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Artificial Intelligence Based Public Air Purifying System

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Abstract:

Introduction: Air pollution poses a significant threat to public health and well-being, necessitating innovative solutions to mitigate its adverse effects. This research presents an AI-based Public Air Purifying System (PAPS) designed to enhance outdoor air quality in urban environments, densely polluted locations and other similar locations. The proposed system leverages artificial intelligence algorithms to monitor, analyze, and respond dynamically to pollution levels in real-time.

Objectives: A system for real-time surveillance of air quality metrics, including particulate matter and contaminants, using IoT-enabled sensors. Develop a system that autonomously initiates and controls air purifiers in response to pollution metrics, guaranteeing energy efficiency and peak performance. Utilize AI algorithms to enhance airflow distribution for optimal pollutant elimination in various regions.

Methods: The proposed technology integrates AI-driven optimization with a sophisticated multi-stage filtration and purification process. The prototype has a modular design with an AI system that adaptively modifies purification levels according to real-time air quality data, guaranteeing efficient and precise pollutant elimination in various settings.

Results: The show results in the air pollution ppm values before and after using the purifier. The results show the data according to the current date and time. A steady decrease in PPM values indicates continuous improvement in air quality over time. PPM values fluctuate, initially rising and then stabilizing, indicating dynamic changes in air quality following the process.

Conclusions: The AI-Based Public Air Purifying System demonstrates a unique and significant method for addressing air pollution. Its cognitive talents facilitate real-time modifications, although enhancement is required to guarantee dependability and efficacy. With further developments, this technology may significantly improve urban air quality, mitigate health hazards, and foster sustainable living in highly populated regions

Keywords: AI based Air Pollution monitoring, , Air purification units, HEPA filters and Activated carbon filters, Smart city infrastructure, Sustainable development.

1. Introduction

The prototype design has sophisticated sensors for the detection of pollutants, including particulate matter (PM2.5 and PM10), volatile organic compounds (VOCs), nitrogen dioxide (NO2), and carbon monoxide (CO). The sensors provide constant data streams to the AI module, which uses machine learning techniques to forecast pollution patterns and enhance the functionality of the air purification units. The PAPS prototype uses high-efficiency particulate air (HEPA) filters and activated carbon filters to efficiently catch and neutralize various contaminants. The system has IoT-enabled communication capabilities for remote monitoring and control, enabling seamless integration with smart city infrastructure.

This paper introduces an artificial intelligence (AI)-based public air purifying system that integrates MQ135 gas sensors, water spray mechanisms, air filters, and HEPA filters to dynamically monitor and purify air in real time. The proposed system uses AI algorithms to analyze sensor data, predict pollution levels, and activate purification components, such as water sprays and air filters, efficiently. By leveraging machine learning, the system not only improves air quality but also optimizes resource utilization, reducing energy consumption and operational costs.

The core of the AI-driven PAPS is the incorporation of machine learning algorithms that provide autonomous decision-making and adaptive responses to changing environmental situations. These algorithms analyze extensive data from pollution sensors and meteorological sources to identify patterns, forecast pollution trends, and enhance the functionality of air purification systems with remarkable precision and efficacy. This adaptive strategy enables the system to modify its efforts to tackle growing pollution hotspots and mitigate the dissemination of dangerous chemicals.

Moreover, AI is helpful in improving the efficiency and scalability of PAPS systems. Through ongoing learning and optimization, AI algorithms assist PAPS in achieving enhanced accuracy in identifying pollution sources, optimizing the efficacy of air purification devices, and reducing energy usage. Moreover, AI enables the seamless integration of current smart city infrastructure by facilitating real-time communication, remote monitoring, and centralized control of PAPS installations across urban environments.

The integration of AI with environmental engineering signifies a transformative phase in air pollution management, presenting potential for a cleaner, healthier future. As governments, industry, and communities confront the complex concerns of climate change and air pollution, AI-based PAPS systems provide promising solutions to protect public health, conserve ecosystems, and promote sustainable development.

The design consists of three primary chambers, sensors, and a microprocessor.

We connect all these chambers to monitor and extract the expected output from them. The Chamber 1 unit will extract contaminated air from the surroundings. The chamber 1 sensor will analyze and detect the air's AQI level. The table below outlines the standard Air Quality Index (AQI) for assessing public air quality. The Central Pollution Control Board (CPCB) of India uses the following Air Quality Index (AQI) classifications to assess air quality:

Pollutant concentrations allow for the classification of air quality levels into five specific categories. An air quality level classified as "Good" ranges from 0 to 50, signifying little pollution and minor health hazards. The "Satisfactory" range, which spans from 51 to 100, signifies adequate air quality, although sensitive individuals may experience minimal discomfort. Air quality classified as "Moderate," ranging from 101 to 200, signifies elevated pollutant concentrations that may provide health risks for vulnerable populations, including young children and those with respiratory ailments.

The classification of air quality as "Poor," with levels between 201 and 300, heightens the risk of adverse health effects, particularly for vulnerable populations. Finally, air quality in the "Very Poor" range, ranging from 301 to 400, poses a significant health risk to the general population, especially with prolonged exposure.

The AQI categories indicate the level of air pollution and the potential health effects:

a) Satisfactory: May cause minor breathing discomfort for people who are sensitive
b) Moderate: May cause breathing discomfort for people with lung disease, heart disease, children, and older adults
c) Very Poor: May cause respiratory illness for people who are exposed for a long time, especially those with lung and heart disease

Air Quality Index - Particulate Matter	
301 – 500	Hazardous
201 – 300	Very Unhealthy
151 – 200	Unhealthy
101 – 150	Unhealthy for Sensitive Groups
51 – 100	Moderate
0 – 50	Good

From Figure 1, we get an overview of the recommendation level of good quality air for living beings. The levels of AQI are monitored periodically to take necessary measures. AI-PAPS system monitors values to give recommendable AQI value air in public places.

- To design a smart air quality monitoring system using MQ135 sensors for detecting harmful gases and pollutants. The goal is to create a smart air quality monitoring system that utilizes MQ135 sensors to identify hazardous gases and pollutants.
- We incorporate purification mechanisms like water spray systems, air filters, and HEPA filters to eliminate airborne pollutants.
- We are implementing an AI-based controller to analyze real-time pollution data and dynamically control purification mechanisms.

2. Literature Survey

Praveenkumar et al [1]. Researchers have suggested a system that can monitor and filter air in confined environments. It underscores the need for an automated air purification system that can sustain clean air autonomously. It presents the notion of a "centralized air purification system" using machine learning technology. The device monitors room occupancy and air quality, initiating the purification process when the air quality index exceeds a specified threshold. It highlights the system's automated, efficient, and sophisticated features, establishing it as an essential option for preserving indoor air quality.

Maryeme Boumahdi et al [2] A method for purifying outdoor air has been proposed, utilizing photocatalysis and artificial intelligence techniques. It addresses the progression of multiphysics simulation, facilitating predictions of fluid dynamics around and inside intricate geometries. The emphasis is on evaluating the efficacy of an innovative outdoor air filtration system using photocatalysis technology. The research intends to use semi-active photocatalytic surfaces in metropolitan roadways to eliminate anthropogenic pollutants, namely volatile organic compounds (VOCs). It integrates physics, chemistry, and computer engineering to design an air purification system for deployment in four streets in Tangier. Techniques assessed by COMSOL and Matlab, in conjunction with artificial intelligence technologies, enhance purifying scenarios by taking into account street aspect ratios. The proposed method involves placing horizontally arranged lamellae coated with photocatalyst (TiO_2) on the walls of street canyons, which are then exposed to UV light. For simulations, a constant starting VOC concentration and a continuous source that mimics street activity are used to come up with effective ways to clean up the air so that the city is cleaner and energy costs are lower.

Pranavi Vashishtha et al.[3] have presented a technology, DMAPS, which can provide filtered air in outdoor environments. The document addresses the pressing problem of outdoor air pollution by presenting DMAPS (Dynamic Mobile Air Purification System), an artificial intelligence-powered mobile air purifier. In contrast to conventional indoor purifiers, DMAPS seeks to cleanse outdoor areas, including residential communities, apartments, and business buildings, where people spend significant durations. The system's benefit is in its mobility and artificial intelligence capabilities, addressing a deficiency in current technology. DMAPS incorporates three essential functions: intelligent mobility using deep reinforcement learning, air purification utilizing Arduino devices, and person identification using the YOLO algorithm. These capabilities operate synergistically, allowing DMAPS to traverse contaminated zones, cleanse the atmosphere, and identify people for precise air supply. The suggested technique aims to improve public health and safety by effectively mitigating outdoor air pollution..

Temirbekov, Nurlan, et al. [4] The purpose of using these algorithms is to look into the connections between COVID-19 infections and the development of respiratory diseases, as well as the link between air pollution levels and public health. The study scrutinizes Almaty's population's respiratory illness incidence and the extent of suspended particle-induced air pollution from 2017 to 2022. The report proposes strategies for reducing hazardous air emissions via the use of machine learning methodologies. The study's results demonstrate that air pollution substantially exacerbates respiratory diseases.

Krupnova, Tatyana G., et al.[5] examine these limits and investigate viable ways to rectify current challenges and environmental inequality. The most effective worldwide strategy is the creation of smart cities; nevertheless, this way may exacerbate environmental inequality, since not all areas have access to machine learning and artificial intelligence technology. Formulating efficient regional initiatives for environmental data analysis is challenging within the current intricate operational framework, given the constraints of time, computing resources, and the context of environmental injustice. Artificial intelligence and machine learning techniques have shown considerable use in the comprehensive analysis of air monitoring data. Implementing AI and ML approaches is a challenging endeavor, regardless of the application. We must acknowledge and often address a multitude of warnings, vulnerabilities, and nuances to provide appropriate solutions, prevent the onset of environmental injustice, and fully utilize these developing paradigms.

Jose, Aparna, et al. [6] the system's efficacy depends on real-time active queue management and sophisticated filtering mechanisms fueled by solar energy. It uses solar energy for sustainable operations while improving interior air quality. The design prioritizes energy efficiency while meticulously removing allergens and contaminants to effectively purify the air. Real-time monitoring allows users to execute intelligent environmental modifications by simultaneously tracking several data points. This holistic strategy promotes sustainability, efficiency, and real-time monitoring, essential for improving indoor air quality. Its dependence on solar energy corresponds with worldwide initiatives to enhance the use of renewable energy, therefore reducing its ecological footprint.

Swamy, G. S. N. V. K. S. N. [7] evaluated a control system that employs a synthetic filtration medium to minimize hazardous gases in indoor environments. The investigation's results indicated that the purification system decreased CO_2 levels by around 40%. The purification system significantly reduced the intake of fresh air by nearly 50%, resulting in a substantial reduction in the thermal burden. This air cleansing system delivered the necessary ventilation flow rates. This apparatus can control CO_2 concentrations in mechanically ventilated structures. The gadget lowered CO_2 concentrations to tolerable levels and then maintained them without the influx of new air into the system.

Landage, Seema S., et al. [8] the system comprises a power storage unit, an effective air purification device, and a real-time air quality monitor. The aim is to create a self-sustaining system that enhances ambient air quality while monitoring and adjusting to variations in air conditions. Effective weatherproofing is crucial for the durability and reliability of this environmentally friendly outdoor equipment. We created the solar-powered outdoor air purifier, including an integrated air quality meter, to tackle the escalating issues of outdoor air pollution. The system employs solar panels to harness renewable energy, making it sustainable and independent of external power sources. A power storage device preserves solar energy, guaranteeing continuous functionality even during periods of less sunlight.

Schürholz, Daniel et.al [9] our team has developed a unique context prediction model that integrates context-aware computing, a precise air pollution prediction technique using Long Short-Term Memory Deep Neural Networks, and data from proximate pollution sources, such as bushfires and traffic levels, together with the user's health profile. They include the model in a functional application, My Air Quality Index (MyAQI), situated in the Melbourne Urban Area (Victoria, Australia), for use and assessment.

Siddique, Abu Buker, et al. [10] A data-driven model in an indoor air quality index monitoring system predicts the AQI using a neural network algorithm and blockchain technology. The Internet of Things (IoT) interlinks devices and analyses data, while economical sensors gather environmental information. The Indoor Air Quality system encompasses temperature, humidity, carbon dioxide, particulate matter, carbon monoxide, and liquefied petroleum gas. Five unique sensors collect data, and the neural network decision-making algorithm predicts the air quality index to avert negative outcomes.

Kalaivani, G., and P. Mayilvahanan. [11] Air pollution is a significant environmental issue in several metropolitan regions. Local authorities may make educated assessments of the city's present traffic situation by using real-time pollution monitoring data. Therefore, it is crucial to implement an early system that monitors and quantifies the extent of air pollution (AP) using air quality (AQ) data, a crucial step in accurately forecasting pollutant concentrations. Sensors based on the Internet of Things (IoT) may improve air quality (AQ) forecasting by substantially modifying AQ forecasts in real time. The forecasting of AP, as assessed by several approaches, is expensive and has low accuracy. This article examines various studies on machine learning techniques for air pollution prediction and monitoring, utilizing data from IoT sensors across multiple cities.

Nasution, Tigor Hamonangan, et al. [12] system is capable of displaying information on temperature, humidity, particle matter, and pollutant concentrations (H_2S, NH_3, CO, NO_2, and SO_2). The Wi-Fi module conveys sensor data to the ThingSpeak Cloud for remote monitoring. Elevated pollutant levels in a room may stem from external sources or internal causes, like cigarette smoke, kitchen emissions, or the application of mosquito repellent.

3. Proposed Framework

With the intensification of urbanization, public air quality is swiftly declining due to vehicular emissions, industrial pollutants, and particulate matter. Subpar air quality presents considerable health hazards, particularly in heavily populated regions, such as urban centers, public parks, and congested thoroughfares. This concept presents an innovative public air filtration prototype that uses sophisticated artificial intelligence (AI) and a modular architecture to provide an efficient, adaptive, and sustainable air purification system for diverse public environments.

The proposed technology integrates AI-driven optimization with a sophisticated multi-stage filtration and purification process. The prototype has a modular design with a sophisticated AI system that adaptively modifies purification levels according to real-time air quality data, guaranteeing efficient and precise pollutant elimination in various settings.

A. Key components and features of the system are as follows

a) Multi-Stage Filtration System: The system has many filtering stages: pre-filters, HEPA filters, activated carbon filters, and UV sterilisation. This configuration eliminates particulate debris, gases, and germs from the atmosphere.

b) AI-Powered Sensors and Control Unit: The prototype, outfitted with AI-enhanced sensors, persistently tracks real-time air quality parameters, including PM2.5, PM10, CO_2, and VOC concentrations. The AI algorithms analyze this data to optimize airflow, filter intensity, and power consumption for peak performance and the lowest energy expenditure.

c) Modular, Scalable Design: The modular design facilitates simple cleaning and maintenance, allowing scaling to suit many environments, ranging from compact urban streets to expansive public spaces.

B. Dynamic Feedback

The prototype operates on a dynamic feedback loop between its sensors and AI control unit:

1) Data Collection: AI sensors gather air quality data in real-time from the immediate environment.
2) Data Processing and Analysis: The AI algorithm analyses this data, identifying specific pollutants and determining optimal purification settings. It can predict pollution peaks and automatically increase purification intensity when necessary.
3) Purification Activation: Based on the AI's recommendations, the system adjusts the fan speed, filtration stages, and power to achieve effective purification with low energy consumption.

C. Unique Benefits of the Prototype

a. Scalability and Flexibility: The modular design supports flexible deployment across multiple locations, making it ideal for outdoor and indoor public spaces like metro stations, malls, public squares, and sports venues. Additional modules can be attached or removed as needed, adapting the prototype's purification capacity to various scales.
b. Enhanced Energy Efficiency: By using AI to optimize power consumption, the prototype operates at minimal energy levels while maintaining purification performance. This efficiency is critical for large-scale deployment across multiple locations, ensuring low operational costs and an eco-friendly footprint.
c. Public Health and Community Awareness: The system can contribute to public awareness of air quality by providing real-time data accessible through mobile apps or public displays. This engagement not only educates but encourages healthier behaviours, such as avoiding high-pollution zones during peak times.

Also, AI can significantly enhance the functionality, efficiency, and adaptability of Plasma Air Purifying Systems (PAPS) by integrating real-time data processing, optimization, and predictive analytics. Here's a breakdown of how AI can be applied to PAPS to improve performance and make it more effective and sustainable:

D. Real-Time Monitoring and Adaptation

➢ Dynamic Adjustment of Filter Intensity: Real-time data collected from MQ135 sensors (gas concentrations, PM levels).
➢ AI Integration: Predict real-time air quality and determine the necessary level of purification. The decision algorithms include threshold-based activation of the water spray, air filter, and HEPA filter. Minimise power consumption and resource usage using AI techniques.
➢ Purification Mechanisms: The design of water spray systems for particulate suppression and HEPA filters captures micro-level airborne particles.
➢ AI in Air Quality Optimization: Uses machine learning models to predict pollution levels and optimize resource consumption. The system analyzes real-time sensor data and dynamically activates purification mechanisms.

Threshold-Based Dynamic Adjustment

The system uses pre-defined pollution thresholds to adjust the filter intensity. These thresholds are categorized as follows:

- Low Pollution (AQI < 40): Minimal filtration; the system operates at off water spray to save energy.
- High Pollution (AQI > 40): Maximum filtration intensity; HEPA filters and water spray operate at full capacity to rapidly reduce pollutants.

AI can analyze and present air quality data in real time via public displays or mobile apps, allowing communities to remain informed about air quality conditions. This information may help promote pollution-mitigating habits, such as limiting outside activities during periods of low air quality.AI-enabled PAPS may interface with other smart city sensors and systems, augmenting the city's capacity to monitor and regulate air quality holistically. This integrated method results in synchronized air quality control across diverse metropolitan areas.

Integrating AI into PAPS transforms the device from a mere static air purifier. It transforms into a sophisticated, versatile system that not only successfully cleanses air but also functions with high efficiency, little maintenance, and the capacity to provide significant environmental insights. AI-driven PAPS are well-suited for extensive implementation in metropolitan public areas, contributing to enhanced public health and environmental standards.

The prototype will undergo rigorous testing in controlled settings to evaluate its effectiveness under diverse pollution levels and weather conditions. Subsequent to successful laboratory evaluations, pilot implementations in densely populated metropolitan regions will provide further insights on practical performance, longevity, and societal acceptability.

4. System Architecture

Figure 1 depicts the various scenarios that transpire following the absorption of air in Chamber 1. We affix the MQ135 sensor to both chambers to monitor the AQI level. If the AQI value of the air is between 0 and 50, Chamber 1 must immediately transfer it to Chamber 2. Chamber 2 will again assess the air quality index (AQI) and then discharge breathable air outside. The display screen connecting both chambers will display the AQI input and output values before and during the filtering operation. The Arduino will monitor and record all real-time data. The retained data will facilitate the analysis of system performance. If the AQI value of the air exceeds 50, the chamber will transfer the contaminated, dangerous, and unhealthy air to the filtration layer. The filter layer comprises several filters, including prefilters, HEPA filters, activated carbon filters, and UV sterilization to clean the air. The filters will direct the purified air to chamber 2. The procedure will proceed intermittently. Upon completion of the filtration cycle and attainment of capacity, the filters will expel the accumulated dust particles into chamber 3. Chamber 3 will collect all particles. We may use the collected dust, particulates, and other non-breathable particles to enhance soil fertility. The collected dust particles may serve as natural fertilizer and enhance soil fertility. This nutritious soil may provide healthier and more vibrant plants and greenery.

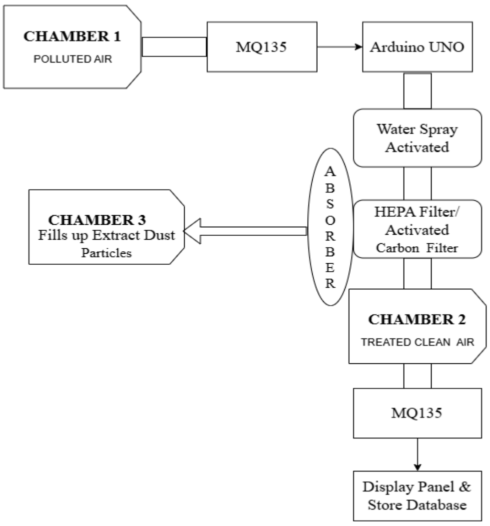

Figure 2 – Prototype Design Diagram of Artificial Intelligence based Public Air Purifying System

Algorithm

Input: The variable input_values[1...n] contains all the input parameters produced by the sensors, including the threshold groups TMin[1...n] and TMax[1...n] for each sensor.

Output: We have activated the trigger for the output device label.

Step 1 : Read all records (R) from the database.

Step 2: Parts [] ← Split(R)

Step 3:

$$\mathrm{CVal} = \sum_{k=0}^{n} \mathbf{Parts[k]}$$

Step 4: check (Cval with respective threshold of TMin [1…n] and TMax [1…n])

Step 5: if (Cval > Tmax)

The water pump activates, initiating the water spray.

FN

Else continue.

The water pump shuts off, and so does the spray.

End for

Step 6: end application

5. Results And Analysis

This graph shows the air pollution ppm values before and after using the purifier. The graph shows the data according to current date and current time. A steady decrease in PPM values indicates continuous improvement in air quality over time. PPM values fluctuate, showing an initial rise followed by stabilization, suggesting dynamic changes in air quality after the process.

Table 1.1 Air pollution ppm values before and after

Time(HH:MM:SS)	Before PPM	After PPM
16:01:38	55	25
16:01:40	80	35
16:01:42	120	40
16:01:44	67	30
16:01:46	90	39

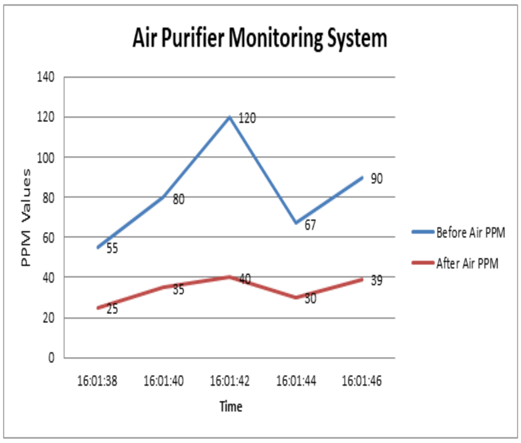

Figure 3 – Air Purifier Monitoring System

Figure 4 – Air Filter

Figure 5 – Hepa

Figure 6 – Air Purifier System

6. Conclusion

The research underscores the efficacy of an AI-based public air purifying system in enhancing air quality by examining particulate matter (PPM) concentrations before and during the system's implementation. The findings indicate that while the system significantly affects air quality, it also creates unpredictability that needs more scrutiny.

Prior to the implementation of the AI-based system, air quality exhibited a consistent improvement attributable to natural sources; nevertheless, the progression was gradual and devoid of proactive intervention. Following the implementation of the AI-driven purification system, the air purification process exhibited increased dynamism, characterized by an early surge in PPM values, subsequent oscillations, and eventual stabilization. Causes such as inconsistent purification cycles, ambient circumstances, or real-time modifications executed by the AI may account for these variances.

The system's capacity to actively monitor and adapt to fluctuating environmental circumstances is a significant advantage, showcasing the promise of AI-driven solutions in mitigating urban air pollution. The observed oscillations highlight the necessity of optimising the system's algorithms, operating settings, and hardware configurations to achieve consistent and steady air purification outcomes.

In conclusion, the AI-Based Public Air Purifying System demonstrates a unique and significant method for addressing air pollution. Its cognitive talents facilitate real-time modifications, although enhancement is required to guarantee dependability and efficacy. With further developments, this technology may significantly improve urban air quality, mitigate health hazards, and foster sustainable living in highly populated regions.

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