



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 12, December 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

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Enhanced Air Quality Monitoring using Machine Learning and IoT

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ABSTRACT: With growing worries about air pollution and its negative impacts on human health and the environment, there is an urgent need for sophisticated monitoring systems that offer real-time and accurate air quality data. The Internet of Things (IoT) plays a critical role in this system, allowing for the seamless collecting of various sensor data from scattered monitoring stations. These stations are deliberately placed in order to collect a variety of contaminants and environmental factors.

Real-time data processing, predictive modelling for pollution forecasting, and adaptive learning to handle changing environmental circumstances are key characteristics of the proposed approach. The combination of ML with IoT not only improves the accuracy of air quality predictions, but also allows for proactive decision-making for pollution control actions. Furthermore, the framework provides a user-friendly interface for stakeholders to access and analyse monitored data, hence increasing public knowledge and involvement in solving air quality issues.

The suggested system's performance is confirmed through extensive experiments and case studies, indicating its capacity to outperform standard monitoring systems. The findings of this study help to develop air quality monitoring systems by providing a scalable and intelligent solution for urban and industrial contexts. The suggested methodology serves as a platform for future environmental monitoring research, giving a route towards sustainable and data-driven air quality management.

KEYWORDS: Air Quality, Machine Learning, Internet of Things (IoT), Environmental Monitoring, Carbon Monoxide (CO).

I. INTRODUCTION

In the face of growing environmental concerns, notably the negative impact of air pollution on human health and ecosystems, it is critical to enhance monitoring technology that give more detailed insights into air quality dynamics. This research presents a ground-breaking way to addressing this essential topic by merging Machine Learning (ML) approaches with Internet of Things (IoT) infrastructure for better Air Quality Monitoring. Traditional monitoring systems, while useful, frequently lack real-time data processing, flexibility to changing situations, and predictive capabilities. Our proposed framework intends to revolutionise the accuracy and scope of air quality assessment by using the strength of ML algorithms, which excel at recognising complicated patterns within large datasets, and IoT technologies, which permit extensive data collecting.

The key to our method is strategically placing scattered monitoring stations outfitted with a variety of sensors capable of gathering a wide range of contaminants and environmental factors. These stations provide real-time data into a dynamic ML model, which evolves continually via adaptive learning to improve predicted accuracy. By combining the powers of ML and IoT, our platform not only anticipates air quality trends but also enables proactive pollution mitigation decision-making. This study is not only theoretical; we give persuasive experimental data and case studies illustrating our system's greater effectiveness over conventional techniques. This work represents a watershed moment in the evolution of intelligent, data-driven air quality management, with far-reaching consequences for urban and industrial environments.

II. RELATED WORK

In this section, we review some of the previous works in the field of IoT based Air quality monitoring. In [1], Global air pollution causes major health problems in susceptible communities. The study presents a three-module system providing real-time information, reducing health hazards associated with travel. In [2], The air quality dataset for key Indian cities offers academics and policymakers with useful insights into urban environmental conditions. However, constraints such as city-centric focus and inadequate contextual data necessitate consideration in national-scale analysis for greater application and accuracy. In [3] The Nagpur air pollution research offers a thorough examination of air quality, with a focus on real-time monitoring and the Air Quality Index (AQI) application. Due to geographical and pollutant scope limitations, larger research including varied contaminants and locations are required for more effective environmental health interventions. In [4], the paper presents the CNN-ILSTM AQI prediction model, which combines Convolutional Neural Networks with Improved Long Short-Term Memory architecture. The model represents a potential development in real-time air quality predictions, demonstrating improved accuracy, low mistakes, and efficient training time, emphasising the necessity of combining deep learning techniques for effective environmental monitoring. In [5], despite its limitations, the study on pre and post-COVID-19 Air Quality Index differences throughout the world provides important insights. Future studies should strengthen analysis to better understand the dynamics of air quality amid global disturbances. In [6], Dongsheng Zhan et al.'s work sheds light on the complex elements influencing air quality in China. It identifies pollution sources, educates policy, and assesses public health consequences through rigorous analysis, making a substantial contribution to urban planning and international collaboration. In [7], The work on an aggregate Air Quality Index for Mediterranean urban regions provides a useful tool for analysing air quality. Despite certain shortcomings, this comprehensive strategy improves pollution control efficacy and educates policymaking for better air quality management. In [8], The study looks at multi-hour, multi-site AQI forecasting in Beijing using CNN, LSTM, CNN-LSTM, and spatiotemporal clustering. Variable model results show strengths and limitations, helping to develop forecasting methods. In [9], despite constraints such as payload capacity, weather sensitivity, and restrictions, using Unmanned Aerial Vehicles (UAVs) for real-time air quality monitoring delivers considerable advantages in comprehensive data, mobility, and responsiveness. In [10], Incorporating machine learning models into smart city air quality prediction offers significant promise for environmental management. While providing high precision and real-time monitoring, difficulties like as data reliance and ethical considerations must be addressed appropriately in order for urban settings to remain sustainable. In [11], Using extended ARIMA, EMD, and truncated SVD, this work presents a better hybrid model for forecasting air quality indicators at numerous sites. Future studies will overcome constraints and investigate advanced models. In [12], The research proposes a low-cost, integrated system for continuous indoor air monitoring to detect pollutants. It makes use of a sensor array and investigates three machine-learning categorization approaches. The technology, which is still being developed, intends for quick, flexible, and dependable deployment in indoor areas, particularly in public or industrial facilities. In [13], This article describes an Indoor Air Quality Detector (IAQD) system that uses Zigbee to monitor PM2.5, CO2, temperature, and humidity all at the same time. It presents a multi-point Internet of Things-based solution for more precise indoor air quality evaluation. The findings highlight environmental elements influencing air quality, with a focus on health concerns. In [14], research describes a unique method for predicting imminent air quality that combines stationary and mobile sensors. The experimental findings show that the hybrid system is successful, implying that it might be implemented in public transit for a variety of purposes.

III. METHODOLOGY

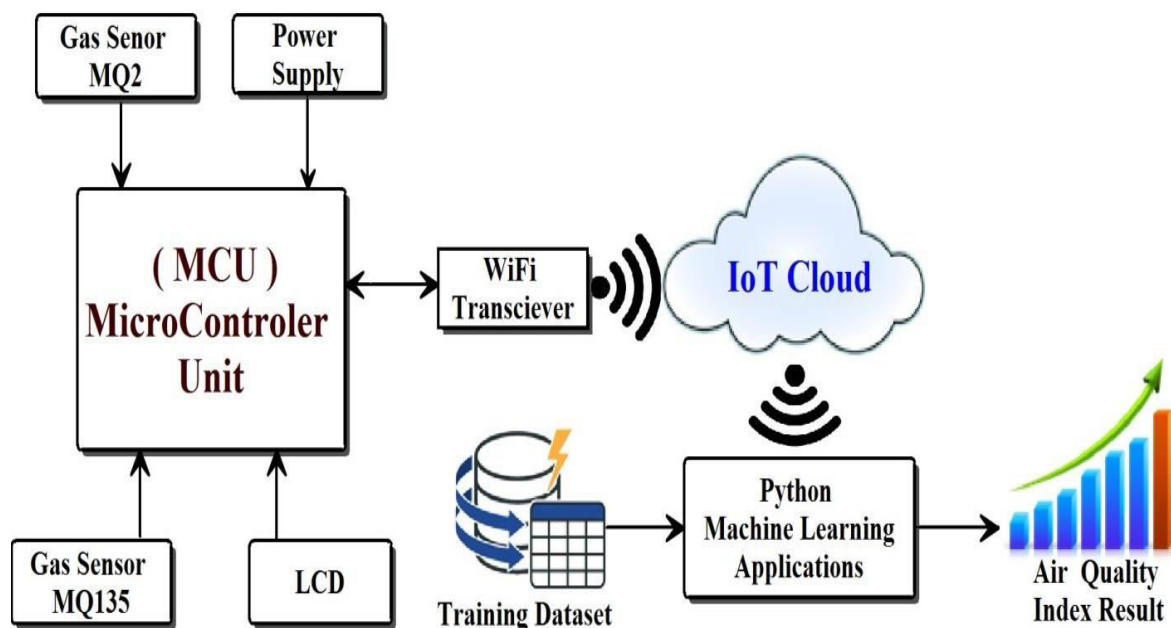
To improve Air Quality Monitoring, our technique combines Machine Learning (ML) and Internet of Things (IoT) technologies. IoT sensors are strategically placed in metropolitan areas to capture real-time data. The obtained data, which includes contaminants and environmental characteristics, is analysed for predictive analysis using ML algorithms. To interpret complicated patterns and anticipate air quality trends, we use sophisticated ML models such as Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). The model is trained using past data and constantly adjusts to changing situations, resulting in increased accuracy over time. The architecture of the system enables smooth communication between scattered sensors, allowing for broad coverage. Our technique not only predicts air quality accurately, but it also provides a scalable foundation for proactive pollution management in smart cities.

IV. PROPOSED SYSTEM

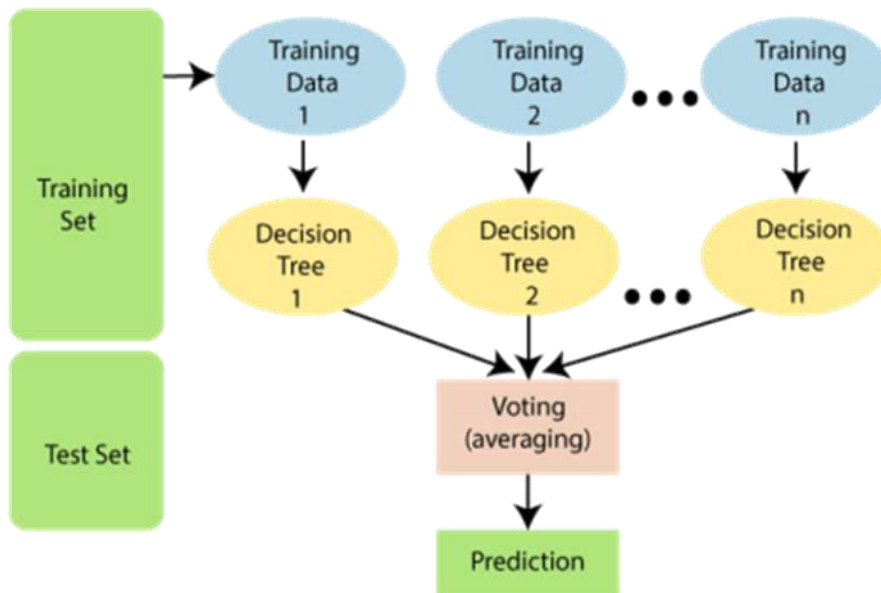
The suggested environmental monitoring system has a strong architecture that is intended for extensive data collecting and processing. Environmental data is sent to Thing Speak, a cloud server, using hardware components such as pressure, temperature, and humidity sensors and a shop floor management system. The system, which is controlled by a microcontroller unit (MCU), incorporates a gas sensor, power supply, and transmitter to assure continuous data transfer. The MCU communicates with the cloud server via a Wi-Fi transceiver, allowing for efficient data storage and retrieval. This architecture lays the groundwork for a comprehensive approach that includes data collecting, cloud-based storage, and interaction with cloud-based Python machine learning programmes.

The system's capability goes beyond data management to include predictive modelling for environmental assessment. Python machine learning programmes compute the Air Quality Index (AQI) from stored sensor data, providing useful insights into air quality. This integrated strategy not only solves real-time monitoring requirements, but it also provides the framework for future environmental forecasting. The system emerges as a holistic solution for air quality evaluation by merging hardware components, cloud connection, and machine learning capabilities, providing users with actionable information, and educated decision-making skills.

1. Proposed Framework:



- Microcontroller unit is interfaced with various Gas Sensors & LCD.
- Wi-Fi Transceiver module is used to transmit all the sensed parameter to the IOT cloud THINKSPEAK and data is relayed from cloud to Python Machine Learning application.
- Using air pollution dataset and with Machine learning technology using python this system must build a trained model which has to receive input parameters from IOT cloud thing speak and predict the Air Quality Index.



Random Forest Architecture

- o It takes less training time as compared to other algorithms.
- o It predicts output with high accuracy, even for the large dataset it runs efficiently.
- o It can also maintain accuracy when a large proportion of data is missing.
- o Random Forest is capable of performing both Classification and Regression tasks.
- o It is capable of handling large datasets with high dimensionality.
- o It enhances the accuracy of the model and prevents the overfitting issue.

V. CONCLUSION

The suggested sophisticated Air Pollution Monitoring system is a ground-breaking solution for real-time monitoring of air quality. The system assures the continuous flow of correct environmental data by utilising an integrated IoT device for data collection and transmission to a Web Server via an IoT Cloud service. The deployment of a Machine Learning-based Air Pollution classification model on the Web Server, powered by the novel Random Forest Classifier algorithm, improves accuracy and efficiency. The system can adapt and correctly categorise air pollution levels because to the dynamic Machine Learning process, which is powered by both historical and real-time data. This fuelled integrated strategy not only delivers a comprehensive and real-time solution, but also greatly contributes to increased environmental awareness and management. The suggested system exemplifies technology's ability to handle difficult environmental concerns, opening the path for more effective and proactive air quality monitoring. The Random Forest Classifier algorithm will be improved in the future, as will pollution monitoring and integration with smart city programmes. This method has the potential to become a global standard for enhanced environmental monitoring.

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