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Tech-Driven Pollution Control: Intelligent Vehicle Monitoring for Cleaner Air

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ABSTRACT

Air pollution in urban areas is increasingly driven by vehicle emissions, which release harmful gases include such things as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), and particulate matter (PM). These pollutants pose significant risks to both environmental quality and public health, highlighting the urgent need for effective monitoring and control systems. This project presents the development of an automated Effective Air Pollution Monitoring System for Eco Balance, designed to detect exhaust gas levels in real-time as vehicles pass designated points. The system employs advanced sensors to monitor pollutant concentrations and utilizes a camera- based recognition system to capture the number plates of vehicles that exceed permissible emission levels. The collected data, including pollution metrics and vehicle details, is transmitted to the Regional Transport Office (RTO) for necessary enforcement actions. By promoting compliance with emission standards, this automated system aims to significantly reduce vehicle-related air pollution, fostering a cleaner and healthier urban environment.

General Terms

Air Pollution: The paper addresses the growing concern of air pollution in urban areas, focusing on the harmful gases emitted by vehicles.

Vehicle Emissions: It discusses the various pollutants released from vehicle exhaust, including carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), and particulate matter (PM).

Monitoring System: The paper introduces an automated system designed to monitor vehicle emissions in real-time.

Pollution Sensors: The system uses advanced sensors to detect and measure pollutant concentrations.

Camera-Based Recognition: A camera system is used to capture vehicle number plates, enabling identification of vehicles that exceed emission limits.

Vehicle Identification: The system identifies vehicles through number plate recognition.

Regional Transport Office (RTO): The collected data is transmitted to the RTO for enforcement actions.

Keywords

Air Pollution, Vehicle Emission, Pollution Sensor, Camera-Based Recognition, Vehicle Identification, Regional Transport Office (RTO)

1. INTRODUCTION

Air pollution is a growing concern in urban areas, largely due to the increasing number of vehicles emitting harmful gases. Vehicle exhaust gases, including carbon monoxide (CO), nitrogen oxides (NOx), nitrogen oxides (NOx), hydrocarbons (HC), and particulate matter (PM), contribute significantly to air pollution, affecting both environmental and public health. An effective system for monitoring and controlling vehicle emissions is urgently needed to address this issue. This project focuses on the development of an automated 'Effective Air Pollution Monitoring System for eco balance' , which can detect the level of exhaust gases released from vehicles and take necessary actions. The system uses advanced sensors to monitor pollutants in real-time as vehicles pass by. Once a vehicle is found to be emitting gases beyond permissible levels, the system captures the vehicle's number plate using a camera-based recognition system. The gathered information, including the pollution levels and vehicle details, is then sent to the Regional Transport Office (RTO) for further action. This automated system aims to enhance compliance with emission standards and reduce vehicle-related air pollution, promoting a cleaner and healthier environment

2. Literature Survey

1) Molina-Moreno, M., González-Díaz, I., & Díaz-de- María, F. (2019). Efficient Scale-Adaptive License Plate Detection System. IEEE Transactions on Intelligent Transportation Systems, 20(6), 2150-2160. In the paper, Molina-Moreno et al. (2019) present an innovative scale-adaptive license plate detection system designed to enhance the efficiency and accuracy of vehicle identification in various environments. The authors focus on the challenges associated with traditional license plate detection methods, particularly in dynamic urban settings where vehicles may be approaching at different speeds and distances.The proposed system incorporates a scale-adaptive approach that allows for RFID enhances efficiency in toll operations Data Management: Discusses how cloud services facilitate the storage and processing of large volumes of emission data.Real-Time Monitoring: Explains the benefits of cloud computing in enabling instant access to data for regulatory authorities. The paper serves as a foundational study for developing an IoT-based vehicle emission monitoring system at toll plazas. It highlights the integration of advanced technologies—RFID for identification and cloud computing for data management—as essential components for effective environmental monitoring. The proposed system has the potential to enhance compliance with regulations and improve air quality, making it a valuable contribution to both transportation and environmental management sectors.effective detection of license plates across

3. Proposed System

The Effective Air Pollution Monitoring System for Eco Balance functions by continuously monitoring air pollution levels using gas sensors such as MQ-135, which detect harmful emissions like carbon monoxide (CO) and nitrogen dioxide (NO_2). These sensors are placed near roadways where vehicle emissions can be measured. When the detected pollution level exceeds a predefined threshold, the system triggers a camera module to capture an image of the vehicle.

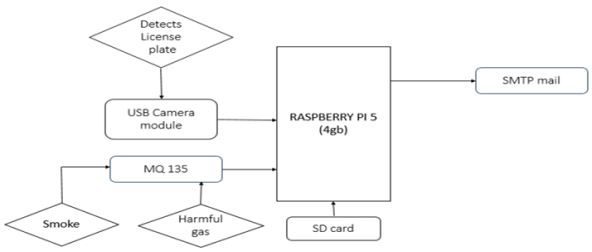

Figure1: Block diagram of proposed system

This image is then processed using OpenCV, where techniques like grayscale conversion, noise reduction, and edge detection are applied to extract the number plate area. The extracted portion is further processed using Tesseract OCR, which converts the image into machine readable text, retrieving the vehicle's registration number. Once the number is recognized, the system compiles the vehicle number, pollution level, date, time, and location, and transmits this data to a central RTO server via SMTP mail. The RTO can then take necessary enforcement actions, such as issuing fines or mandating vehicle pollution checks. The entire process is automated and operates in real-time, reducing human intervention and improving the efficiency of monitoring polluting vehicles on roads

4. Algorithm for Proposed System

The entire system process is explained below in detail by step by step process.

1. Initialize System
   • Power on Raspberry Pi.
   • Initialize gas sensors, camera module
2. Monitor Pollution Levels
   • Continuously read air quality data from gas sensors (MQ-135).
   • Measure emissions from passing vehicles.
3. Check Pollution Threshold
   • If pollution level ≤ threshold, continue monitoring.
   • If pollution level > threshold, proceed to capture the vehicle image.
4. Capture Vehicle Image
   • Activate the camera module.
   • Capture an image of the vehicle passing through the sensor detection area.
5. Preprocess the Image
   • Convert image to grayscale.
   • Apply noise reduction and edge detection (using OpenCV). • Crop and isolate the number plate region.
6. Extract Number Plate Information
   • Use OCR (Tesseract) and haae cascade algorithm to recognize the vehicle registration number.
   • Validate extracted text for accuracy.
7. Store and Process Data
   • Log vehicle number, pollution level, date, time, and location in a local database.

8. Transmit Data to RTO Server

9. • Send vehicle details and pollution level to the RTO via SMTP mail Notify Authorities and Vehicle Owner

   • Generate an alert for the RTO.

   • Send an automated notification to the vehicle owner if applicable.

10. Repeat Process.

5. Trajectory Recognition Algorithm

1. Sensor Data Acquisition: The pollution sensors detect vehicle emissions.

2. Trigger Image Capture: When pollution exceeds a threshold, the camera captures the vehicle's number plate.

3. OCR Processing: Extract the number plate details from the image.

4. Haar Cascade algorithm: •Haar Features: It help detect edges, lines, and changes in intensity that are typical in objects like number plates. •Cascade Classifier: The classifier is organized into a cascade of stages, where each stage is a weak classifier that rejects negative samples quickly.

5. Data Transmission: Send the number plate and pollution level to the RTO database via API.

6. RTO Notification: Authorities can access the reported data for enforcement actions.

5. Results

Sample Data Output:

Vehicle Number	Pollution Level (ppm)	Threshold (ppm)
MH02H2444	**352**	**500**
MH12RK1111	**370**	**500**
MH40BE2580	**394**	**500**

Email Result:

The Threshold For MQ135 was crossed.

Extracted Text:

MH11AQ1111

Explanation of the Results

1. Pollution Threshold Exceeded:
   • The message "The threshold for MQ135 was crossed." indicates that the air pollution level detected by the MQ-135 gas sensor has exceeded the predefined limit.
   • This means a vehicle emitting excessive pollutants was detected in the monitored area.
2. License Plate Extraction:
   • The system captured an image of the violating vehicle's license plate.
   • Using Optical Character Recognition (OCR) ,Haar Cascade the extracted number is displayed as MH02H2444 (twice, likely due to multiple detections or confirmations).
   • The OCR algorithm successfully identified and converted the number plate from the image into text.
   3. Image Processing:
   • The small image in the result shows a captured license plate, though it appears upside-down in the display.
   • The system might need image orientation correction in future improvements. 4. Final Action:
   • Since the pollution threshold was crossed, the system can now automatically send this data to the RTO (Regional Transport Office) for enforcement.
   • Authorities or vehicle owners could be notified for necessary action (e.g., fine or pollution check).

6. Discussion

The proposed system efficiently detects and reports polluting vehicles using gas sensors, a camera module, OCR, and cloud communication. When emissions exceed a set threshold, the system captures the vehicle's license plate, extracts the number using image processing and OCR, and sends the data to the RTO server for enforcement. This real-time, automated approach reduces human intervention and enhances pollution control. Challenges like low-light imaging and OCR errors can be improved with AI and machine learning. The system provides a scalable and efficient solution for enforcing emission norms and reducing vehicular pollution.

7. Future Scope

The scope of the Effective Air Pollution Monitoring System for Eco Balance project encompasses several key areas: Monitoring Framework: Develop a comprehensive monitoring framework that includes the selection of advanced sensors for detecting various pollutants (CO, NOx, HC, PM).Establish protocols for data collection, analysis, and reporting.Technological Integration: Integrate vehicle number plate recognition systems with pollution sensors to create an automated detection and reporting mechanism.Ensure compatibility with existing traffic management systems and infrastructure. Geographic Implementation: Pilot the system in high- traffic urban areas with significant air pollution issues. Evaluate the potential for expansion to other regions based on initial findings and effectiveness.Data Management and Analysis: Develop a centralized database for storing and analyzing pollution data, vehicle details, and enforcement actions.Implement data visualization tools for easy interpretation by authorities and the public.Regulatory Collaboration: Collaborate with regional transport offices and environmental agencies to ensure the system aligns with existing regulations and policies.Create feedback mechanisms for regulatory bodies to act on collected data.Public Engagement and Awareness: Design outreach programs to inform the public about the system's purpose and benefits.Promote community involvement in pollution reduction efforts.

8. REFERENCES

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