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IoT-Based Manhole Detection and Monitoring System

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Abstract

Urban drainage systems face numerous challenges, including blockages, harmful gas accumulation, and flooding, which pose risks to public safety and environmental health. This project introduces an IoT-enabled solution designed to monitor and address these issues efficiently. The system incorporates sensors to detect critical parameters such as gas levels, temperature, water presence, and nearby obstacles. A unique lifting mechanism ensures the hardware adapts to challenging conditions, maintaining uninterrupted operation. The system transmits real-time data to a mobile application, allowing authorities to monitor drainage systems efficiently. It features live updates, historical data visualization, and a user-friendly interface that aids in swift decision-making. By identifying trends and potential hazards early, the application enhances public safety and operational efficiency. Its scalable and reliable architecture supports seamless integration into smart city infrastructure. This proactive approach to drainage management not only reduces risks but also ensures timely maintenance and resource allocation. As a result, the solution promotes sustainability, improves urban resilience, and supports the broader goals of intelligent infrastructure and effective urban planning.

Keywords: IoT, drainage monitoring, real-time data, urban safety, hazard prevention, smart city, infrastructure management

INTRODUCTION

Urban drainage systems are crucial for managing wastewater and stormwater, preventing flooding, and ensuring the safety and hygiene of urban areas. However, these systems often face issues such as blockages, water overflow, and the presence of hazardous gases, which can be difficult to monitor using traditional methods. Manual inspections take a lot of time, are prone to human mistake, and frequently do not give up-to-date information on the health of the system. The need for more automated, dependable, and efficient systems to monitor and manage these infrastructures grows as urban populations rise.

By putting in place a cutting-edge, Internet of Things-based solution for real-time drainage monitoring, this initiative seeks to address these issues. To guarantee smooth operation, the system makes use of a variety of sensors, mobile app integration, and creative hardware design. The dynamic location of the monitoring hardware, which automatically adapts to water levels, and a mobile app that gives authorities real-time sensor data, graphical representations, and instant notifications are two of the project's key characteristics.

LITERATURE SURVEY

Using IoT-based solutions, Natu *et al.* talk about improvements in urban sewage management. The study's importance stems from its use of cutting-edge technologies to update sewage control procedures [1].

In their 2023 article, Hadal *et al.* describe a real-time Internet of Things (IoT)-based manhole

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monitoring system designed to increase urban safety. Their work demonstrates how IoT technology can be integrated to monitor manholes continuously, guaranteeing that any problems, like dangerous situations or obstructions, are found and fixed quickly [2].

To prevent accidents, Mankotia A *et al.* investigate an Internet of Things-based manhole detection and monitoring system. Their research offers guidance on incorporating IoT sensors to track manhole conditions and identify possible dangers [3].

Devi and Bala suggest an Internet of Things (IoT)-based subterranean drainage monitoring system in response to the smart city concept. Their research demonstrates how IoT may be used to keep an eye on subterranean drainage systems, identify problems, and guarantee appropriate upkeep.

The paper's contribution to infrastructure management and smart city development makes it noteworthy. This study shows how IoT may be used to monitor underground drainage systems, spot issues, and ensure proper maintenance. The study is notable for its contribution to smart city development and infrastructure management [4].

The goal of Ganpat and Bansoe's IoT-based manhole monitoring system is to improve urban safety. Their research highlights the installation of many sensors to monitor climatic variables and manhole conditions, offering vital information for averting mishaps and guaranteeing public safety. The study emphasizes how crucial it is to incorporate IoT technology in order to successfully handle urban safety issues [5].

The study by Ruheena and Shereen provides information on a trustworthy Internet of Things-based manhole safety monitoring system. Their research highlights the necessity of strong monitoring systems to guarantee manhole safety and avert mishaps. The paper's emphasis on creating dependable methods to improve public safety in urban settings makes it significant [6].

With an emphasis on manhole monitoring, Papageorgiou and Papandrianos talk about an Internet of Things-based system created for the safety of urban infrastructure. Their research demonstrates how real-time data and alarms from IoT technology can enhance operational effectiveness and safety [7].

An IoT-based system for tracking the state of urban manholes is investigated by Vijay *et al*. Their study offers a thorough method for monitoring manhole health and guaranteeing prompt repairs. The practical ramifications of the article for infrastructure management and urban safety make it significant [8].

The construction of an autonomous drainage monitoring system utilizing IoT and AI to improve urban safety is demonstrated by the project of Parameshachari *et al*. Without the need for human interaction, it seeks to identify obstructions, temperature increases, gas leaks, and other dangers in real time and notify local authorities [9].

The importance of technology in urban infrastructure is highlighted in Rasheed and Abdulla's study on smart city development using an Internet of Things-based manhole cover monitoring system. Their research demonstrates how IoT may be used to track manhole covers, identify problems, and enhance safety [10].

METHODOLOGY

The IoT-based manhole detection and monitoring system aims to create a smart, integrated drainage monitoring system using a combination of hardware and software to ensure efficient and safe management of sewage and drainage systems. Additionally, Figure 1 shows the flow chart of the system.

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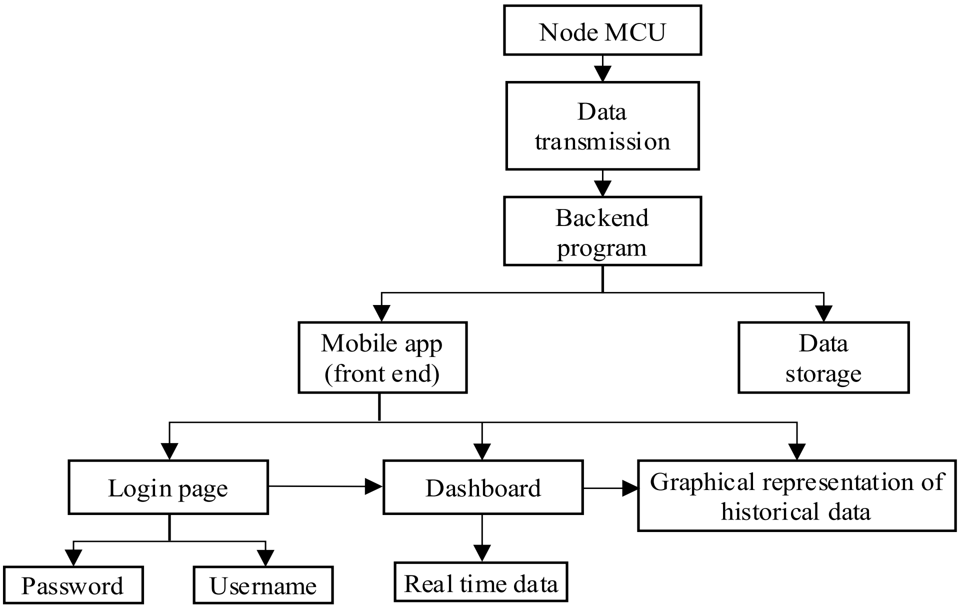

Figure 1. Flow chart of the system.

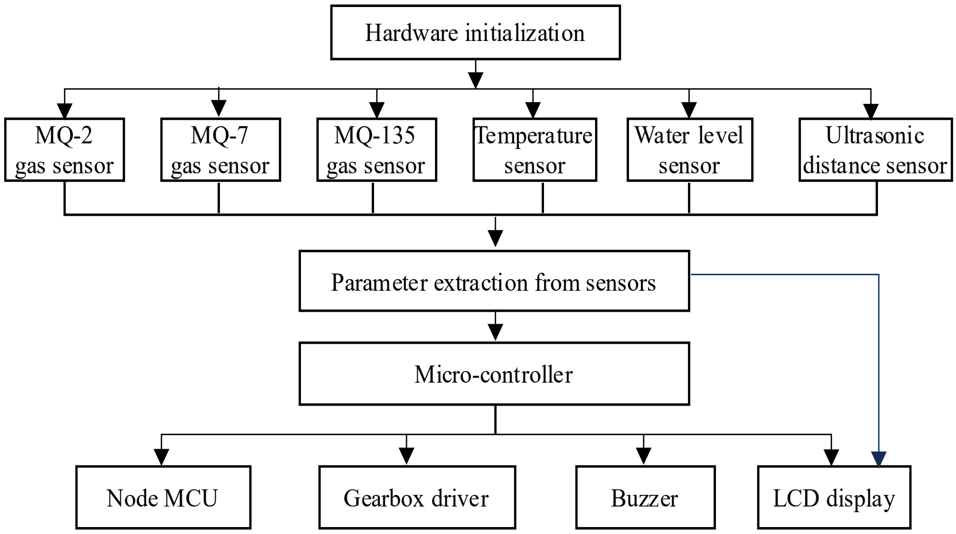

Figure 2. Hardware initialization.

Hardware Initialization

The system begins with the initialization of the hardware components, which are controlled by the Arduino Mega microcontroller (Figure 2). It serves as the central processing unit, receiving data from the sensors, controlling the gearbox motor driver, and transmitting information to the mobile app via the ESP8266 NodeMCU Wi-Fi module.

Sensor Working

The core of the system lies in its ability to sense environmental conditions inside the drainage system. The system includes six sensors, each playing a crucial role in ensuring a comprehensive understanding of the drainage conditions:

1. *Gas Sensors (MQ2, MQ7, MQ135):* These sensors monitor the air for harmful gases, such as methane, carbon monoxide, and other toxic substances, ensuring the safety of the drainage area and nearby environments.
2. *Temperature Sensor:* This sensor monitors the temperature inside the drainage system, helping detect any abnormal fluctuations that might indicate a problem.

3. *Water Level Sensor:* It measures the water level in the drainage system, providing data about humidity and potential flooding.
4. *Ultrasonic Sensor:* The ultrasonic sensor detects obstacles near the hardware, helping prevent any collisions with surrounding structures or debris inside the drainage system.

The *LCD display* connected to the Arduino Mega shows the readings from each of these sensors in real-time, offering immediate feedback about the system's condition.

Dynamic Hardware Movement

An innovative feature of this system is its dynamic adjustment based on water levels. When the water level sensor senses the presence of water, the gearbox motor driver (L298 motor driver) in the system immediately raises the hardware by 10 cm. This ensures that in the face of increasing water levels, the system will continue to function and be shielded from water damage. After the water level decreases and no longer poses a risk, the hardware returns to its initial position, thanks to the motorized movement provided by the gearbox.

Data Transmission and Mobile App Integration

The data collected from all sensors is transmitted to the mobile app using the ESP8266 NodeMCU Wi-Fi module. This module connects to a mobile hotspot created by the user's smartphone, which allows the system to avoid the need for costly internet domains. Rather, the laptop is set up with a static IP address to receive and show real-time sensor data, and the system runs on a local network.

The mobile application offers a login screen for user authentication and was developed with Flutter. To access the system, the user inputs their username and password. Once logged in, the app displays a dashboard with six fields showing the real-time sensor data, including readings for the gas sensors, water level, temperature, and distance measurements.

Mobile App Features and Graphical Representation

In addition to displaying real-time data, the mobile app offers advanced features that enhance its usability:

1. *Sensor Data Selection:* Users can select any of the six sensors (gas 1, gas 2, gas 3, distance, temperature, and water level) to view the specific readings from that sensor.
2. *Graphical Representation:* The app provides a graphical view of the historical data for each sensor. The mobile application offers a login screen for user authentication and was developed with Flutter. To access the system, the user inputs their username and password.
3. *Alerts and Notifications:* The app also provides alerts when any sensor's reading exceeds the pre-defined threshold values, indicating a hazardous situation. These notifications ensure that the user is immediately informed of any abnormal conditions, enabling timely intervention.

Backend Program and Data Storage

The processing, storing, and administration of the sensor data are handled using Python Django, which powers the system's backend. The database utilized to effectively store sensor readings is SQLite. This backend application guarantees that all data is safely kept, readily available, and prepared for analysis when required. Before transferring the sensor data to the mobile app for display, it also takes care of any necessary processing.

IMPLEMENTATION

The hardware setup includes several sensors: gas sensors (MQ2, MQ7, MQ135) that monitor harmful gases, an LM35 temperature sensor that tracks temperature, a water level sensor for detecting water levels, and an ultrasonic sensor to check for obstacles. The Arduino Mega, which handles data processing and hardware component control, is connected to these sensors. While the gearbox (L298 Motor Driver) raises and lowers the hardware in response to water levels, preventing flooding, the LCD display provides real-time sensor data for convenient monitoring. When sensor levels surpass predetermined thresholds, a buzzer warns users of possible problems. Through the use of a mobile hotspot and a Wi-Fi connection, the ESP8266 NodeMCU transmits sensor data to the mobile application.

The mobile app, built using Flutter, displays real-time sensor data. It features a login page for secure user authentication, a dashboard that shows the current sensor readings for gas levels, temperature, and water levels, and a graphical representation that tracks historical data trends. The app also sends alerts to the user when any sensor reading exceeds preset thresholds.

The backend system, developed with Python Django, processes and stores sensor data in an SQLite database. An API facilitates real-time data transfer between the hardware and the app, ensuring seamless communication.

The ESP8266 NodeMCU plays a key role in transmitting data from the hardware to the backend, sending updates through the mobile hotspot, ensuring real-time data visibility.

RESULT AND DISCUSSION

The system successfully integrates hardware and software components to provide real-time monitoring of drainage systems. The sensors accurately detect harmful gases, temperature, water levels, and obstacles, while the LCD display and mobile app offer intuitive ways to view and manage this data. The gearbox mechanism ensures proper hardware positioning based on water levels, preventing damage. The app's login functionality, dashboard, and graphical representation enhance the user experience, and alerts keep users informed of potential hazards. The backend efficiently processes and stores data, enabling seamless communication between the hardware and mobile app. Overall, the project demonstrated reliable performance, providing a scalable solution for smart drainage system monitoring. Moreover Table 1 compares the key features between the proposed project and existing methods.

- *Expanded Sensor Network:* Additional sensors, such as water quality sensors, vibration sensors, or even CCTV for visual monitoring, could be integrated to provide a more comprehensive view of the drainage system's health and potential threats.
- *Automated Response System:* The integration of automated control systems could enable the system to take corrective actions automatically, such as activating pumps or valves when dangerous gas levels or water levels are detected.

Table 1. Comparison of key features between the proposed project and existing methods.

Features	Proposed Project	Existing Methods
Real-Time Monitoring Accuracy	100% with continuous data updates	May have delays or manual reporting
Hardware Efficiency	Low power consumption, efficient use of resources	Typically consumes more power and resources
Scalability	Easily scalable with more sensors and nodes	May require complex setup for scaling
Alert and Hazard Detection	Instant alerts when thresholds are exceeded	May lack alerts or show only warnings without action
Data Representation	Graphical representation for historical data	Limited or no graphical representation

CONCLUSION

The proposed project demonstrates the integration of IoT sensors, microcontroller systems, and mobile app development for real-time monitoring of drainage systems. By utilizing multiple sensors to detect harmful gases, temperature variations, water levels, and obstacles, the system ensures better safety and efficiency in urban infrastructure management. The mobile app provides easy access to real-time data and historical trends, while the dynamic positioning of the hardware through a gearbox adds a unique feature for mobility. The integration of these technologies in a scalable and efficient manner highlights the potential for smart city applications, offering a robust solution for monitoring drainage systems.

Future Scope

- *Integration with AI for Predictive Maintenance:* By incorporating artificial intelligence, the system can analyze sensor data patterns over time to predict potential failures or hazardous situations, helping in proactive maintenance and early detection of issues in the drainage system.

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