Chapter 10
AI-Powered Enhanced Air Quality Monitoring

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ABSTRACT

Air monitoring assesses atmospheric quality by analyzing data on pollutants and environmental factors, tracking parameters like temperature and pollutant levels to detect hazards and guide air quality management. This chapter introduces air monitoring fundamentals and explores AI's role in enhancing these activities. Beginning with the principles of air quality monitoring, it examines advanced methods for data collection and AI-driven analysis. Emphasis is placed on sensors that gather real-time data on pollutants and temperature, using machine learning models to predict future air quality from real-time and historical data. This predictive approach identifies issues like pollutant surges and temperature spikes. Additionally, the chapter highlights AI's role in creating energy-efficient monitoring systems, optimizing energy use while ensuring accurate real-time data analysis.

INTRODUCTION

Air quality monitoring has become increasingly critical as industrialization, urbanization, and population growth have led to significant air pollution. Poor air quality affects millions of people worldwide, contributing to respiratory diseases, cardiovascular problems, and premature deaths. Traditionally, air quality monitoring has relied on fixed monitoring stations equipped with standardized sensors. However,

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such methods are often limited in their spatial and temporal resolution, providing only localized insights and delayed responses to dynamic environmental changes.

Recent advances in artificial intelligence (AI), machine learning (ML), and sensor technologies offer a transformative approach to monitoring air quality. By integrating AI-powered techniques, air quality monitoring systems can now provide real-time, high-resolution data, predictive analytics, and more efficient decision-making processes. These systems leverage a network of advanced sensors, IoT devices, satellite data, and AI algorithms to analyse and predict pollution patterns, offering a comprehensive and adaptable solution to environmental monitoring challenges. The advent of AI in air quality monitoring signifies a paradigm shift, enabling us to tackle the pressing challenges of environmental health in a more precise, efficient, and scalable manner. Multisensory fusion of air pollutant data plays a critical role in improving the well-being and comfort experienced by occupants. By integrating data from multiple sensors, these systems provide a more holistic and precise understanding of air quality, enabling the environment to be optimized for health and comfort.

AI-powered technologies for air quality monitoring have revolutionized how air pollution is detected, analysed, and managed. These technologies leverage advanced machine learning (ML) algorithms, big data analytics, and Internet of Things (IoT) devices to enhance the efficiency and accuracy of air quality monitoring systems. Some of the key AI-powered technologies for air quality monitoring include machine learning models for data prediction and analysis, sensor networks and IoT devices, satellite remote sensing with AI integration, AI-based image processing for pollution detection, AI for energy-efficient air quality monitoring systems.

Air quality monitoring has become increasingly vital due to the growing concerns over pollution and its impact on public health and the environment. Traditional methods, which rely on fixed monitoring stations, are often expensive, have limited spatial coverage, and are unable to provide real-time data in a distributed manner. Wireless Sensor Networks (WSNs) offer a transformative solution by enabling decentralized, scalable, and real-time air quality monitoring across large geographic areas. The key components of WSN-based air quality monitoring systems include environmental sensors, wireless communication protocols, data aggregation and transmission. One of the challenges of WSN-based air quality monitoring is energy consumption. While WSNs are designed for low energy consumption, managing the energy needs of large-scale networks can be a challenge. Nodes that frequently transmit data or operate in high-pollution areas may require more frequent battery replacements or energy-harvesting techniques.

This chapter explores the evolution of air quality monitoring through energy-efficient sensor-based air quality monitoring systems focusing on how data collection, analysis, and predictive capabilities can be optimized. It discusses the algorithms used, their integration with environmental sensors, and real-world applications.

1. WSN-BASED AIR QUALITY MONITORING

Wireless Sensor Network (WSN)-based air quality monitoring is a cutting-edge approach that leverages the power of decentralized, low-cost, and scalable sensor networks to continuously track and analyze air pollution levels in real time. WSNs consist of spatially distributed sensor nodes that communicate wirelessly, allowing data on air pollutants and environmental parameters to be collected, transmitted, and analysed efficiently. The data collected by the sensors is aggregated and sent to a central location