gas depends on the type and the majority charge carrier of the sensor [13]. The change in resistance is equivalent to the concentration of the gas. The sensor's analog output voltage (at the A0 pin) changes with the concentration of gases. The higher or lower the concentration the higher or lower the corresponding output voltage. The MQ series sensors can detect multiple gases but cannot identify them, therefore they are best suited for measuring changes in a known gas density continuously. The Gas sensors send data about gas density continuously to the Arduino Nano. The MCU along with the transmitter send data to the ground station Arduino which is connected to a central PC. The data received from the ground station system is plotted on a graph in real time and deployed to a website that can be accessed by the concerned authorities. They can use this data for continuously monitoring as well as a warning system for when there is a dangerous spike in gas density that could be harmful for people within the area.

With the system being combined with a drone we can not only autonomously run continuous sweeps of a specific area to be alerted of any danger that can be caused by irregular spikes in concentration of known gases.

We can use the UAV in disaster-stricken areas to monitor the impact zone by determining the spread area of the gas, set up a perimeter and take appropriate action, all with minimal risk to human life. In case of inaccessible areas, such as Gas Pipelines, or areas that are not safe for humans to be around, such as landfills, waste dumping sites, the UAV can be flown to monitor the concentration of dangerous gases continuously within the area without any human intervention, thus improving safety of people all around.

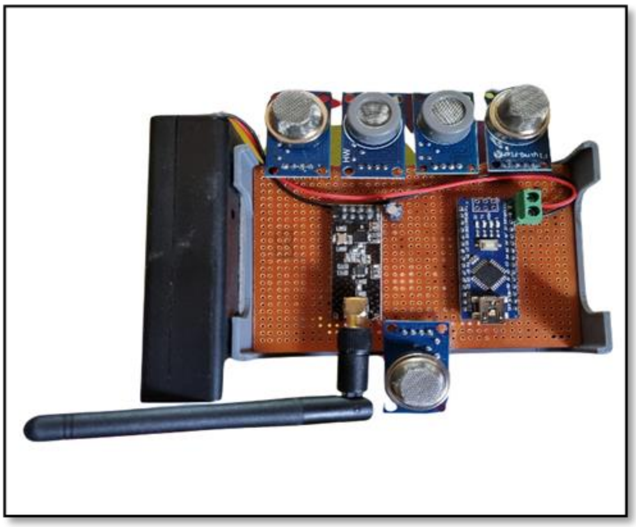

Fig 5. Transmitter Module

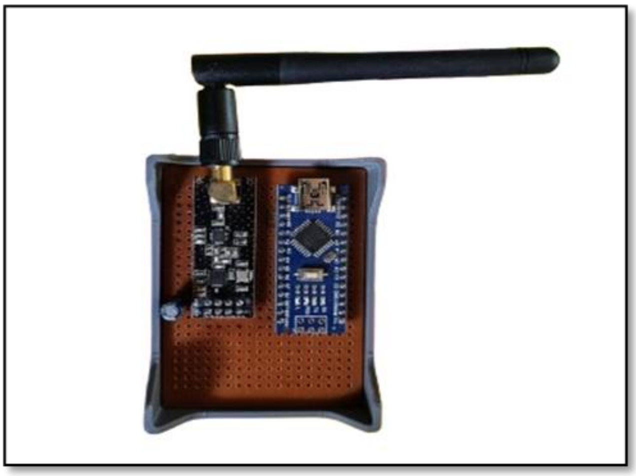

Fig 6. Receiver Module

IV. RESULTS

A quadcopter setup was used for this project. With an estimated flight time of 18 minutes and a payload of 250 grams this UAV can be used for detecting and monitoring the density of an array of gases within a region. The purpose of the experiments was to test the responsivity of the MQ series sensors. In the first graph, the results of concentration of gases in a base environment is illustrated, a house. The second graph shows the change in measurement of density of gases outside, particularly near a high density of vehicles. The third graph illustrated the changes in density when the embedded system is placed near a natural gas source.

These results confirm that while the embedded system is not capable of identification of gases, it is capable of detecting the change in density of a known gas within an area, to this reason we are currently looking at other sensors that can not only detect changes in quantity/density, but also identify volatile gases. With this system we achieved a total of 22 minutes of continuous gas sampling which is longer than the flight time of the UAV, this is because of the separate power source provided to the gas sensing system.

Fig 7. Quadcopter

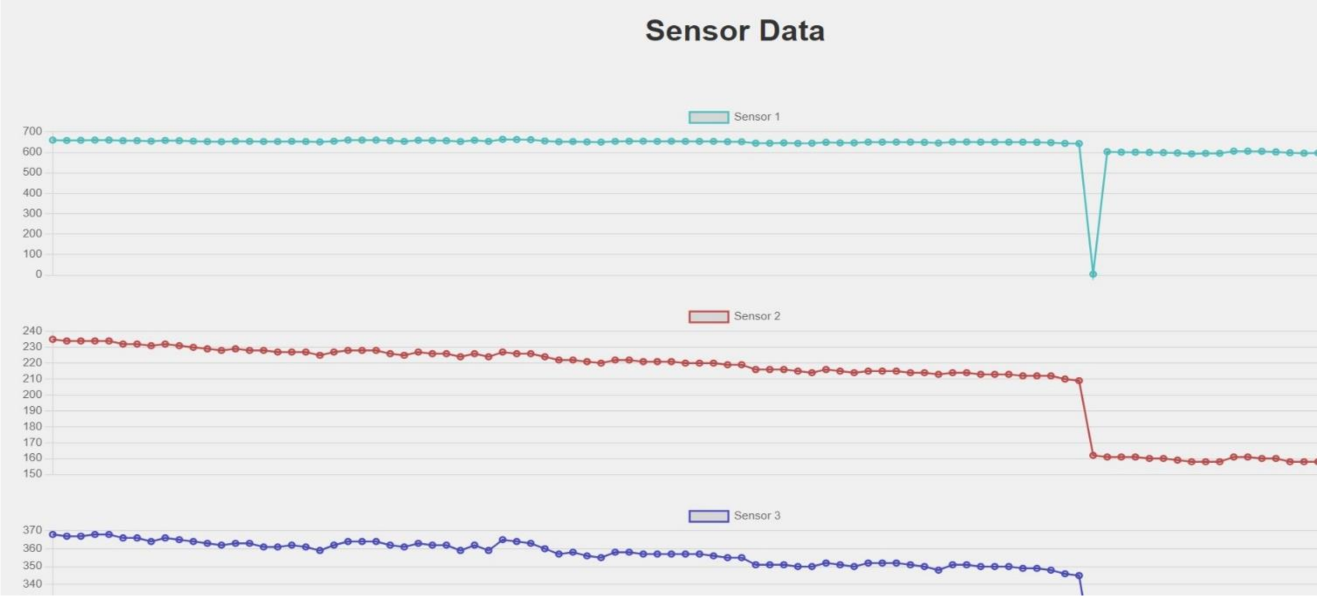

Fig 8. Website Layout

V. CONCLUSION

The proposed gas monitoring and detection system combining an unmanned aerial vehicle with an array of MQ series gas sensors demonstrates the potential for continuous autonomous monitoring of volatile gases in various environments. The integration of the gas sensing system with a drone platform offers several advantages, such as accessibility to hazardous or inaccessible areas, minimized risk to human personnel, and continuous monitoring capabilities. The autonomous flight capabilities further enhance the system's efficiency and potential for large-scale deployments.

However, there is room for improvement, particularly in the area of gas identification. Future work may involve incorporating additional sensors capable of identifying specific volatile gases, as well as exploring advanced data analysis techniques for more comprehensive gas monitoring and mapping.

Overall, the proposed system demonstrates the potential of combining unmanned aerial vehicles with gas sensing technologies for enhanced safety, environmental monitoring, and emergency response applications. As technology advances, such integrated solutions can play a crucial role in addressing the challenges posed by gas leaks and emissions, ultimately contributing to a safer and more sustainable industrial landscape.

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