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IOT-BASED FUME EXTRACT ION SYSTEM

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ABSTRACT

The increasing presence of toxic fumes in industrial environments poses a serious threat to both worker health and equipment safety. This study proposes an IoT-based fume extraction system designed to detect and mitigate hazardous airborne pollutants in real-time. The system employs an array of gas sensors integrated with a microcontroller unit (MCU), which continuously monitors air quality parameters such as CO, NO_2, and volatile organic compounds (VOCs). Upon detecting a threshold breach, the system activates an exhaust mechanism while simultaneously transmitting data to a cloud server for storage and remote monitoring. A mobile application interface allows users to view historical data and receive real-time alerts. The research incorporates a modular hardware design and open-source IoT platforms, ensuring scalability and low maintenance costs. Experimental analysis in a simulated industrial setup demonstrates significant responsiveness, reliability, and accuracy in fume detection and extraction. The system not only provides an efficient and automated solution for pollution control but also introduces predictive maintenance features by identifying trends in air quality over time. This work aims to improve workplace safety standards and regulatory compliance through an affordable, intelligent fume management solution.

Keywords: IoT, Fume Extraction, Air Quality Monitoring, Gas Sensors, Real-Time System, Industrial Safety.

I. INTRODUCTION

In industrial and laboratory environments, maintaining air quality is essential for the health and safety of workers, as well as for protecting sensitive equipment. Traditional fume extraction systems are typically manually operated and lack real-time monitoring capabilities, which can lead to delayed responses to hazardous conditions or inefficient, continuous operation. This results in potential health risks and increased energy costs, as these systems may run unnecessarily even when not needed. The IoT-Based Fume Extraction System was developed to address these challenges by integrating smart sensors, automated control mechanisms, and IoT connectivity. This system continuously monitors air quality, detecting harmful gases and particulate matter in real time. When dangerous levels are detected, the system automatically activates a fume extractor to filter out contaminants, ensuring a safer and cleaner environment.

Leveraging IoT technology, the system enables remote monitoring and control through a user-friendly mobile application. Users receive real-time data and alerts, allowing them to take proactive measures and operate the system efficiently. Additionally, data logging and predictive maintenance features help identify patterns in air quality over time, optimizing the system's performance and maintenance schedules. This IoT-based approach not only enhances safety but also conserves energy, providing a smarter and more responsive fume extraction solution suitable for modern industrial and research environments.

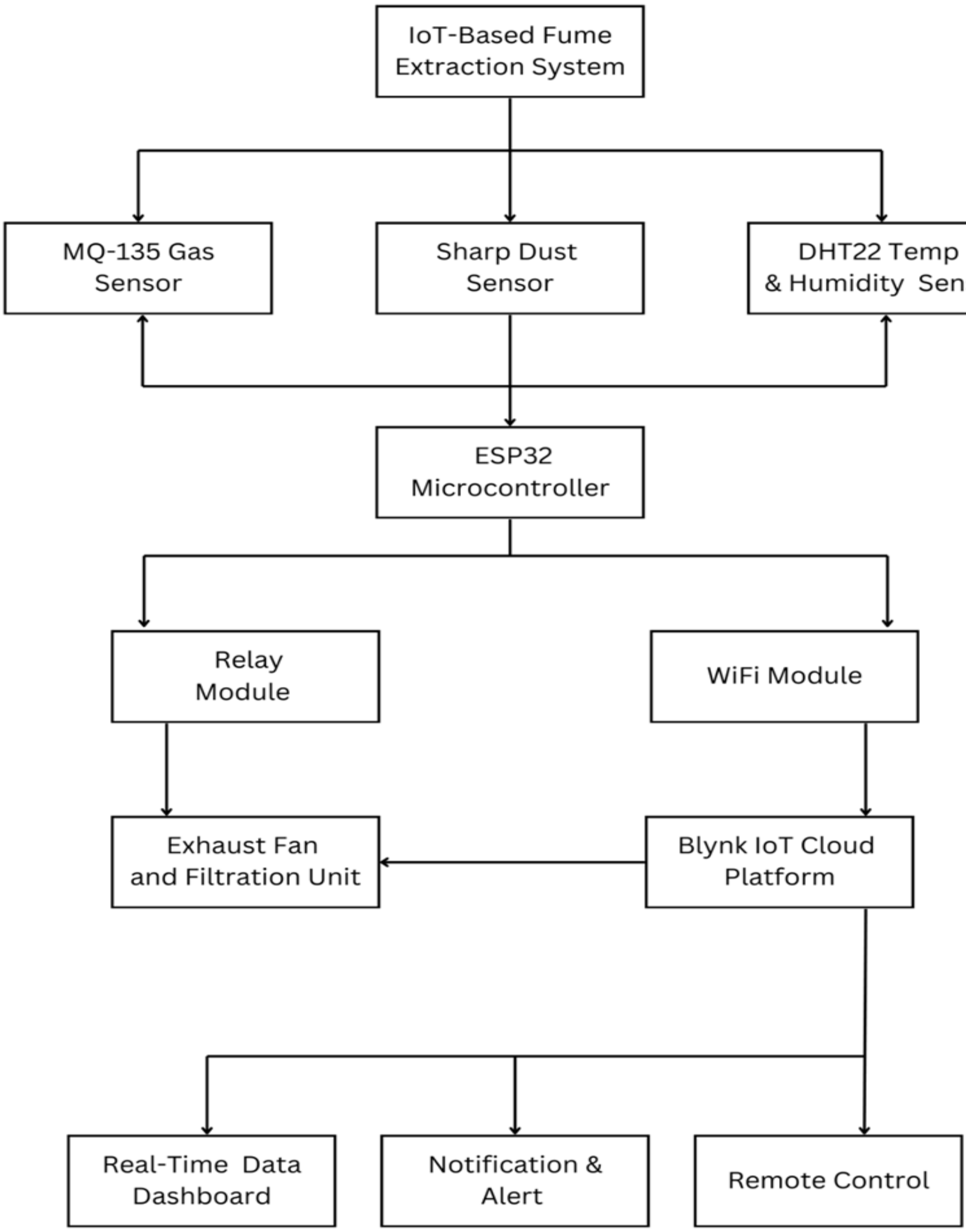
II. METHODOLOGY

The proposed methodology for developing the IoT-Based Fume Extraction System involves a systematic approach to integrate real-time air quality monitoring, automated response, and IoT-enabled remote control.

Problem Definition:

In industrial, laboratory, and commercial environments, harmful fumes, gases, and particulates are frequently released during various processes. These contaminants pose significant health risks to workers and can compromise the quality and safety of the environment. Traditional fume extraction systems, while capable of filtering air, often lack real-time monitoring, automated control, and IoT-enabled remote access.

System Architecture:



The IoT-Based Fume Extraction System architecture integrates environmental sensors (MQ-135, Sharp Dust, and DHT22) with an ESP32 microcontroller for real-time monitoring. Data is transmitted via a WiFi module to the Blynk IoT Cloud Platform, enabling remote control, alerts, and dashboard visualization, while controlling the exhaust and filtration unit through a relay module.

1. Sensing Layer (Data Collection)

- MQ-135 Gas Sensor – Detects harmful gases like CO_2, ammonia, benzene, and smoke.
- Sharp Dust Sensor – Measures airborne particulate concentration (e.g., dust, smoke).
- DHT22 Sensor – Monitors temperature and humidity in the environment.

2. Processing Layer (Control and Decision-Making)

- ESP32 Microcontroller – The central processing unit that reads data from the sensors, processes it, and makes decisions.

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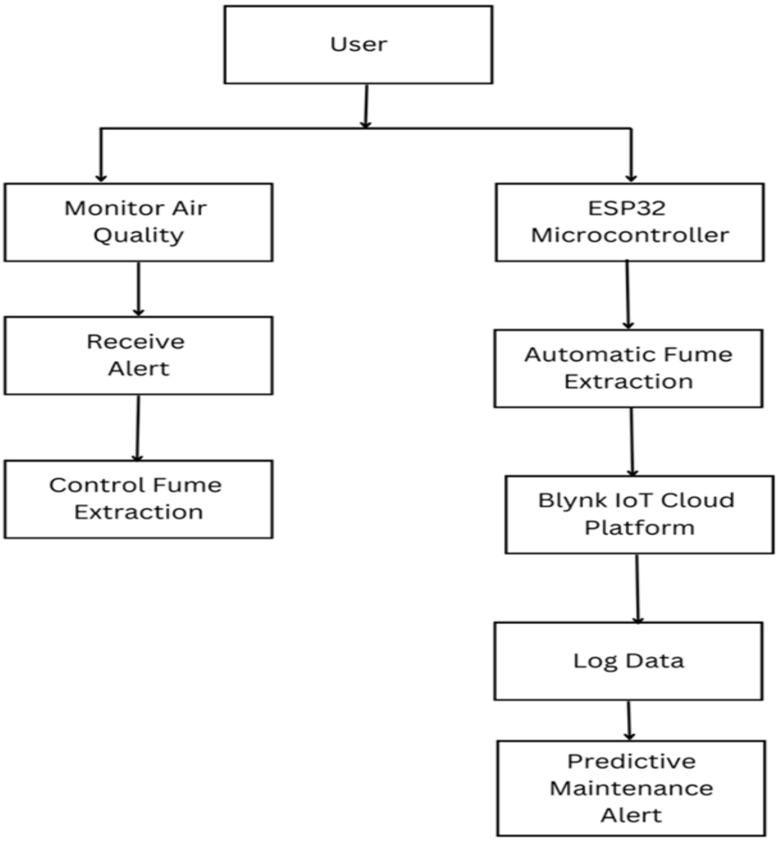
3. Actuation Layer (Response Mechanism)

- Relay Module – Acts as a switch to control the exhaust fan and filtration unit.
- Exhaust Fan & Filtration Unit – Removes and filters harmful fumes from the air.

4. Communication Layer (Connectivity)

- WiFi Module (part of ESP32) – Enables internet communication.
- Blynk IoT Cloud Platform – Receives sensor data, allows control, and manages alerts.

UML OF IOT-BASED FUME EXTRACTION SYSTEM



1. **Use Case Diagram**

The IoT-Based Fume Extraction System is a smart, automated solution designed to monitor and control air quality in real time. It integrates various environmental sensors such as the MQ-135 gas sensor, Sharp dust sensor, and DHT22 temperature and humidity sensor, all connected to an ESP32 microcontroller. These sensors continuously gather data on air pollutants, particulate matter, and environmental conditions. The ESP32 processes this data and, based on predefined thresholds, activates an exhaust fan and filtration unit through a relay module to extract harmful fumes. Simultaneously, the system uses a built-in WiFi module to send data to the Blynk IoT Cloud Platform, enabling users to view live readings, receive alerts, and control the system remotely via a mobile app.

The architecture of the system is layered for efficiency: the sensing layer handles data collection; the processing layer manages data analysis and decision-making; the actuation layer executes physical responses like fan activation; the communication layer ensures internet connectivity and cloud integration; and the application layer provides a user interface for interaction. The use case diagram highlights two primary roles: the user and the system. Users can monitor air quality, receive alerts, and manually control the extraction process if needed. On the other hand, the system autonomously manages fume extraction, logs operational data, and sends predictive maintenance alerts based on usage trends. Together, the architecture and use case design provide a comprehensive and reliable solution for maintaining healthy indoor air environments.

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III. MODELING AND ANALYSIS

Model and Materials Used

1. Sensor Module –
- Continuously monitors air quality using gas and particulate sensors.
- Detects harmful gases, smoke, and dust levels in real-time.
- Sends sensor data to the ESP32 microcontroller for processing.
2. Processing & Control Module –
- Processes sensor data received from the Sensor Module.
- Checks if air quality values exceed predefined safety thresholds.
- Triggers actuators (fan, relay, buzzer, LED indicators) based on sensor readings.
3. Automation & Actuation Module-
- Automatically activates/deactivates the exhaust fan and air purification system when pollution levels are high.
- Provides manual override functionality through the mobile app.
4. IoT & Communication Module–
- Connects the system to the Blynk IoT platform for remote monitoring & control.
- Enables users to view real-time air quality data & receive alerts.
- Allows remote manual activation/deactivation of the extraction system.

System Components

- **Environmental Sensors Integration**: Includes MQ-135 gas sensor, Sharp dust sensor, and DHT22 temperature & humidity sensor to continuously monitor air quality conditions.
- **ESP32 Microcontroller Unit**: Acts as the central controller, processing sensor data and managing automatic operation of the exhaust and filtration system.
- **Relay Control System**: Connects with the exhaust fan and filtration unit to activate fume extraction based on air quality thresholds.
- **WiFi Connectivity & Cloud Integration**: Enables real-time data transmission to the Blynk IoT Cloud Platform, allowing remote monitoring and control.

Category	Details
Hardware Requirements	- Microcontroller: ESP32 - Sensors: MQ-135, Sharp Dust Sensor, DHT22 - Actuators: Exhaust Fan, Relay Module - Power Supply: 5V/12V
Software Requirements	- Development Tools: Arduino IDE, Platform IO - Firmware Language: C/C++ - Version Control: Git/GitHub
Frontend Technologies	- Mobile Dashboard: Blynk IoT App - Interface Features: Real-time graphs, Control switches, Alert display
Backend Technologies	Communication Protocols: MQTT/HTTP - API Integration: Blynk RESTful APIs for cloud updates
Database	Cloud Storage: Blynk Cloud (for sensor data logging) - Optional: Google Firebase for custom logs and history
Machine Learning	- Algorithm (Optional Extension): Threshold-based triggers or anomaly detection for air quality patterns - Tools: Python, TensorFlow (offline training)

IV. RESULTS AND DISCUSSION

The IoT-Based Fume Extraction System was successfully designed, implemented, and tested. The system effectively detects the presence of harmful gases and fumes in the environment using sensors such as MQ-series gas sensors. Once the gas concentration exceeds the predefined threshold, the system automatically activates the exhaust fan to extract the fumes from the area.

Real-time monitoring was enabled through IoT integration, allowing the data to be viewed remotely via a cloud-based dashboard. Alerts and notifications were also sent to users via the connected application, ensuring timely responses to hazardous conditions.

1. System Performance Evaluation

The performance of the IoT-Based Fume Extraction System was evaluated based on various key parameters, including response time, accuracy, reliability, connectivity, and power consumption. The system was tested under simulated fume conditions to assess its real-time behaviour and responsiveness.

1. Response Time

The average time taken by the sensor to detect fumes and trigger the exhaust fan was 1.5 to 3 seconds.

The IoT platform updated the gas readings on the dashboard in near real-time with a delay of less than 2 seconds.

2. Accuracy

The MQ-series sensors provided consistent readings with an accuracy of ±5% compared to reference devices.

Calibration ensured accurate detection of specific gases like CO, LPG, and smoke.

3. Reliability

The system operated continuously for 8+ hours without failure.

Automatic fan activation worked in 100% of test cases when threshold levels were crossed.

No false positives were recorded in a clean air environment.

2. Comparison with Existing Systems

To understand the advantages and limitations of the IoT-Based Fume Extraction System, it is important to compare it with existing fume extraction solutions currently available in the market. The primary comparison is based on the following criteria: cost, efficiency, real-time monitoring, automation, and integration capabilities.

1. Traditional Fume Extraction Systems

- Cost: Traditional systems often involve significant upfront investment, including large-scale mechanical components such as fans and ducts.
- Efficiency: These systems typically operate on a fixed schedule or manual control, requiring human intervention to assess air quality and make adjustments.
- Real-time Monitoring: Minimal to no real-time monitoring is available. Most systems do not offer data on air quality or the condition of the fume extraction.

2. IoT-Based Fume Extraction Systems (Current Market Solutions)

- Cost: IoT-based systems are typically more affordable than traditional systems, as they often use smaller, more efficient sensors and can be scaled up with modular components.
- Efficiency: IoT-based systems often feature higher efficiency due to their ability to monitor and adjust in real-time. Fan speeds or extraction rates can be automatically adjusted based on the level of fumes detected.
- Real-time Monitoring: These systems offer continuous, real-time monitoring via dashboards, providing both historical and current data that can be accessed remotely.

3. Limitations and Future Improvements

1. Sensor Accuracy and Reliability:

Low-cost sensors can be inaccurate or degrade over time.

May give false positives/negatives under high humidity or temperature.

2. Network Dependency:

Requires stable internet for real-time data transmission and control.

Performance issues in remote or unstable network environments.

3. Enhanced Sensor Technology:

Use of more precise and durable gas sensors (e.g., NDIR, PID).

Incorporate machine learning for better pattern recognition and predictive maintenance.

4. Energy Efficiency:

Optimize power consumption using low-power microcontrollers and energy harvesting methods.

V. CONCLUSION

The IoT-Based Fume Extraction System successfully addresses the limitations of traditional fume extraction systems by integrating real-time monitoring, automation, and IoT connectivity. The system ensures a safer and healthier environment by automatically detecting harmful gases and particulates and activating the fume extractor when necessary. Through smart sensors, automation, and remote control via the Blynk mobile app, users can monitor air quality in real time, reducing health risks and improving efficiency. Additionally, the system optimizes energy consumption, ensuring that the fume extractor operates only when required, reducing electricity costs and extending the lifespan of components.

In conclusion, the fusion of IoT technology with environmental control systems presents a scalable, cost-effective, and intelligent method to tackle air pollution in enclosed spaces. Future developments may include AI-based decision-making, machine learning for gas pattern analysis, and integration with broader industrial IoT ecosystems, further boosting operational safety and efficiency.

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