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IoT-Based Environment Monitoring System

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Abstract

Pollution combined with climate change is creating long-term problems for natural resources. Their impact on soil, air, and water cleanliness is growing, and this requires smart, immediate solutions. In this paper, we report on an internet of things (IoT)-based environment monitoring system whose purpose is to monitor the air quality, temperature, humidity, and soil moisture content. It consists of an Arduino Uno, gas sensors (MQ135, MQ9, MQ6), a temperature sensor LM35, a soil moisture sensor, and a GPRS (general packet radio service) modem used for transmitting data. After data collection, Python and machine learning is used for data processing, trend analysis, and hazards prediction. The frontend implementation is based on React while the backend is built using Node.js to provide real-time user interactivity. Users can easily monitor environmental parameters using web and mobile dashboards created with React and React Native. When pollutant levels rise above preset levels, the system automatically sends SMS notifications through a cloud service to appropriate institutions. Implementing machine learning improves prediction capabilities, consequently enabling timely responses to environmental disasters. This system, which is affordable and easy to scale, can be used in agricultural, industrial and urban settings. By utilizing cloud, IoT, machine learning, and artificial intelligence (AI), the suggested method fosters automation and efficiency in monitoring the environment. The system proved to be accurate in estimating the number of pollutants and predicting their changes over time, which makes it a suitable alternative to the traditional approaches. This thesis underlines the possibilities offered by IoT around environmental problems and the need to act based on information when dealing with pollution issues. Adding 5G, supporting edge solutions for quicker computation, and AI-based advice will automate the management of the environment for future developments.

Keyword: Management, harm, resources, pollution, recycle, organic matter, materials, landfills, harmful gases, environment, nutrient-rich fertilizer, air quality, emissions, sustainability, collaboration

INTRODUCTION

The harmful effects of pollution and climate change have become a growing concern as they have had an impact on the natural resources such as air, water, and soil. Resting on a traditional environmental monitoring approach often turns out to be inefficient since it is neither real time responsive nor scalable enough to deal with the emerging issues. An advanced internet of things (IoT)-based environment monitoring system provides an easier and more affordable way to automate the tracking of critical environmental parameters such as temperature, humidity, moisture, and air quality, especially carbon monoxide, methane, and volatile organic compounds (VOCs). The system is composed of multiple sensors like the LM35 temperature sensor, soil moisture sensor, humidity sensor, and gas

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sensors which are MQ6, MQ135, and MQ9, all connected to an Arduino Uno microcontroller for data collection [1]. The smart monitoring system can relay information over a GPRS (general radio packet service) modem for remote sensing applications which makes it convenient for these programmable logic controller (PLC)-based devices to be placed in settings with little to no access to the internet. The monitored information is centralized in a MySQL database so that users can study it over time, analyze, compare, and forecast with the trends observed. To enhance accessibility, the system features an intuitive web-based dashboard built with PHP and JavaScript for real-time data visualization [2]. Users receive automated SMS or email alerts when pollution levels or environmental conditions exceed safety thresholds, allowing timely interventions. With applications spanning agriculture, urban air quality monitoring, and industrial emissions tracking, this system provides a proactive approach to environmental management. By integrating IoT, cloud computing, and machine learning, the solution fosters sustainable development and supports data-driven decision-making to mitigate environmental risks. Future enhancements, including 5G integration and artificial intelligence (AI)-driven analytics, will further improve efficiency and response time, ensuring a smarter and more resilient environmental monitoring system.

LITERATURE REVIEW

Introduction to Internet of Things and Environmental Monitoring

Environmental monitoring has traditionally been limited by manual data collection methods, which are labor-intensive and often lack real-time [3]. With the rise of IoT, the field has seen significant advancements. IoT technologies allow for continuous, real-time data collection through the use of interconnected sensors and devices, vastly improving the accuracy, timeliness, and scale of environmental monitoring efforts [4].

Smart Sensors in IoT-Based Environmental Monitoring

Research has consistently emphasized the role of smart sensors in IoT ecosystems. For instance, Mowla et al. explored the deployment of smart sensors in air quality monitoring, noting that these devices can detect a wide range of pollutants and transmitting data to central systems for real-time analysis [5]. Similarly, in water monitoring systems, sensors can measure factors such as pH, temperature, and contamination levels with higher accuracy compared to traditional methods [6]. These studies demonstrate how smart sensors can continuously track environmental parameters, reducing human error and intervention.

Cloud Computing and Data Processing

The introduction of cloud computing has further enhanced IoT-based environmental monitoring by enabling massive data storage and powerful analytics capabilities. Numerous studies have highlighted the benefits of cloud computing in handling the large datasets generated by IoT sensors. For example, a study demonstrated how cloud platforms allow for the real-time processing of environmental data, leading to quicker response times in detecting pollution events. The integration of big data analytics with cloud infrastructure also enables predictive modeling, allowing organizations to foresee environmental hazards before they become [7].

Machine Learning and Predictive Analysis

Machine learning plays a crucial role in processing and interpreting the vast amounts of data generated by IoT systems. Recent research highlighted how machine learning algorithms can analyze historical environmental data to predict future trends in pollution levels, allowing for proactive rather than reactive management strategies. By training models on large datasets, systems can identify patterns that would otherwise go unnoticed, thus improving the accuracy of environmental predictions [8].

Automated Alert Systems

Automated alert systems form a critical component of IoT-enabled environmental monitoring, enabling authorities to act swiftly in the face of environmental hazards. Several studies have focused on the design and efficacy of these alert systems. For example, a study explored how early-warning systems, based on IoT sensors and cloud infrastructure, successfully mitigated the impact of chemical spills in waterways. These automated systems can instantly notify key stakeholders when pollutant levels exceed safe thresholds, allowing for timely remediation [9].

METHODOLOGY

Requirement Analysis and Role Definition

The system requires IoT sensors, cloud storage, and real-time alerts, ensuring efficient environmental monitoring while enabling proactive decision-making and intervention.

System Design and Architecture

The IoT-based environment monitoring system is designed to track environmental conditions in real time, ensuring quick responses to changes in air quality, temperature, humidity, and soil moisture. It all begins with sensors placed in the environment, collecting crucial data about these factors. The Arduino Uno microcontroller processes this data, ensuring accuracy before sending it forward. To make the system accessible even in remote areas, data is transmitted using a GPRS module, eliminating the need for constant Wi-Fi access. The collected data is stored in a cloud-based MySQL database, making it easy to retrieve, analyze trends, and generate reports. Users, including farmers, industrial workers, and general citizens, can log in through a web or mobile dashboard to check real-time updates. They can also set threshold values for different environmental conditions, ensuring they receive alerts when limits are exceeded. If everything remains within safe levels, the system takes no action. However, if pollution or extreme environmental changes are detected, immediate alerts are triggered. Notifications are sent via SMS or email, and warnings appear on the dashboard to prompt quick decision-making. For administrators, an advanced panel allows them to monitor sensor functionality, track data trends, and ensure connectivity. Machine learning further enhances the system, predicting potential hazards based on historical data. Figure 1 represents the system design and architecture of an IoT-based environmental sensor.

WORKFLOW IMPLEMENTATION

At the onset, this system incorporates environmental sensors which monitor air quality, temperature, and soil moisture levels. This unrefined information is transformed into useful data via IoT devices, such as Arduinos. For transmission, the data is formatted and prepared for sending. Using a data gateway (4G/5G), the raw data is transmitted in real time ensuring seamless connection. Once the data is captured, it is first stored in the system, after which it is processed using cloud systems like Google cloud. This makes retrieval, data storage, and computation of previously collected information efficient [10]. The operations at the backend form a structure using PHP and MYSQL, which ensures that database operations are performed and data is managed in a secure manner. On the other side, the front end is worked on by users through the intuitive web and mobile dashboards created using CSS (cascading style sheet) and HTML. Users can monitor environmental conditions in real time, visualize the data, and set the monitoring levels. The system helps significantly improve decision making by providing timely insights and warnings for better managing the environment. Figure 2 showcase the workflow and implementation of IoT devices.

Database Schema and Storage Strategy

The database is tailored to keep sensor data, user information, and alert details in real time. The database consists of several lists such as “Sensors” that stores measurements of temperature, humidity, air quality, and soil moisture along with the attributed timestamps. The “Users” table keeps users’ login information together with their roles which can either be admin, farmer or industry, and their settings. The “Alerts” table captures threshold breaches and the corresponding actions taken, such as alerts sent as well as the time taken to respond [9]. A “Device Management” table helps to track the state of the sensors and their corresponding health and connectivity log. Relational data is stored in MySQL, which allows for efficient optimization of queries and scale out into the cloud for real-time data access.

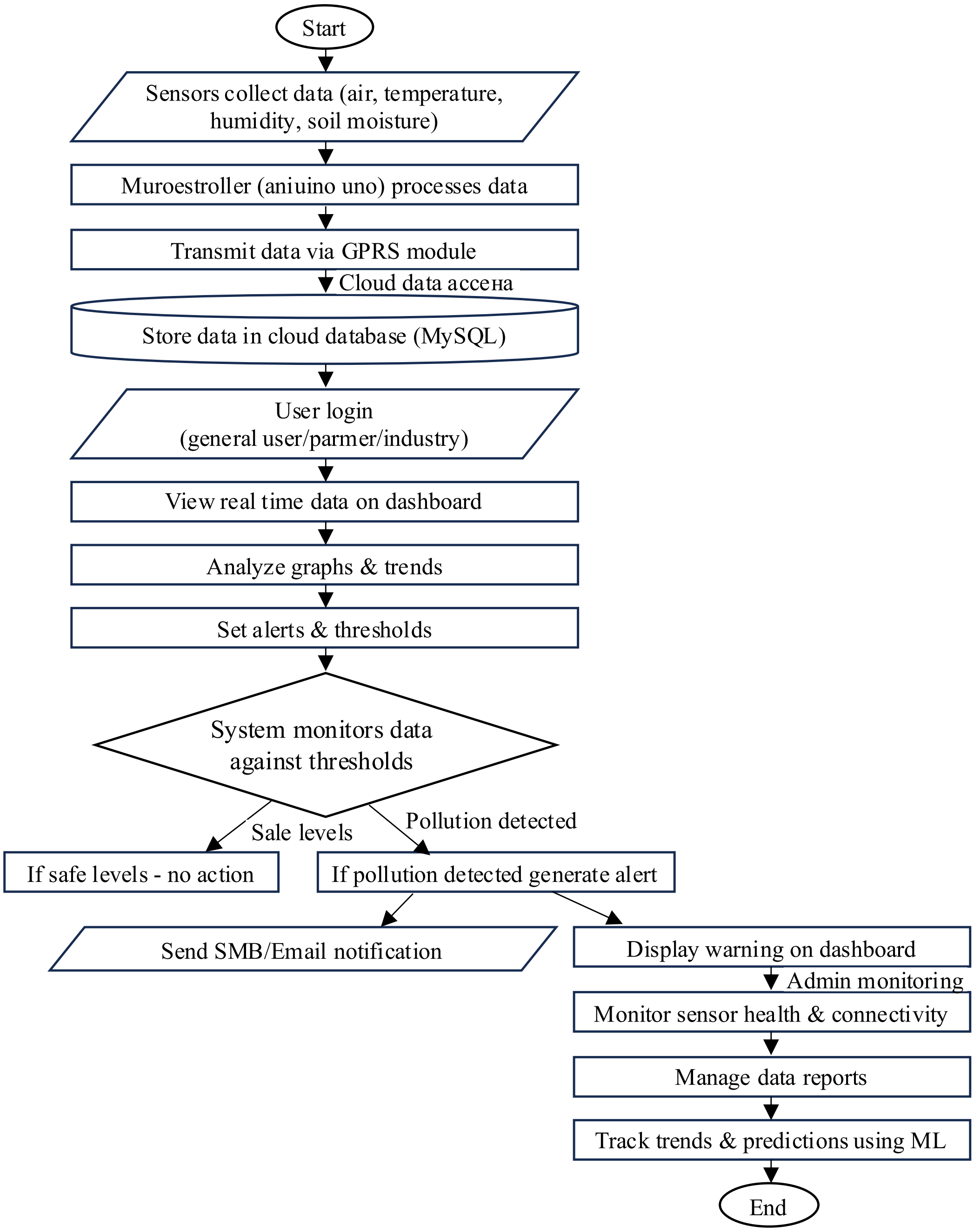

Figure 1. System design and architecture.

User Interface Development (CSS)

The user interface is designed for seamless interaction, offering a dashboard with real-time environmental data visualization. Users can access sensor readings, analyze trends through interactive graphs, and configure alerts. The responsive design ensures accessibility across web and mobile platforms, enhancing usability for farmers, industries, and administrators with intuitive navigation and controls [7].

Notification and Status Updates

The system notifies users in real time through SMS or email whenever an environmental threshold is exceeded. Users are also always provided with the dashboard's status so they can stay alerted to rapidly changing conditions.

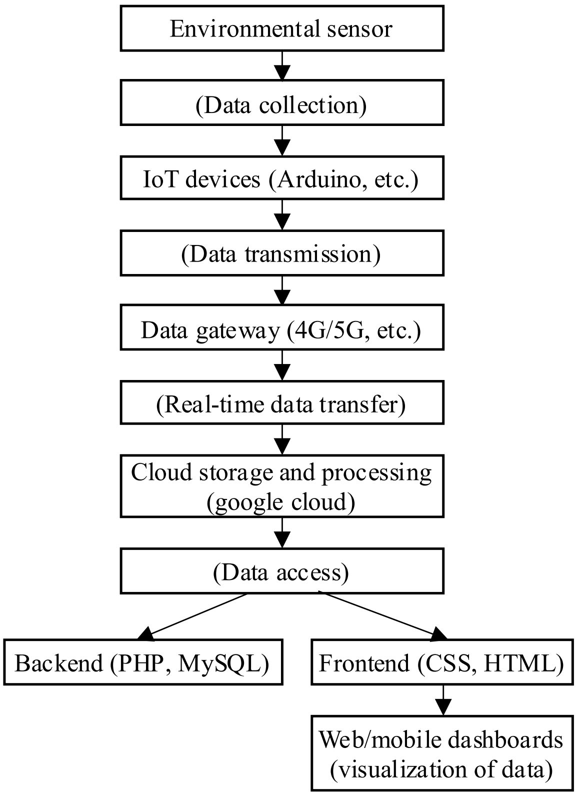

Figure 2. Workflow and implementation.

Testing and Validation

Before finally acceptance, the system goes thorough trials for verification of accuracy for the sensors, reliability for data transmission, and alerts for real time scenario. Validation includes all the checks for computer performance in terms of cross functioning and includes user experience and detailed analysis.

Deployment and Maintenance

In order to set up an IoT-enabled ecosystem monitoring system, sensors are placed on site, the microcontroller (Arduino) is configured, and a stable data transmission service over GPRS or 4G/5G is established. PHP and MySQL powered backend is hosted on cloud servers which allows the system to process and store data in real-time. The frontend, developed in HTML, CSS, and JavaScript, is hosted on a secure web server which makes it possible for users to log in and view their dashboards on mobile and web applications. The data encryption and transmission security during storage are protected by adequate firewall policies [1–4].

Yet, the system should be operated and maintained on a regular basis for smooth transactions. Taking periodic measurements to check for skips is one part of maintaining the sensor's precision. Also monitoring network goes hand in hand with preventing failure in information relay. There is an automatic procedure to create backups of the stored data and certain databases organized so that they can be accessed quickly. Real-time monitoring through the administrative panel allows proactive issue resolution by keeping track of sensor status and system performance. New system updates are rolled out regularly to improve user experience, debug problems, and add additional features. Parts like microcontrollers and sensors undergo routine checks and replacements of broken parts. Continuous oversight guarantees the system operates effectively and dependably [5]. All problems that users mention are resolved quickly to sustain extraordinary service. Effective implementation along with constant maintenance allows the system to provide dependable monitoring of the environment, timely alerts, and seamless, and environmental agencies to make accurate decisions.

Implemented Model Image

The developed model actively tracks environmental conditions, providing real-time insights and alerts to help maintain safer and healthier surroundings (Figure 3).

RESULTS

The IoT-based environmental monitoring system efficiently gathers and analyzes real-time data, helping users make informed decisions. It improves pollution detection, sends timely alerts, and provides valuable insights for a healthier environment.

1. *Data collection:* Table 1 shows the data collected during the development of IoT-based environmental sensor.
2. *Web Dashboard:* The web dashboard of the IoT-based environmental monitoring system presents an intuitive interface for users to track environmental parameters, view historical data, and manage system settings.
3. *SMS Alert:* The IoT-based environmental monitoring system is capable of sending SMS alerts to users in real-time, notifying them of critical changes in environmental conditions, such as pollution levels or other significant sensor readings.

Table 1. Data collected during the development of sensor.

IoT-Based Environment Monitoring System						
Temperature (°C)	*Humidity (%)*	*Soil Moisture*	*MQ6 Sensor*	*MQ9 Sensor*	*MQ135 Sensor*	*Date / Time*
27	21	123	13	49	57	2025-03-27 15:55:59
25	21	118	13	50	57	2025-03-27 15:52:24
25	22	128	13	51	59	2025-03-27 15:22:29
25	22	205	13	51	59	2025-03-27 15:18:19
25	20	194	13	50	59	2025-03-27 15:11:38
25	20	150	12	46	66	2025-03-15 22:27:14
25	20	145	12	46	62	2025-03-15 22:26:44
25	20	140	12	46	60	2025-03-15 22:26:13
27	20	136	12	51	54	2025-03-15 22:25:43
37	20	126	12	51	57	2025-03-15 22:25:13
30	19	123	12	52	57	2025-03-15 22:24:42
30	19	132	12	52	58	2025-03-15 22:24:12
30	20	131	12	52	58	2025-03-15 22:23:42
30	20	131	12	52	58	2025-03-15 22:23:11
30	20	132	12	52	60	2025-03-15 22:22:41
30	20	130	12	52	60	2025-03-15 22:22:10
29	20	130	12	56	60	2025-03-15 22:21:40
29	20	130	12	56	60	2025-03-15 22:21:10
29	20	130	12	56	60	2025-03-15 22:20:39
29	20	130	12	56	60	2025-03-15 22:20:09
30	20	134	17	147	153	2025-03-15 22:19:39
30	26	143	12	61	56	2025-03-15 22:18:42
30	42	124	201	51	52	2024-11-05 18:07:42
30	42	124	201	51	52	2024-11-05 18:06:41
30	42	124	201	51	52	2024-11-05 18:06:16

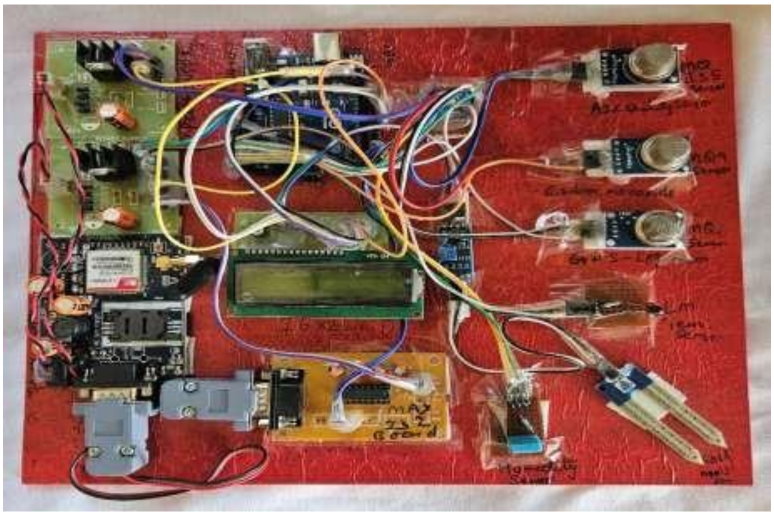

Figure 3. Model of internet of things (IoT)-based environmental monitoring system.

CONCLUSION

An intelligent and effective method of monitoring environmental factors such as temperature, humidity, soil moisture, and air quality is provided by the IoT -based environment monitoring system. It facilitates rapid warnings and data-driven decision-making through the use of Arduino, cloud storage, machine learning, and real-time dashboards. It is a powerful substitute for conventional techniques because to its cost, scalability, and capacity to operate in remote locations. Machine learning enhances proactive reactions by improving danger prediction. The system will become even quicker and more intelligent with future developments like 5G integration and AI-driven insights. This study demonstrates how IoT may promote sustainability and more successfully handle environmental issues.

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