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Air and Noise Pollution Monitoring Systems: A Critical Review

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Abstract: ***Air and noise pollution are serious environmental issues that must be addressed if sufficient monitoring is required for the world to achieve sustainable growth while preserving a healthy society. With advancements in the internet of things (IoT) and the creation of sophisticated sensors, environmental monitoring has evolved into a smart environment monitoring (SEM) system in recent years. An energy efficient and cost-effective air and noise pollution management system are constructed by many workers. In this context, the current publication attempts to provide a critical assessment of significant contributions and research works that involve monitoring of air quality and noise quality. System uses air sensors to sense the presence of harmful gases/compounds in the air and transmit the data to the microcontroller continuously. The system also measures noise level and reports it to the online server over IOT/ interfaced with raspberry pi to detect pollution in the environment. The air quality sensors interact with a microcontroller which processes the data and transmits it over the internet. If the air quality deteriorates below permissible level and noise pollution exceeds above permissible level, the system alerts the administration / security to take necessary measures to control the issues. A comprehensive and detailed review of the existing methods of air and noise quality monitoring systems is done along with their comparisons.***

Keywords: air pollution, noise pollution, monitoring systems, Internet of Things IoT, and environmental monitoring

1. Introduction

In terms of air quality, India is the world's second most polluted country. Air pollution reduces the average Indian life expectancy by 6.3 years when compared to the World Health Organisation (WHO) standard. Delhi and its surrounding region score significantly worse than the national average, with air pollution reducing life expectancy by more than ten years. Ninety-four percent live in locations where air quality surpasses India's own limits. Every year, air pollution contributes to the early deaths of 2 million Indians. Arun Raj *et al*. (2017) define air pollution as the presence of one or more contaminants in the atmosphere, such as gases, in sufficient quantities to affect humans, animals, and plants. Any change in the natural composition of air may pose serious injury or life-threatening diseases to Earth's life forms. Air pollution can cause breathing difficulties, coughing, bronchitis, pneumonia, lung cancer, and other respiratory disorders (Leman and Hidayah, 2013; Matthews *et al*., 2018). Air pollution is mostly caused by fuel contamination, transportation congestion, and greenhouse gas emissions. The Air Quality Index (AQI) measures the level of pollution in the atmosphere. The higher the AQI value, higher the pollution and greater the health risk. The AQI is divided into six categories, each of which is represented by a distinct colour (Anonymous, 2022). The colour allows people to quickly determine whether the air quality in their communities has reached unsafe levels. An AQI of 50 or less (green colour) indicates good air quality. When AQI values exceed 100, air quality becomes unhealthy: initially for some vulnerable groups of individuals, then for everyone as AQI values advance. An AQI value of 300 or above (maroon colour) indicates hazardous air quality. For AQI, there are five primary air contaminants specified. These are: ground-level ozone, particulate matter (PM2.5 and PM10), carbon monoxide, sulphur dioxide, and nitrogen dioxide.

Noise is something unwanted or disturbing sound which either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one's quality of life. Noise pollution rules have defined the acceptable level of noise in different zones for both daytime and night-time. In industrial areas, the permissible limit is 75 dB for daytime and 70 dB at night. Use of loudspeakers, blowing horns, sound systems during marriages has led to serious health threats like hearing loss or impaired, increasing stress levels, behavioural and mental problems, insomnia, heart ailments, hypertension and many more.

It is a need of hour to develop air quality and noise management systems which will alert the administration and people to take measures to control these burning issues. In the past decade, human life has changed because of the internet. The Internet of Things (IoT) has been considered as one of the major developments to be realized throughout the internet portfolio of technologies. The Internet of Things is a network of physical objects or devices that are linked to one another. These devices collect data and share it among themselves over the internet. IoT plays a significant role in the development of pollution monitoring systems as well as the effective approach to monitor the pollution level in a specific area on a regular basis. The Internet of Things and connected modules will aid in the analysis of pollution levels. Through this data, efforts to manage pollution can be taken, resulting in a reduction in the consequences of pollution on human health, living beings, and the surrounding environment.

With rapid advancements in transportation and industry, air and noise pollution has become a severe concern for developing nations like India, drawing more attention from both the public and the government. If air and noise quality continue to deteriorate, the expense of pollution may become a significant burden for governments. Inevitably as a consequence, pollution monitoring systems are quite beneficial before the situation deteriorates. The present review is an attempt to collect all the available literature on monitoring of pollution parameters, architecture used in monitoring systems, IoT based applications, sensor devices and machine learning algorithms in monitoring systems and are presented systematically under different sub heads.

Monitoring of pollution parameters

Monitoring is an approach for assessing the amount of air pollution within an area. Installing an air quality monitoring system aids in the detection of pollutants and reveals the state of the air we breathe. The long-term data allows stakeholders to figure out patterns that help support air pollution control policies, which results in better environmental conditions for humans to live in and minimizes the likelihood of any health issues developing by ensuring a moderate ambiance.

Malik and Adria (2003) and Sankhe *et al*. (2017) reviewed some of the research work done for pollution monitoring systems in a wide area for creating a smart environment, as well as the many methodologies and algorithms used. Architectures, applications, and design issues in general were also addressed. They emphasised in their work how smart environments signify a trend towards improved automated environmental monitoring through the association of wireless sensing devices with environmental events and phenomena. Environmental behaviours were actively collected as a streaming database to determine environmental circumstances and efficient decision making; sensor distribution was also offered, dissemination by sensors was also provided.

Using Arduino, XBee modules, and micro gas sensors, a low-cost wireless sensor network system for indoor air quality monitoring was designed (Abraham and Li, 2014). The system developed is capable of collecting six air quality parameters from different locations simultaneously. A linear least square estimation-based method was used for sensor calibration and measurement data conversion.

Architecture used in monitoring system

Sankhe *et al*. (2017) and Singh *et al*. (2017) furnished a description of the integrated network architecture and the interconnecting mechanisms for the reliable measurement of parameters by smart sensors and data transmission via the internet. The longitudinal learning system could provide a self-control mechanism for better device operation during the monitoring stage. The monitoring system's structure was built around a combination of pervasive distributed sensing units, an information system for data aggregation, and reasoning and context awareness. The dependability of sensing information transfer via the proposed integrated network architecture is 97 percent, which is encouraging. Rather than a test bed scenario, the prototype was evaluated to generate real-time graphical information (Kaur et al., 2016).

In conjunction with a web server, Nayak *et al*. (2017) created an IoT-based air pollution monitoring system that triggered an alarm whenever the air quality drops below the acceptable threshold. The model displays the air quality in parts per million on a Liquid Crystal Display (LCD) screen and on a webpage in order to achieve real-time monitoring. Using a Raspberry Pi, noise and air pollution levels in the environment were detected in another Internet of Things project (Kumar *et al*., 2017). Okokpujie *et al*. (2018) devised a model that monitors and analyses air quality in real time and logs data to a remote server, keeping the data updated over the internet. Using an Arduino Uno microcontroller, Wi-Fi module 8266, MQ135 Gas Sensor, and a 16 by 2 liquid crystal display (LCD) screen, the model estimated air quality in parts per million (PPM).

Borate *et al*. (2018) presented a conceptual versatile, flexible, and cost-effective architecture for monitoring a specific site's air and sound quality via IOT. The system employs air sensors to detect the presence of potentially hazardous gases/compounds in the air and constantly communicates this data. An IoT-based air pollution monitoring system was deployed in conjunction with the forthcoming, long-range communication medium LoRa to showcase real-time data at all critical locations in the city (Walling *et al*., 2019). The authors conducted an empirical investigation to demonstrate that LoRa operates better in broad deployment areas, is advantageous, and is also cost effective.

Jo *et al*. (2020) created an IoT-based indoor air quality monitoring platform consisting of an air quality-sensing device entitled "Smart-Air" and a web server. This platform relies on IoT and cloud computing technology to monitor indoor air quality in real time and from anywhere. Smart-Air was created to efficiently monitor air quality and communicate data to a web server through LTE in real time. The device is composed of a microcontroller, pollutant detection sensors, and LTE modem to measure a concentration of aerosol, VOC, CO, CO_2, and temperature-humidity.

IOT based applications

The Internet of Things (IOT) is focused on connecting together communicating things. The internet of things concept is useful in achieving real-time monitoring of sensor data. IOT is based on information sensing equipment such as RFID, infrared sensors, GPS, laser sensors, and so on to exchange information in accordance with protocols that provide intelligent information, location tracking, monitoring, and management. The Internet of Things (IOT) is a networked system in which matter and people are given limited identities and the ability to move data without the necessity for two-way human-to-human (source-to-destination) or human-to-computer (human-to-computer) communication. As a result, many researchers (Marques *et al*., 2019; Taştan and Gökozan, 2019) have investigated an integration of these technologies into indoor air quality monitoring systems. Combining these new technologies, which include a wireless sensor network that automatically transmits, processes, analyses, and visualises data, can result in considerable improvements in indoor air quality (Ghayvat *et al*., 2015).Wireless sensor networks (WSN), a critical component of IoT, were the focus of middleware concepts (Ghayvat *et al*., 2015; Gupta and Rakesh, 2018).

A few workers have discussed IoT-based projects that predict outdoor air and noise pollution. An IOT-based air pollution monitoring system is used to monitor air quality over a web server connected to the Internet. It generates an alert when the air quality falls below a certain level, indicating that there are sufficient amounts of harmful gases present in the air like CO_2, smoke, alcohol, benzene, NH_3 and Nox (Deshmukh *et al*., 2018).

Saiye and Ajose-Ismail (2020) developed Smart-Air using IoT technology to efficiently monitor air quality and transmit information to a web server through LTE in real time. A microcontroller, pollutant detection sensors, and an LTE modem comprise the developed low-cost device. Arduino Uno microcontroller was used as the backbone to develop the wireless sensor network system. With IoT monitoring, one can analyze dynamic systems and processes, billions of events and alerts. IoT monitoring also enables us to bridge the gap between devices and business by collecting and analyzing diverse IoT data at web-scale across connected devices, customers and applications.

Verma *et al.* (2020) presented an assessment of existing Multimedia Big Data (MMBD) computing approaches and architectures for Internet of Things (IoT) applications in Precision Agriculture, highlighting opportunities, issues, and challenges. As a consequence of the digital revolution and ease of availability of electronic devices, a massive amount of data is being acquired from a variety of sources. On the one hand, this enormous quantity of multimedia data offers numerous obstacles, from storage to transmission; on the other hand, it presents a chance to provide insight into business trends, intelligence and render rich decision support. According to Hase *et al.* (2022), the Internet of Things (IoT) is a global network of "smart gadgets" that perceive and communicate with their environment, as well as interact with humans and other systems. The air elements will be displayed in PPM on the display and on the website so that we can readily monitor them.

Sensor devices

To collect data from the atmosphere or its contents, a variety of sensors are utilised. Ultrasonic sensors are used to measure the distance between the Garbage Bin lids. The IoT Platform integrates the fire alarm and monitoring systems which can detect smoke, temperature changes, and flames, among other things. The data from these sensors is essentially analogue which is then digitally transformed. The system also required a Wi-Fi module for transferring data to other locations or gaining access to data from afar (Gupta and Rakesh, 2018). The typical air quality monitoring method used by the Pollution Control Department is too expensive. Wireless Sensor Networks are a novel and difficult study subject for embedded system design automation because their design must adhere to strict power and cost constraints.

A secure access standard and an intelligent remote protocol were delivered, which were required for operating, managing, reprogramming, and configuring wireless sensor devices, as well as monitoring remote or hostile environments using environmental monitoring systems that were installed for independent operation (Kaur *et al*., 2016). A unified access with respect to the context model and adaptive applications were developed, along with this the executable model was discussed with its state at runtime. A seamless interaction model was developed for user interface adaptation and reconfiguration to build context-adaptive applications over a test bed. A layered architecture of sensors and context models was proposed to support context modelling in different phases of development. Along with the wireless sensor network, a ZigBee device and RFID with temperature module were employed to construct. The sensor and actuator nodes were distributed using wireless networking technologies and generated real-time data linked to the object's movements and usage inside the home. The extension of the smart home system to smart buildings, in addition to reliability and performance, were demonstrated.

Parmar *et al.* (2017) proposed a low-cost pollution monitoring system. The system utilized semiconductor gas sensors with Wi-Fi modules to measure concentration of target gases such as CO, CO_2, SO_2 and NO_2. A Raspberry Pi micro-computer was also provided to act as a base station to handle data transmitted from the nodes and act as a web server for data visualization.

Patil (2017) developed a smart IoT based system for vehicle noise and pollution monitoring. The hardware architecture as well as the software implementation are thoroughly detailed. IoT technology is also used to verify the system's performance. The clever intelligent environmental system that was built monitors the pollutants produced by automobiles and alerts vehicle owners to take action to reduce pollution. Saha *et al*. (2018) developed raspberry Pi controlled cloud based air and sound pollution monitoring system with temperature and humidity sensing using Raspberry Pi, Wi-Fi module.

Kavitha *et al.* (2018) employed Raspberry-Pi and IoT to monitor the leakage of toxic gases and hence the level of pollution in order to prevent fatal accidents. MQ135/6/7 gas sensors were used to sense the poisonous gases and a Wi-Fi module connects the whole process to the internet and LCD is used for the visual Output.

MQ2 air sensors capture air pollutants (methane, propane, butane, alcohol, noxious gases, carbon monoxide, etc.) and a sound sensor module mic captures sound (Borate et al., 2018). These sensors interact with the Arduino, which processes the data and delivers it to the mobile application. WIFI modem is also installed to transmit data to remote locations. When air pollution is detected, a buzzer immediately beeps, and when noise pollution is detected, an LED begins blinking continuously.

Pattar et al. (2018) reported a survey on an IoT-based air pollution monitoring system that monitored the air quality over the internet using a web server and activated an alarm when the air quality dropped below a certain level, indicating that there was a sufficient amount of harmful gases in the atmosphere such as CO_2, smoke, alcohol, benzene, and NH3 gas. Shah et al. (2018) created an IOT-based air pollution monitoring system with an ATmega328P, ESP8266 Wi-Fi module, MQ135 gas sensor, MQ6 LPG gas sensor, LM35 temperature sensor, and SY-H5220 humidity sensor. The Internet of Things-based air pollution monitoring system was used to monitor the air quality via a web server. Gupta *et al.* (2019) developed an IoT based air pollution monitoring system for smart cities.

Saiye and Ajose-Ismail (2020) developed a system using Arduino Uno, WIFI module and MQ135 gas sensor. They designed air quality detection and monitoring systems which employed a wireless sensor network to monitor air quality in various places while also producing near real-time information and data that can be retrieved via smartphones, tablets and internet compatible devices. Designed system can track the amount of contaminants in the air developed by using Arduino Uno, a WIFI module, and a MQ135 gas sensor. Chourey *et al*. (2022) designed an IoT based air pollution monitoring system using MQ135, MQ7, and DHT11 gas sensors. These sensors will respond to the esp32 module, which will show the information on the ThinkSpeak web server, and configure a buzzer to notify us if the air quality drops below the set value.

Machine learning algorithms in monitoring system

The air and sound pollution monitoring system is an IoT (Internet of Things)-based application that uses machine learning techniques to detect pollution (Sumithra et al., 2016). Malik and Adrio (2003) developed learning activity models for multiple agents in a smart space for modelling and automating resident activity in multiple-resident intelligent environments, employing passive sensors to identify individuals and their behaviours in an intelligent environment.

IOT based air and sound pollution monitoring system was developed by Reddy (2020) using machine learning algorithms K-NN and Naive Bayes. In this system, analog to digital converter, global service mobile communication, temperature sensor, humidity sensor, carbon monoxide and sound sensors are interfaced with raspberry pi using serial cable. The sensor data was uploaded in Thinkspeak (IoT) and webpage (Sumithra *et al*., 2016*;* Reddy, 2020).

Srivastava et al. (2018) employed Linear Regression, SDG Regression, Random Forest Regression, Decision Tree Regression, Support Vector Regression, Artificial Neural Networks, Gradient Boosting Regression, and Adaptive Boosting Regression to forecast the Air Quality Index of major pollutants such as PM2.5, PM10, CO, NO2, SO2, and O3. The strategies are then evaluated using Mean square error, Mean absolute error, and R2, and the results demonstrated that Support Vector Regression and Artificial Neural Networks are the best suited for predicting air quality in New Delhi.

Shah *et al.* (2020) proposed a real-time IoT-based system that enables real-time machine learning of air quality and environmental noise prediction in the surrounding area. The SVM model outperformed all other models for real-time prediction in the real-time machine learning experiments. The web-based interface offered a map display enabling end-users to visualise the expected results.

2. Conclusions and Future Scope of Work

This paper provided a thorough and critical examination of research works on air and noise pollution monitoring systems for a sustainable environment. The analysis and discussion of the review suggested major recommendations for participation of environmental organizations, regulator bodies and general awareness that would strengthen efforts towards smart environment monitoring by curbing air and noise pollution. The poor quality of sensory data can be pre-processed using appropriate filters and signal processing methods to make the data more suitable for all subsequent tasks associated in achieving a sustainable environment. The need for extensive research on deep learning, handling big data and noisy data issues, and a framework of robust classification approaches has been realized while reviewing this article. The future scope of the work aims at studying other factors of the environment such as sound pollution and disasters etc. Same technologies can be employed to monitor the air quality in agriculture fields and air and noise quality monitoring in area's near different industries.

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