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Full Length Article

Pollution Detection From Vehicle Exhaust

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Abstract
The rapid increase in the number of automobiles has significantly contributed to air pollution, primarily due to harmful gases emitted from vehicle exhaust systems. Although vehicle emissions cannot be completely eliminated, monitoring and controlling them can greatly reduce environmental impact. This project proposes the design and implementation of an Internet of Things (IoT)–based pollution detection system that monitors emissions from vehicle exhaust in real time.The system utilizes semiconductor gas sensors positioned near the exhaust outlet to detect the concentration of harmful gases such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), and hydrocarbons (HC). These sensors measure pollutant levels and transmit the data to a microcontroller-based monitoring unit. When the concentration of any gas exceeds a predefined threshold value, the system activates an alert mechanism such as a buzzer to warn the user about excessive emissions.High emission levels are often caused by incomplete combustion of fuel, which commonly occurs due to poor engine maintenance or inefficient combustion processes. Continuous monitoring of exhaust gases helps identify such issues early and encourages timely vehicle servicing. The proposed Emission Gas Detector (EGD) prototype evaluates pollutant concentrations in motorcycle exhaust and provides a real-time indication of emission levels, reflecting the operational condition of the vehicle.By implementing this IoT-based monitoring approach, the system enables effective detection of excessive exhaust emissions and promotes proactive maintenance practices. This contributes to reducing vehicular pollution and minimizing the risk of respiratory and environmental health problems associated with air contaminants.
Keywords
Vehicular Emissions, Internet of Things (IoT), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydrocarbons (HC), Emission Gas Detector, Air Pollution Monitoring.

Introduction
Air pollution has become one of the most critical environmental challenges in modern urban societies. A major contributor to deteriorating air quality is the increasing number of motor vehicles that release harmful gases through their exhaust systems. Rapid urbanization and economic growth have significantly increased vehicle ownership, particularly in developing countries such as India. As traffic density continues to rise, vehicular emissions have become a dominant source of air pollution in metropolitan areas. These emissions contain harmful pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), and carbon dioxide (CO_2), which pose serious risks to both human health and the environment. Prolonged exposure to these pollutants can lead to respiratory diseases, cardiovascular problems, and other health complications.To address this issue, governments and environmental agencies have implemented various regulatory measures including stricter emission standards, improved fuel quality, and enhanced traffic management strategies. Despite these initiatives, monitoring the emission levels of individual vehicles in real time remains a major challenge. Traditional emission testing methods are typically performed periodically at authorized inspection centers and may not reflect the actual emission conditions during regular vehicle operation. As a result, there is a need for a continuous monitoring system capable of detecting excessive emissions directly from vehicle exhaust systems.This project proposes an intelligent system titled “Pollution Detection from Vehicle Exhaust”, which aims to monitor and analyze harmful gases emitted from vehicles. The system is designed using gas sensors capable of detecting pollutants such as carbon monoxide, hydrocarbons, and nitrogen oxides. These sensors continuously monitor the emission levels and provide real-time feedback regarding the environmental impact of the vehicle. When the concentration of harmful gases exceeds predefined safety thresholds, the system generates an alert to inform the vehicle owner about potential emission problems. This early detection mechanism allows timely maintenance or repair of the vehicle, thereby preventing excessive pollution.The proposed system utilizes an Internet of Things (IoT)–based architecture that integrates gas sensors,

a microcontroller, and communication modules to monitor emissions effectively. By implementing such a system, the project aims to encourage responsible vehicle maintenance practices and reduce the release of harmful pollutants into the atmosphere.

Related Work

Air pollution in urban environments has been widely studied due to its severe impact on human health and ecological balance. Previous research has shown that vehicular emissions are among the primary contributors to air pollution in major cities. The rapid growth of transportation systems has increased fuel consumption and pollutant release, resulting in deteriorating air quality. To address these challenges, researchers have proposed several monitoring and detection systems designed to measure vehicle emissions and analyze environmental pollution levels.Earlier monitoring systems primarily focused on measuring average air quality levels using stationary sensors installed in specific locations. Although these systems provide valuable information about overall pollution levels in a region, they often fail to identify individual vehicles responsible for excessive emissions. Some approaches use smoke sensors or gas sensors placed near traffic zones to monitor emission levels in real time. In many implementations, microcontrollers such as PIC controllers were used to process sensor data and display emission statistics through Liquid Crystal Display (LCD) modules. However, these systems often involve complex programming structures and limited scalability.Recent developments in sensor technology and embedded systems have enabled the design of more efficient emission monitoring solutions. Gas sensors such as MQ135 and MQ9 are widely used for detecting pollutants including carbon dioxide, carbon monoxide, nitrogen dioxide, hydrocarbons, and volatile organic compounds. These sensors can provide real-time data regarding pollutant concentrations and help assess the environmental impact of vehicular emissions. By integrating these sensors with microcontroller platforms such as Arduino, researchers have developed cost-effective and flexible monitoring systems. Arduino-based platforms are particularly advantageous because they are open-source, easy to program, and compatible with a wide range of sensors and communication modules.The proposed system builds upon these existing technologies by integrating MQ135 gas sensors with an Arduino microcontroller to monitor emissions from vehicle exhaust. The sensor readings are continuously analyzed to determine whether pollutant levels exceed predefined threshold values. When abnormal emission levels are detected, a warning signal is generated using a buzzer and notification mechanisms such as GSM communication. This approach provides an efficient method for detecting harmful emissions and encouraging timely vehicle maintenance.Despite the advantages of sensor-based pollution monitoring systems, several limitations remain. Sensor accuracy may vary depending on environmental conditions, which can lead to measurement errors in some cases. Additionally, certain sensors may not detect all types of pollutants, resulting in incomplete emission analysis. Regular sensor calibration and maintenance are required to ensure accurate readings, which can increase operational costs. Furthermore, the detection range of sensors is limited, making it challenging to monitor emissions from vehicles located at greater distances. Addressing these challenges remains an important area of ongoing research in vehicular emission monitoring systems.

Requirement Analysis

Requirement analysis plays a crucial role in the development of any technological system as it defines the necessary functionalities and operational constraints required to achieve the intended objectives. In the proposed vehicle exhaust pollution detection system, requirements are categorized into functional and non-functional aspects to ensure efficient system performance and reliability.

Computational Resources

The successful implementation of the proposed pollution detection system requires appropriate hardware and software resources. The software component is developed using Embedded C programming language, which provides efficient control over the microcontroller and sensor operations. The system also utilizes supporting libraries such as LiquidCrystal_I2C to enable communication with the LCD display module.On the hardware side, the system is built using an Arduino UNO microcontroller, which acts as the central processing unit responsible for data acquisition and processing. An MQ135 gas sensor is used to detect harmful gases emitted from the vehicle exhaust. A Liquid Crystal Display (LCD) module is included to display real-time emission readings to the user. Jumper cables are used to establish connections between hardware components. A piezo buzzer serves as an alert mechanism when gas concentrations exceed the threshold limits. Additionally, a GSM module is incorporated to enable SMS-based notifications for remote monitoring and alert transmission.

System Design

Architecture

System Architecture

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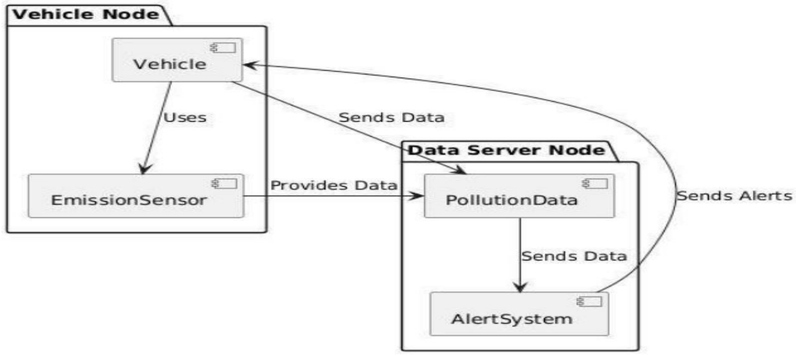

Fig.1 System Architecture

System architecture describes the overall structure of a system and defines how different components interact to achieve the desired functionality. It provides a high-level representation of the system workflow and illustrates the relationships between hardware and software modules. In the proposed vehicle exhaust pollution detection system, the architecture is designed to ensure efficient data acquisition, processing, and alert generation.The system mainly consists of gas sensors, a microcontroller unit, a display interface, and a communication module. The gas sensors continuously monitor the concentration of pollutants released from the vehicle exhaust. The sensed data is transmitted to the microcontroller, which processes the information and determines whether the emission levels exceed the predefined safety limits. If the pollution level crosses the threshold value, the system activates warning mechanisms such as a buzzer and notification alerts. The architecture ensures seamless communication between system components while maintaining reliability, scalability, and performance. It also serves as a design blueprint that guides the implementation and integration of hardware and software modules throughout the development process.

Technical Architecture

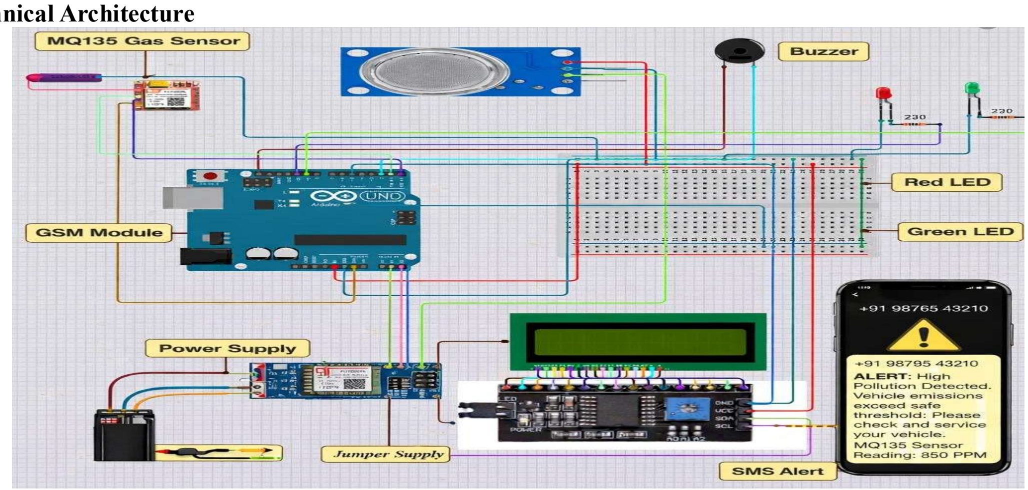

Fig. 2 Technical Architecture

The technical architecture defines the internal organization of system components and the way data flows among them. It generally includes multiple layers such as the sensing layer, processing layer, and presentation layer. In the proposed pollution detection system, the sensing layer consists of gas sensors that detect harmful pollutants emitted from the vehicle exhaust. These sensors capture environmental data in the form of electrical signals that represent gas concentrations.The processing layer is implemented using an Arduino Uno microcontroller, which collects sensor readings and converts them into meaningful pollutant concentration values. The microcontroller performs threshold comparison to determine whether the detected emission levels fall within permissible limits. The presentation layer consists of an LCD display that provides real-time information about the pollution levels to the user. Additionally, a GSM communication module is integrated into the system to transmit alert messages when dangerous gas concentrations are detected. This layered technical architecture ensures efficient data handling, reliable communication between components, and flexibility for future system upgrades.

Methodology

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The methodology for detecting pollution from vehicle exhaust involves a structured approach for measuring and analyzing harmful gases emitted during vehicle operation. The process begins by defining the objective of identifying and monitoring major pollutants commonly present in exhaust emissions. These pollutants include carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), and hydrocarbons (HC), all of which contribute significantly to air pollution and pose serious risks to human health.After identifying the target pollutants, appropriate detection techniques are selected. Gas sensors from the MQ series are commonly used in emission monitoring systems because of their affordability, reliability, and ease of integration with microcontrollers. In this project, the MQ135 gas sensor is employed to detect pollutants such as carbon monoxide, nitrogen oxides, and hydrocarbons. Other sensor technologies, including infrared sensors for carbon dioxide detection and electrochemical sensors for precise gas analysis, may also be considered in advanced systems.Once the sensors are selected, the system setup is performed. The sensors are installed near the vehicle exhaust outlet to capture accurate emission samples. These sensors are connected to an Arduino microcontroller, which collects and processes the sensor data. A display unit is integrated to present real-time pollution levels, while a communication module enables remote notifications.During system operation, the vehicle engine is started and emissions are monitored under different operating conditions, including idle and acceleration states. Sensor readings are collected continuously to observe variations in gas concentration levels. The analog signals obtained from the sensors are converted into digital values and then translated into gas concentration measurements expressed in parts per million (ppm). These values are compared with standard emission limits such as Bharat Stage emission norms to determine whether the vehicle complies with environmental regulations.If the detected pollution levels exceed predefined thresholds, the system activates an alert mechanism. This may include a buzzer warning and an SMS notification to the vehicle owner through the GSM module. The detected values are also displayed on the LCD screen and can be stored for future analysis. This methodology allows continuous monitoring of vehicular emissions and supports timely maintenance actions to reduce environmental pollution.

System Modules

The proposed system is divided into several functional modules, each responsible for performing a specific task within the overall pollution detection process. Modular design improves system organization, simplifies development, and facilitates future expansion.The vehicle module represents the source of exhaust emissions and interacts with the sensing system. This module generates emission gases during engine operation, which are then monitored by the sensing components. The emission sensor module is responsible for detecting pollutants released from the vehicle exhaust. Gas sensors measure the concentration of harmful gases and convert the detected chemical signals into electrical signals that can be processed by the microcontroller.The data processing module receives sensor readings and performs analysis using the microcontroller. This module evaluates the collected data and compares the detected gas concentrations with predefined threshold values to determine the severity of emissions. Finally, the alert module monitors the processed data and generates warning signals when pollution levels exceed safe limits. The alert mechanism includes activating a buzzer and sending SMS notifications to inform the vehicle owner about excessive emissions. Through the interaction of these modules, the system effectively monitors vehicle exhaust pollution and provides timely alerts to prevent environmental harm.

Implementation

System Implementation

The implementation of the vehicle exhaust pollution detection system involves the integration of both hardware and software components. The system is designed to continuously monitor harmful gases emitted from the vehicle exhaust and generate alerts when the emission levels exceed permissible limits.The hardware implementation begins with the selection of appropriate components. The system utilizes an Arduino Uno microcontroller as the central processing unit, along with MQ135 and MQ9 gas sensors for detecting pollutant gases. Additional components include an LCD display for visual monitoring, a piezo buzzer for warning alerts, and a GSM module for sending SMS notifications. These components are interconnected using jumper cables according to the designed circuit configuration.The software component of the system is developed using the Arduino Integrated Development Environment (IDE). The program is responsible for reading sensor values, processing the data, and controlling the output devices. Sensor readings are continuously acquired from the gas sensors and analyzed by the microcontroller. When pollutant levels exceed predefined threshold values, the system triggers the alert mechanisms. The detected gas concentration values are displayed on the LCD screen, and warning messages are transmitted through the GSM module.System integration ensures that the hardware and software components function together effectively. During operation, the sensors continuously collect emission data from the vehicle exhaust. The microcontroller processes these readings and determines whether the gas levels exceed acceptable limits. If abnormal emission

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levels are detected, the buzzer is activated and an SMS alert is sent to notify the vehicle owner. This integrated approach enables real-time monitoring and rapid response to excessive pollution levels.Testing and validation are essential steps in the implementation process. Individual components such as sensors, the microcontroller, the LCD display, and the GSM module are first tested separately to verify their functionality. After unit testing, the complete system undergoes integration testing to ensure that all components operate together correctly. Sensor readings are compared with standard emission values to validate accuracy. Field testing is also performed using different vehicles under real-world conditions to confirm that the system provides reliable and consistent results. Performance evaluation ensures that the system delivers real-time data processing and timely alerts with minimal delay.

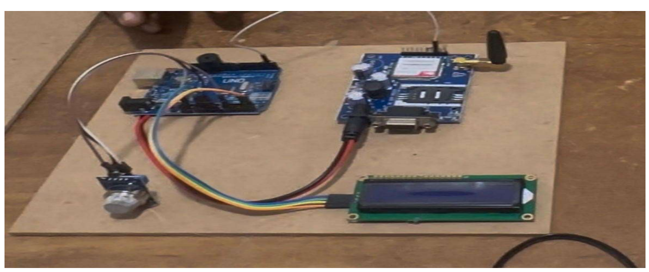
Embedded C Programming

Embedded C is a specialized extension of the C programming language used for developing software for embedded systems. Embedded systems are dedicated computing systems designed to perform specific tasks within electronic devices such as sensors, microcontrollers, and industrial equipment. Embedded C provides the ability to directly interact with hardware components while maintaining efficient memory usage and real-time performance.One of the main advantages of Embedded C is its capability to access hardware registers and memory locations directly, allowing precise control over microcontroller operations. This feature is essential for applications that require interaction with sensors, input/output devices, and communication interfaces. Embedded C also supports efficient memory management, which is particularly important in microcontroller-based systems where processing power and memory resources are limited.Embedded C is widely used in microcontroller programming for developing firmware in applications such as automotive control systems, industrial automation, and robotics. It is also used for creating device drivers that enable communication between software and hardware peripherals. In the proposed pollution detection system, Embedded C is used to develop the control program that reads sensor data, processes emission values, and activates output devices such as the LCD display, buzzer, and GSM module.

Program Logic

The program logic implemented in the system follows a continuous monitoring approach. During system initialization, the microcontroller configures input and output pins, initializes the LCD display, and prepares the communication interface for sending alerts. Once initialization is complete, the system continuously reads analog values from the gas sensor connected to the microcontroller.The obtained sensor values are displayed on the LCD screen to provide real-time information about pollution levels. The program then compares the measured gas concentration with a predefined threshold value. If the detected value exceeds the safe limit, the system activates the buzzer to generate an audible warning. At the same time, an SMS message is sent to a predefined mobile number using the GSM module to inform the user about the dangerous emission levels.After the alert is generated, the system continues monitoring the sensor readings and updates the display accordingly. This continuous monitoring mechanism ensures that harmful emissions are detected promptly and that appropriate actions can be taken to reduce environmental pollution.

Screenshots



IOT Kit

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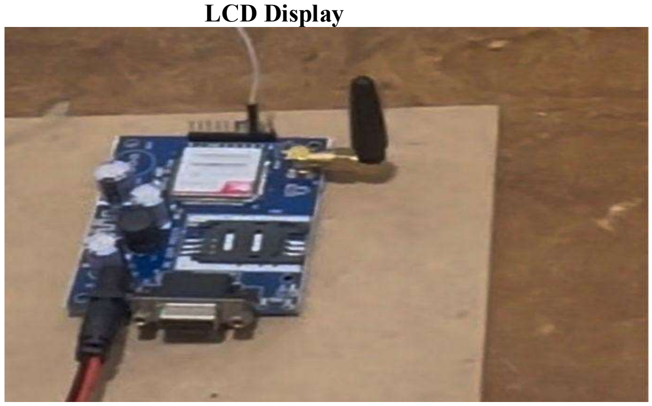
LCD Display



GSM CONNECTION

Final Output

Testing

Test Cases

To evaluate the performance and reliability of the proposed vehicle emission monitoring system, several functional tests were carried out under different operating conditions. The testing process verified the accuracy of the gas sensor, the responsiveness of the alert system, and the proper functioning of system components such as the LCD display, buzzer, and GSM communication module.During the first test scenario, a vehicle emitting excessive exhaust gases was simulated. The gas sensor detected a high concentration of pollutants, and the system successfully triggered an alert mechanism. As expected, the buzzer was activated and an SMS notification was sent to the registered mobile number indicating a high pollution level.In the second test case, the system was exposed to normal emission levels to verify its ability to differentiate between safe and harmful conditions. The LCD screen displayed a normal status and no alerts were generated, confirming the correct functioning of the threshold detection logic.Real-time monitoring capabilities were evaluated in another test where the sensor continuously received exhaust gas samples. The system demonstrated stable performance by continuously updating gas concentration values on the LCD display. This ensured that the system can monitor emissions dynamically without interruption.The alert generation mechanism was also verified by intentionally exceeding the predefined gas concentration threshold. When this occurred, the system immediately activated the buzzer and transmitted a warning message through the GSM module to the user's mobile device.The display module was tested to confirm that sensor readings in parts per million (PPM) were correctly shown on the LCD. The results indicated that the gas concentration values were accurately displayed under normal operation. In addition, the MQ135 gas sensor functionality was tested by exposing it to various gases to ensure that it correctly captured and transmitted emission data to the microcontroller.Power supply stability was also verified. When the system was powered on, all components operated continuously without interruption, demonstrating reliable hardware integration. However, one test scenario revealed a display inconsistency where the LCD occasionally showed incorrect values, indicating the need for calibration or improved signal processing in future versions.Overall, the testing results confirmed that the proposed system effectively detects vehicle emissions, provides real-time monitoring, and alerts users when pollution levels exceed safe limits.

Conclusion

This project focused on developing an efficient system for monitoring pollution generated from vehicle exhaust emissions. The primary objective was to detect harmful gases released from vehicles and notify the user when the emission level exceeds a predefined safety threshold. The developed prototype integrates a gas sensor, microcontroller, buzzer, LCD display, and GSM communication module to provide real-time monitoring and alert notifications.The system successfully detects the concentration of exhaust gases and provides immediate feedback to users through both visual and audible alerts. When pollution levels surpass the threshold limit, the system activates a buzzer and sends a notification message to the user's mobile phone. This approach ensures that vehicle owners become aware of excessive emissions and can take corrective actions.By implementing such monitoring mechanisms, it becomes possible to reduce environmental pollution caused by vehicles. Regular monitoring can encourage vehicle owners to maintain their engines properly, replace damaged components, or upgrade outdated vehicles that contribute significantly to air pollution. As a result, harmful emissions released into the atmosphere can be minimized.Reducing vehicular emissions also contributes to improving public health by lowering the risk of respiratory diseases and other health problems associated with poor air quality.

Future Scope

Although the developed system successfully monitors vehicle exhaust emissions, several enhancements can further improve its performance and applicability. One potential improvement is the integration of advanced gas sensors capable of detecting a broader range of pollutants with higher sensitivity and accuracy.Another important enhancement involves incorporating Internet of Things (IoT) technology to enable cloud-based monitoring. By connecting the system to cloud platforms, emission data from multiple vehicles can be collected and analyzed in real time. This would allow authorities and environmental agencies to monitor pollution trends across different locations and identify areas with high emission levels.Artificial intelligence and machine learning techniques could also be integrated to analyze historical emission data and predict future pollution patterns. Such predictive capabilities could help identify vehicles that require maintenance before their emission levels become harmful.Additionally, the system could be redesigned to be more compact and portable, allowing it to be easily installed in different types of vehicles. A mobile application could also be developed to provide users with real-time notifications, historical emission records, and maintenance suggestions.Future versions of the system may also incorporate renewable energy solutions such as small solar panels to power the device, improving energy efficiency and sustainability. Wireless communication technologies like Bluetooth, Wi-Fi, or 5G can be integrated to enable faster and more reliable data transmission.Another useful feature would be the automatic generation of emission reports that can be shared with regulatory authorities for compliance monitoring.

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