Review on Prediction of Air Pollution in Specific City

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Abstract - Air pollution has become a serious environmental and public health issue in urban areas, driven by factors such as rapid urbanization, increased vehicular traffic, and industrial activities. Predicting air pollution in a specific city is challenging due to the dynamic and interrelated nature of influencing factors, including weather conditions, traffic patterns, seasonal variations, and geographical characteristics. In addition, issues such as incomplete or noisy data, limited real-time availability, and the difficulty of selecting suitable prediction models reduce forecasting accuracy. These challenges highlight the need for an efficient, localized, and real-time air pollution monitoring and prediction system.

To address these issues, this system proposes a low-cost air pollution prediction system using an ESP32 microcontroller integrated with MQ-135, DHT11, and PM2.0 sensors. The system continuously monitors harmful gases, particulate matter, temperature, and humidity, and transmits the collected data wirelessly for further processing. Machine learning techniques are applied to analyze historical and real-time data to predict future air quality levels and classify them according to standard AQI categories. The predicted results are displayed on a web or mobile dashboard, with alerts generated when pollution exceeds safe limits. This system supports early warning, effective air quality management, and smart city development while improving public awareness and public health protection.

Key Words: Esp32 Mq135,Dht11,Pm2.0 dust sensor ,I2C Lcd16x2 ,Zero PCB,Jumper wires

1.INTRODUCTION

Accurate prediction of air pollution in specific cities is challenging due to the complex interplay of multiple dynamic factors. Reliable data collection is often hindered by incomplete, noisy, or inconsistent measurements from monitoring stations, reducing the effectiveness of predictive models. such as Delhi consistently exhibiting extremely poor air quality. Monitoring and predicting air pollution in urban environments is essential Urban air pollution is a major environmental and public health concern, contributing to respiratory and cardiovascular diseases worldwide. India experiences some of the highest pollution levels globally, with average PM2.5 concentrations of approximately 50.6 µg/m³, far exceeding the World Health Organization's safe guideline of 5 µg/m³. Notably, six of the ten most polluted cities in the world are located in India, with metropolitan areas to enable timely interventions, safeguard public health, and promote sustainable urban living.Weather variables such as temperature, humidity, wind speed and direction, and rainfall significantly influence pollutant dispersion and fluctuate frequently, complicating forecasting. Traffic density, industrial emissions, seasonal variations, and geographic features further contribute to spatiotemporal variability in air quality. In addition, the selection of appropriate machine learning or statistical models is non-trivial, as algorithm performance varies with data characteristics, and issues such as overfitting or underfitting can reduce prediction accuracy. High computational demands, limited real-time data availability, and differences in pollution sources between cities present additional technical challenges. Effective interpretation and integration of prediction results into existing infrastructure are also critical for practical implementation.

Recent advances in low-cost sensor technologies and embedded systems offer promising solutions for continuous air quality monitoring and forecasting. Systems integrating the ESP32 microcontroller with sensors such as MQ-135, DHT11, and PM2.0 enable real-time measurement of harmful gases, particulate matter, temperature, and humidity. The ESP32 collects and processes sensor data, applies filtering to reduce noise, and transmits it via Wi-Fi to cloud or local databases. Machine learning models trained on historical air quality data can then predict future pollution levels, classify air quality based on standard indices, and provide timely alerts when pollutant concentrations exceed safe limits. Such systems offer a scalable, economical, and efficient alternative to traditional monitoring stations, which are often costly and spatially limited.

The deployment of predictive air quality monitoring systems is particularly relevant for smart city development. By providing localized and real-time information, these systems enable citizens to take preventive health measures and support authorities in planning effective pollution mitigation strategies. Furthermore, predictive insights raise public awareness of pollution trends and contribute to long-term environmental management. Overall, low-cost sensor-based air quality prediction systems represent a practical and effective approach to addressing urban air pollution challenges and improving public health outcomes.

2. Body of Paper

Air pollution prediction in a specific city is challenging due to dynamic environmental, seasonal, and human-related factors. Accurate data collection is difficult because monitoring stations may generate incomplete or noisy data. Weather conditions such as temperature, humidity, wind speed, and rainfall significantly influence pollutant levels. Traffic density, industrial emissions, and seasonal variations further increase prediction complexity. Selecting suitable machine learning models is also challenging due to issues like overfitting, underfitting, and high computational requirements.

To address these challenges, the proposed system uses an ESP32 microcontroller integrated with MQ-135, PM2.0, and DHT11 sensors for real-time monitoring. The sensors measure harmful gases, particulate matter, temperature, and humidity. The ESP32 collects and processes sensor data, applies basic filtering, and transmits it to a cloud server using Wi-Fi. A machine learning model analyzes real-time and historical data to predict future air quality levels. The system classifies air quality based on AQI standards and displays results on a web or mobile dashboard with alert notifications.

This system is necessary because existing monitoring stations are costly and limited in coverage. The proposed solution provides a low-cost, scalable, and efficient method for continuous monitoring and early warning. It supports smart city development and helps citizens and authorities take preventive measures against harmful pollution levels.

3.Litreture survey

1. Air Quality Analysis & Prediction Using Machine Learning: Pune Smart City Case Study by Pranav Sonawane and P. Mahalle focuses on real-time air quality prediction specifically for Pune city. The study employs machine learning regression models to forecast air pollution levels, offering city-specific insights for local policymakers. While the methodology provides timely predictions, its applicability is limited to the context of Pune, reducing generalizability to other cities.

2. Spatiotemporal Deep Learning Model for Citywide Air Pollution Interpolation & Prediction by W.-D. Le, T.-C. Bui, and S.-K. Cha proposes a spatiotemporal convolutional neural network (CNN) approach for citywide air pollution forecasting. The model is noted for its high accuracy in interpolating and predicting pollution across urban areas. However, it involves high computational complexity, which may limit its real-time application.

3. Air Pollution Prediction Using Deep Learning by K. Saisadhana and G. Sravya employs machine learning regression models for real-time air quality prediction in Pune. The approach effectively supports forecasting tasks but faces challenges due to limited data availability, which can impact model performance and robustness.

4. Air Pollution Prediction by Deep Learning Model by S. Jeya and L. Sankari utilizes spatiotemporal CNNs to provide predictive insights into citywide air pollution. This method is strong in predictive capability but prone to overfitting, particularly when applied to smaller datasets.

5. Air Quality Prediction Model Based on Spatio-Temporal Graph Convolution Neural Networks by W. Shi and A. Song applies deep neural networks for accurate air pollution forecasting. The approach captures both spatial and temporal dependencies effectively but is computationally complex, posing challenges for large-scale deployment.

6. Bi-LSTM Based Air Pollution Risk Likelihood Prognostic using Ensemble Approach by S. Sharan, P. Bansal, and A. Dev leverages LSTM and GRU models combined with ensemble techniques to predict future pollution levels. The method achieves high accuracy but

suffers from slow training times due to the complexity of recurrent networks and ensembles.

7. Air Pollution Prediction with Machine Learning: A Case Study of Indian Cities by Kumar et al. implements Spatio-Temporal Graph Convolutional Networks (ST-GCN) for modeling air quality across multiple cities. This multi-city approach handles diverse datasets but faces challenges due to data variation and inconsistency across urban regions.

8. Spatiotemporal Graph Convolution Recurrent Neural Network Model for Citywide Air Pollution Forecasting by ArXiv authors integrates Bi-LSTM with ensemble methods to predict pollution risk. The model is advanced and highly effective, but its complexity requires careful tuning and significant computational resources.

9. HighAir: Hierarchical Graph Neural Networks-Based Air Quality Forecasting Method by Sasaki and Harada employs random forest and XGBoost across multi-scale urban datasets in India. The method supports multi-scale analysis but requires dense datasets for optimal performance.

10. Airex: Neural Network-Based Air Quality Inference in Unmonitored Cities by Sasaki and Yamasaki develops ST-GCRNN to forecast citywide pollution in unmonitored areas. While it effectively infers missing data, the approach is heavily data-dependent and may underperform with limited historical records.

11. Air Pollution Prediction in Smart Cities, Deep Learning Approach (Authors not specified) leverages graph inference neural networks to estimate PM2.5 levels in cities lacking monitoring infrastructure. The model shows potential for unmonitored regions but is constrained by limited datasets, affecting reliability.

12. Air Quality Prediction in Smart Cities Using ML Technologies by D. Iskandaryan and F. Ramos provides a comprehensive review of machine learning approaches for smart city air quality prediction. While the review is thorough, some methodologies discussed are outdated, which may limit practical applicability.

13. Predicting Air Quality Index Using Attention Hybrid Deep Learning and Quantum Inspired Particle Swarm Optimization by Nguyen A.T. and Pham D.H. integrates attention-based deep learning with quantum-inspired particle swarm optimization to enhance AQI prediction. This hybrid approach is innovative and powerful, yet its complexity may limit ease of implementation.

14. Revolutionizing Air Quality Forecasting in Bengaluru with Advanced Machine Learning Techniques by A. Neeraja and T.V. Smitha deploys ensemble machine learning models for practical air quality forecasting in Bengaluru. The methodology is effective locally, but its scope is limited to the specific city context.

15. Air Quality Forecasting and Rating Based on Machine Learning Algorithm and Cumulative Logit Model by Ting Xu and Yuzhu Tian combines machine learning algorithms with a cumulative logit model to predict and rate air quality in Lanzhou. This approach integrates predictive modeling with rating systems but is city-specific, which limits wider applicability.

4.Sensor Trends

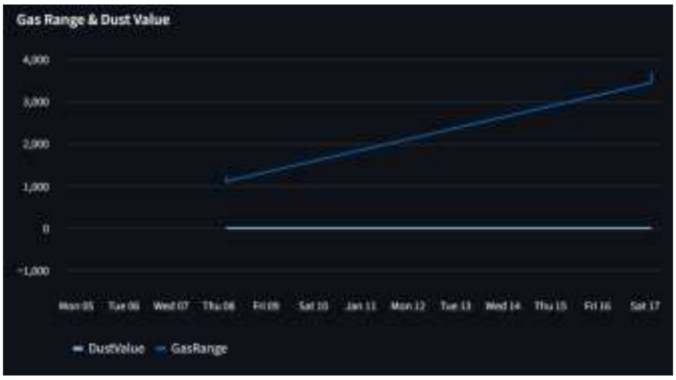

Fig 1: Gas Range & Dust Value

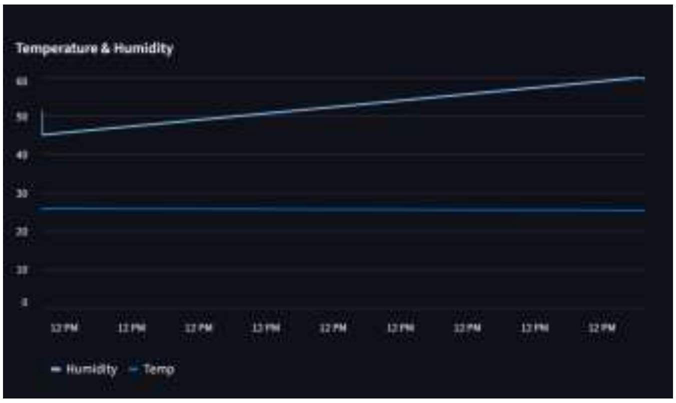

Fig 2: Temperature & Humidity

5. CONCLUSIONS

This review highlights the growing importance of accurate air pollution prediction in urban environments, where rapid urbanization, traffic growth, and industrial activities significantly impact air quality and public health. The surveyed literature demonstrates that machine learning and deep learning techniques, including spatiotemporal models, graph neural networks, and ensemble approaches, have substantially improved air quality forecasting performance. However, these methods often face practical limitations such as high computational requirements, dependency on large and high-quality datasets, limited real-time applicability, and reduced generalization across different cities. Additionally, variations in meteorological conditions, seasonal patterns, and pollution sources introduce further complexity into prediction tasks.

The review also reveals that many existing approaches rely on costly infrastructure or centralized monitoring systems, restricting large-scale and localized deployment. Recent advancements in low-cost sensor technologies and embedded systems offer promising alternatives by enabling continuous, real-time air quality monitoring at finer spatial resolutions. Integrating such sensor networks with machine learning-based prediction models can enhance forecasting accuracy while reducing deployment and maintenance costs. Furthermore, effective visualization and alert mechanisms play a crucial role in translating predictive insights into actionable information for policymakers and the public.

Overall, the findings suggest that future air quality prediction systems should emphasize scalability, real-time operation, robustness to data uncertainty, and adaptability to city-specific conditions. A hybrid approach combining low-cost sensing, efficient data processing, and intelligent predictive models holds significant potential for smart city applications and sustainable urban development. This review underscores the need for interdisciplinary research to develop reliable, accessible, and impactful air pollution forecasting solutions.

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