Developing an Algorithm for Air Quality Visualizer and Forecast App to Generate Granular, Real-time, and Predictive Air Quality Information

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Abstract - *Air pollution has become one of the most critical environmental and public health challenges worldwide. Rapid urbanization, industrialization, and increased vehicular emissions have significantly deteriorated air quality, affecting millions of people, particularly in densely populated cities. Existing air quality monitoring systems often provide limited spatial coverage, delayed updates, and minimal predictive capabilities, which restrict timely decision-making for both authorities and citizens. To address these limitations, this research proposes the development of an Air Quality Visualizer and Forecast Application that provides granular, real-time, and predictive air quality information through an intelligent data integration and forecasting framework.*

The proposed system integrates multiple data sources, including air monitoring stations, meteorological data, and environmental APIs such as OpenAQ and OpenWeatherMap. Pollutant parameters including PM2.5, PM10, NO_2, CO, and O_3 are processed to calculate the Air Quality Index (AQI) according to CPCB standards. A centralized data processing module stores real-time and historical information, enabling trend analysis and visualization through an interactive web-based dashboard. Machine learning and time-series forecasting models, such as ARIMA and Prophet, are used to predict AQI levels for the next 24–72 hours, allowing users and authorities to anticipate potential air quality deterioration. The application provides dynamic dashboards displaying pollutant breakdown, historical AQI trends, location-based monitoring, and predictive insights. Additionally, the system generates health recommendations based on AQI severity levels, helping users take preventive measures. By combining real-time monitoring, predictive analytics, and user-friendly visualization, the proposed system enhances environmental awareness and supports data-driven decision making for pollution control and public health planning. The framework also aims to extend air quality coverage to rural and underserved regions, ensuring equitable access to environmental information.

Key Words: **Air Quality Index (AQI), Air Pollution Monitoring, Machine Learning, Time Series Forecasting, ARIMA, Prophet, Environmental Data Visualization, Real-Time Monitoring, Predictive Analytics, Public Health.**

1.INTRODUCTION

Air pollution has become one of the most serious environmental and public health challenges worldwide. Rapid industrialization, urban expansion, and increasing vehicular emissions have significantly contributed to the deterioration of air quality in many regions. According to the World Health Organization (WHO), air pollution is responsible for millions of premature deaths every year and is considered one of the leading environmental health risks globally [1]. Pollutants such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3) have severe impacts on respiratory and cardiovascular health.

To measure and communicate air pollution levels effectively, the Air Quality Index (AQI) has been widely adopted by environmental monitoring agencies. The Central Pollution Control Board (CPCB) in India has established AQI standards that classify air quality into different categories such as Good, Moderate, Unhealthy, and Hazardous, helping citizens understand pollution levels and associated health risks [2]. However, traditional monitoring systems often rely on a limited number of regulatory monitoring stations, which leads to sparse spatial coverage and delayed updates.

Modern advancements in data analytics, machine learning, and environmental sensing technologies have created opportunities to improve air quality monitoring systems. Integrating real-time data from multiple sources such as environmental sensors, meteorological information, and satellite observations can provide more accurate and detailed insights into air pollution patterns. Additionally, predictive analytics techniques enable forecasting of future air quality conditions, allowing authorities and individuals to take preventive measures.

This research proposes the development of an Air Quality Visualizer and Forecast Application that provides granular, real-time, and predictive air quality information. The system integrates environmental datasets from APIs such as OpenAQ and OpenWeatherMap, processes pollutant data to calculate AQI, and applies time-series forecasting models like ARIMA and Prophet to predict air quality for the next 24–72 hours. The application also offers interactive dashboards, pollutant breakdowns, historical trends, and health recommendations to improve public awareness and support data-driven decision-making.

1.1 Background of Air Pollution Monitoring

Air pollution monitoring has traditionally relied on government-operated monitoring stations equipped with high-precision instruments. These stations measure pollutant concentrations and provide validated environmental data. While these systems offer high accuracy, their limited number restricts the spatial coverage of monitoring, especially in rural or underserved regions [14]. Consequently, many areas lack real-time air quality information that could help residents understand environmental conditions and protect their health.

1.2 Importance of Air Quality Forecasting

Forecasting air pollution levels plays a critical role in environmental management and public health planning. Predictive models enable authorities to anticipate pollution spikes and implement control strategies such as traffic restrictions or industrial regulations. Machine learning and time-series forecasting techniques, including ARIMA models and statistical forecasting approaches, have demonstrated effectiveness in predicting environmental variables and pollution trends [4][5]. Advanced forecasting frameworks like Prophet, developed for scalable time-series prediction, further enhance prediction accuracy and reliability [6].

1.3 Role of Data Integration and Visualization

Data visualization and integration are essential components of modern environmental monitoring systems. Platforms that combine multiple datasets and present them through intuitive dashboards allow users to easily interpret air quality conditions. Environmental data platforms such as OpenAQ provide open-access air quality datasets collected from global monitoring stations [7]. When combined with meteorological data from services like OpenWeatherMap, these datasets enable comprehensive environmental analysis and visualization [8]. Interactive dashboards displaying AQI values, pollutant concentrations, and historical trends can significantly improve public awareness and encourage informed decision-making.

1.4 Motivation of the Proposed System

Despite the availability of air quality monitoring platforms, many existing systems lack real-time predictive capabilities, hyperlocal coverage, and integrated health recommendations. Most applications provide only current AQI information without forecasting future conditions or offering actionable insights. Therefore, there is a need for a comprehensive system that combines real-time monitoring, predictive analytics, and user-friendly visualization. The proposed Air Quality Visualizer and Forecast Application addresses these challenges by integrating multiple environmental data sources, applying machine learning-based forecasting techniques, and presenting information through an interactive dashboard. By providing real-time AQI updates, pollutant breakdowns, and predictive insights, the system aims to support environmental monitoring, public health awareness, and policy decision-making.

2. PROPOSED SYSTEM

The proposed system presents a comprehensive Air Quality Visualizer and Forecast Application designed to provide granular, real-time, and predictive air quality information for different geographic locations. The system integrates environmental data from multiple sources, processes pollutant concentrations to calculate the Air Quality Index (AQI), and applies machine learning techniques to forecast future air quality conditions. Unlike conventional air quality platforms that primarily display current pollution levels, the proposed system combines real-time monitoring, historical trend analysis, and predictive forecasting within a single web-based platform. This integration enables users, researchers, and policymakers to understand current environmental conditions and anticipate future pollution trends for improved decision-making and health protection.

The system is structured around several interconnected modules that handle data acquisition, data processing, prediction, visualization, and health advisory generation. Environmental data collected from monitoring stations and public APIs is stored in a centralized database where it undergoes preprocessing and analysis. Forecasting models such as ARIMA and Prophet analyze historical patterns in pollutant concentrations and meteorological conditions to generate AQI predictions for the next 24–72 hours. The processed results are then presented through an interactive dashboard that allows users to monitor air quality conditions and receive health recommendations.

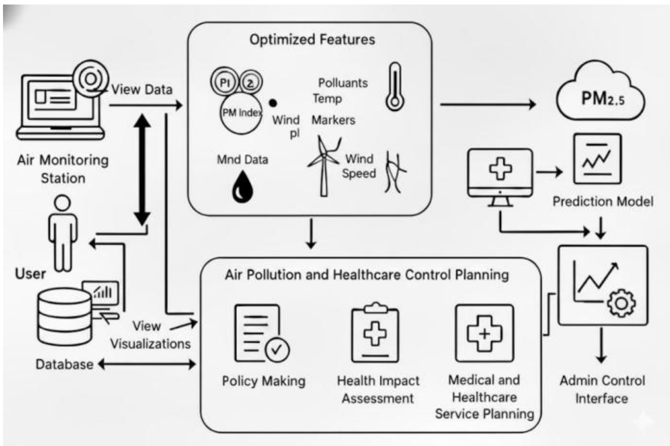

Fig. 1 illustrates the overall system architecture of the proposed Air Quality Visualizer and Forecast System, showing the interaction between data sources, processing modules, prediction models, and user interfaces.

2.1 Data Acquisition and Integration

The proposed system collects air quality and environmental data from multiple reliable sources to ensure accurate and comprehensive monitoring. Real-time pollutant measurements are obtained from environmental data platforms such as OpenAQ, which aggregate information from government air monitoring stations. In addition, meteorological parameters including temperature, humidity, and wind speed are retrieved from weather data services such as OpenWeatherMap.

These datasets contain important pollutant indicators including particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3). The integration of meteorological and pollutant data enables the system to capture environmental conditions that influence pollution dispersion and accumulation. All collected data is transmitted to a centralized database where it is stored for further analysis and forecasting.

2.2 AQI Computation and Data Processing

After collecting environmental data, the system performs preprocessing operations to clean and normalize the datasets. Pollutant concentration values are converted into standardized Air Quality Index values based on the guidelines established by the Central Pollution Control Board (CPCB). The AQI calculation module evaluates pollutant concentrations and categorizes air quality into different health-related levels ranging from good to hazardous conditions. The processed AQI values allow the system to present pollution information in a simplified and understandable format. This conversion helps users interpret environmental conditions easily and understand potential health risks associated with different pollution levels.

2.3 Air Quality Prediction Using Machine Learning

To provide predictive insights, the proposed system employs time-series forecasting techniques to estimate future air pollution levels. Historical AQI data and environmental parameters are analyzed using forecasting models such as AutoRegressive Integrated Moving Average (ARIMA) and Prophet. These models identify temporal patterns and seasonal trends within the data, enabling the system to generate accurate predictions of air quality conditions for the upcoming 24 to 72 hours.

The forecasting component helps users anticipate potential pollution spikes and take preventive measures. By incorporating predictive analytics into the monitoring system, the application enhances environmental awareness and supports proactive public health planning.

2.4 Visualization and Interactive Dashboard

The processed and predicted data is presented through an interactive web dashboard designed to provide intuitive and informative visualizations. The dashboard displays real-time AQI levels, pollutant concentrations, and historical air quality trends for selected locations. Users can monitor multiple cities simultaneously and observe variations in pollution levels over time. Graphical representations such as AQI trend charts and pollutant breakdown panels help users understand changes in environmental conditions quickly. The dashboard also supports location-based monitoring, allowing users to save and track air quality information for specific regions.

2.5 Health Advisory and Decision Support

An important feature of the proposed system is the generation of health recommendations based on AQI severity levels. When pollution levels exceed safe limits, the system automatically provides precautionary guidelines to help users reduce exposure to harmful pollutants. These recommendations may include reducing outdoor activities, wearing protective masks, or improving indoor ventilation.

In addition to supporting public awareness, the insights generated by the system can assist policymakers and environmental authorities in developing pollution control strategies and healthcare planning initiatives. By combining monitoring, forecasting, and health advisory features, the proposed system offers a comprehensive solution for managing air quality information.

3. IMPLEMENTATION DETAILS

The implementation of the proposed Air Quality Visualizer and Forecast Application focuses on developing a reliable system capable of collecting environmental data, processing pollutant concentrations, forecasting air quality levels, and presenting the results through an interactive web interface. The system is implemented using a combination of web technologies, data processing libraries, and machine learning models to ensure efficient data handling and accurate prediction of air quality conditions. The overall implementation process includes data acquisition, data preprocessing, AQI computation, forecasting model integration, and visualization through a user-friendly dashboard.

3.1 Data Acquisition and API Integration

The first stage of the implementation involves collecting real-time environmental data from reliable external sources. Air quality data is obtained through environmental data APIs such as OpenAQ, which aggregates pollutant measurements from multiple monitoring stations worldwide. Meteorological parameters including temperature, humidity, and wind speed are retrieved using the OpenWeatherMap

API. These parameters play a significant role in determining the dispersion and concentration of air pollutants. The system periodically sends API requests to retrieve updated environmental information. The retrieved data is stored in the system database, ensuring that both real-time and historical air quality records are available for analysis and forecasting.

3.2 Data Preprocessing and Storage

After data acquisition, the collected environmental datasets undergo preprocessing to improve data quality and consistency. This step includes handling missing values, removing inconsistent entries, and normalizing pollutant concentration values. Cleaned data is then stored in a centralized database that supports efficient retrieval for analysis and prediction tasks.

The database also maintains historical records of pollutant concentrations and meteorological parameters. These historical datasets are essential for identifying pollution trends and training forecasting models used in the prediction module.

3.3 AQI Calculation Module

The AQI calculation module processes pollutant concentration values and converts them into standardized Air Quality Index values according to the guidelines provided by the Central Pollution Control Board (CPCB). Each pollutant contributes to the overall AQI value based on its concentration level and health impact. The module categorizes air quality into different levels such as good, moderate, unhealthy, very unhealthy, and hazardous. This categorization allows users to easily understand the severity of air pollution and the potential health risks associated with different AQI levels.

$$AQI = \frac{(AQI_{high} - AQI_{low})}{(Conc_{high} - Conc_{low})} \times (Conc - Conc_{low}) + AQI_{low}$$

Fig - 2: Air Quality Index (AQI) Calculation Formula Based on Pollutant Concentration Breakpoints

3.4 Forecasting Model Implementation

To predict future air quality levels, the system implements time-series forecasting models including ARIMA and Prophet. These models analyze historical AQI data and identify temporal patterns, seasonal trends, and variations in pollutant concentrations. The forecasting module processes historical data and generates predictions for the next 24 to 72 hours.

The predicted AQI values enable users to anticipate future pollution levels and take preventive measures when pollution levels are expected to rise. The integration of predictive models significantly enhances the system's capability to provide proactive environmental insights.

3.5 Data Visualization and User Interface

The final stage of implementation focuses on presenting the processed data through an interactive web interface. The application dashboard visualizes real-time AQI levels, pollutant concentrations, and historical air quality trends using graphical representations such as line charts and comparison graphs. The user interface is designed to be intuitive and accessible, enabling users to easily navigate through different sections of the application. The dashboard also displays predicted AQI values and health recommendations based on pollution severity. This visual representation of environmental data helps users better understand air quality conditions and supports informed decision-making.

4. RESULTS AND PERFORMANCE ANALYSIS

The performance of the proposed Air Quality Visualizer and Forecast Application was evaluated by analyzing its ability to collect real-time environmental data, compute Air Quality Index (AQI) values, forecast future air quality conditions, and present the results through an interactive dashboard. The system successfully integrates data from environmental APIs and processes pollutant information such as PM2.5, PM10, NO_2, CO, and O_3 to generate AQI values according to CPCB standards. The developed application provides users with a comprehensive view of air pollution levels, historical trends, and predicted AQI values.

The implementation results demonstrate that the system effectively retrieves real-time air quality data and visualizes it in a structured format. Users can observe pollutant concentration levels, AQI categories, and historical variations through graphical representations displayed on the dashboard. In addition, the forecasting models generate short-term predictions of air quality conditions, enabling users to anticipate future pollution levels.

Fig. 2 shows the main dashboard interface of the Air Quality Visualizer application, where users can monitor real-time AQI values, pollutant concentrations, and air quality status for selected locations. The dashboard presents environmental information in an easily interpretable format, allowing users to quickly understand current pollution conditions.

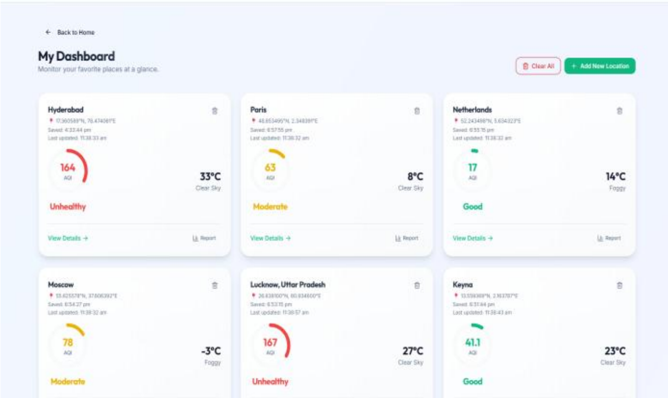

Fig - 3. Dashboard showing real-time AQI values and pollutant concentrations

The dashboard visualization provides a clear representation of pollution levels and supports location-based monitoring. By displaying real-time environmental data alongside AQI categories, the system helps users assess pollution severity and identify potential health risks associated with poor air quality.

The forecasting component of the system analyzes historical AQI data and generates predictive results for upcoming hours or days. The prediction module evaluates pollutant trends and meteorological conditions to estimate future AQI values. These predictions allow users and authorities to anticipate pollution spikes and take preventive actions.

Fig. 3 illustrates the AQI trend visualization and prediction results generated by the forecasting module. The graph displays historical AQI data along with predicted air quality levels, enabling users to analyze pollution trends and understand expected changes in environmental conditions.

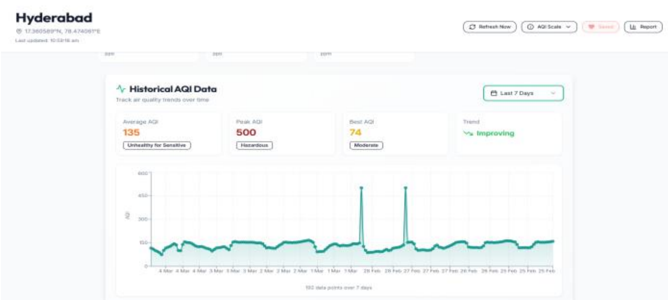

Fig - 4. AQI trend analysis and prediction results

The experimental results indicate that integrating real-time monitoring with machine learning-based forecasting significantly improves the usability of air quality monitoring systems. The proposed system successfully provides detailed environmental insights, predictive analysis, and health-related recommendations, making it a valuable tool for environmental awareness and public health protection. Overall, the results confirm that the developed system effectively combines data acquisition, AQI computation, forecasting models, and visualization techniques to deliver accurate and user-friendly air quality information. The application demonstrates the potential of intelligent environmental monitoring systems in supporting pollution control strategies and promoting sustainable urban development.

5. CONCLUSIONS

Air pollution has become a critical environmental and public health issue that requires effective monitoring and timely decision-making. The proposed Air Quality Visualizer and Forecast Application was developed to provide granular, real-time, and predictive air quality information through an integrated data-driven framework. The system successfully combines environmental data from multiple sources, including air quality monitoring APIs and meteorological services, to generate accurate Air Quality Index (AQI) values and visualize pollution conditions through an interactive web-based dashboard.

The implementation of the system demonstrates that integrating real-time monitoring with machine learning and time-series forecasting techniques can significantly improve the accessibility and usefulness of air quality information. Forecasting models such as ARIMA and Prophet analyze historical environmental data to predict future AQI levels for the next 24 to 72 hours, enabling users to anticipate pollution trends and take precautionary measures in advance. The dashboard visualization further enhances user understanding by presenting pollutant concentrations, AQI categories, and historical trends in an intuitive format.

In addition to monitoring and prediction, the system also provides health recommendations based on AQI severity levels. This feature helps individuals reduce exposure to harmful pollutants and supports public awareness about environmental health risks. By combining real-time monitoring, predictive analytics, and health advisory capabilities, the proposed system offers a comprehensive solution for improving air quality awareness and supporting environmental decision-making.

Overall, the developed application demonstrates the potential of intelligent environmental monitoring systems in addressing the challenges of air pollution. The proposed framework can assist policymakers, researchers, and citizens in understanding pollution patterns, predicting environmental changes, and implementing strategies to improve air quality and protect public health.

6. FUTURE WORK

Although the proposed Air Quality Visualizer and Forecast Application successfully provides real-time monitoring, visualization, and short-term prediction of air pollution levels, several improvements can be made to enhance the system's capabilities in the future. The current system focuses on integrating environmental APIs and forecasting AQI values using time-series models; however, additional technologies and data sources can further improve prediction accuracy and system functionality. In future work, the system can be extended by incorporating advanced deep learning models such as Long Short-Term Memory (LSTM) and Recurrent Neural Networks (RNN), which are highly effective for analyzing sequential and time-series data. These models can improve the accuracy of air quality forecasting by capturing complex temporal patterns and long-term dependencies in environmental datasets.

Another possible enhancement is the integration of satellite-based environmental monitoring data and Internet of Things (IoT) sensor networks. By combining satellite observations with ground-based sensors, the system can provide more precise and hyperlocal air quality information, particularly for rural and underserved regions where monitoring stations are limited. The application can also be expanded into a mobile platform to improve accessibility and usability for a wider range of users. A mobile application with push notifications could alert users when pollution levels exceed safe thresholds, allowing individuals to take immediate precautionary measures. In addition, future versions of the system could incorporate pollution source identification and mapping techniques to determine the major contributors to air pollution in specific areas. This feature would help environmental authorities and policymakers develop targeted pollution control strategies.

Finally, integrating advanced visualization tools and geographic information systems (GIS) can further enhance spatial analysis and allow users to explore air quality patterns across different regions. These improvements would make the system more effective in supporting environmental monitoring, public awareness, and sustainable urban planning.

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