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Development of a Compact IoT Enabled Device to Monitor Air Pollution for Environmental Sustainability †

Vijayaraja Loganthan [1,*], Dhanasekar Ravikumar [1], Vidhya Devaraj [1], Uma Mageshwari Kannan [1] and Rupa Kesavan [2]

[1] DEEE, Sri Sairam Institute of Technology, Chennai 600044, Tamil Nadu, India; dhanasekar.eee@sairamit.edu.in (D.R.); sit21ee010@sairamtap.edu.in (V.D.); sit21ee031@sairamtap.edu.in (U.M.K.)

[2] DCSE, Sri Venkateswara College of Engineering, Sriperumbudur 602117, Tamil Nadu, India; rupakesavan@svce.ac.in

* Correspondence: vijayaraja.eee@sairamit.edu.in

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Abstract: Degrading air quality has been a matter of concern nowadays, and monitoring the air quality helps us keep a check on it. Air pollution is a pressing global issue with far-reaching impacts on public health and the environment. The need for effective and real-time monitoring systems has become increasingly apparent to combat this growing concern. Here, an innovative air pollution surveillance system (APSS) that leverages internet of things (IoT) technology to enable comprehensive and dynamic air quality assessment is introduced. The proposed APMS employs a network of Io enabled sensors strategically deployed across urban and industrial areas. These sensors are equipped to measure various pollutants, including particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), and volatile organic compounds (VOCs). Here, a regression model is created to forecast air quality using sensor data while taking into account variables including weather information, traffic patterns, and pollutants. Additionally, air quality categories (such as good, moderate, and harmful) are classified using classification algorithms based on preset thresholds. The IoT architecture facilitates seamless data transmission from these sensors to a centralized cloud-based platform. The developed APSS monitors the air quality using a MQ-135 gas sensor, and the data are shared over a web server using the internet. An alarm will trigger when the air quality goes below a certain level. Also, the air quality, which is measured in parts per million (PPM), is displayed on the unit connected to it. Further, an alert message is sent to the air pollution control board when the PPM goes beyond a certain level, which takes preventive measures to control the pollution and also alerts the people, which helps each person in that society save their environment from pollution and have a good air quality environment. Additionally, the APSS offers user-friendly interfaces, accessible through web and mobile applications, to empower citizens with real-time air quality information. The effectiveness of the IoT-based air pollution monitoring system has been validated through successful field trials in urban and industrial environments, and it has the ability to provide real-time data insights and empower stakeholders in promoting environmental sustainability and fostering citizen engagement.

Keywords: APSS; Internet of Things; parts per million; sensors

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1. Introduction

Air pollution is the contamination of the indoor and outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. It has effects on humans, animals, plants, and the environment. It affects long-term health issues like heart disease, lung cancer, and respiratory diseases in humans. It also affects animals and plants, causing some diseases and causing damage to the environment. A device used to measure this polluted air is an air pollution monitoring system, which helps control air pollution. There are some existing approaches that are discussed here: A wireless air pollution monitoring system is created, and when the level of measured pollutants exceeds the acceptable amount, alarms are sent to the user through the Internet. The MQ135 sensor is used, together with a microcontroller, to track indoor pollution [1]. A model, which combines Arduino UNO hardware and software with sensors MQ135, MQ7, and a dust sensor to sense gases like NO_2, CO, and PM2.5.

This also monitors the air quality utilizing Thing Speak and hardware connected to the internet through Wi-Fi module [2]. The Air Sensing System in [3] monitors the quality over a cloud-based platform and sounds an alarm when the quality goes below a certain level, which shows that there are a number of pollutants present in the surrounding air. The AQI scale goes high when the air is more hazardous to human health. The model in [4] combines the Arduino UNO hardware and software with gas sensors such as MQ135, MQ7, and the dust sensor GP2Y1010AU0F, which aid in detecting gases like NO_2, CO, and PM2.5 by accurate measuring. Additionally, the air quality is monitored using an IOT platform. In [5], sensors will collect data on a range and transmit it to a Raspberry Pi, which serves as a base station. On a Raspberry Pi 3-based webserver; the data is collected by sensors. To show data on websites, a MEAN stack is created. Distribution to all stakeholders is the key component of the proposed task. The project in the system [6] forecasts the city's pollution level and also monitors the air contaminants to produce alerts. It is made to accommodate gases produced by vehicle pollution.

A sensor-based hardware module in [7] that can be installed along roads is demonstrated. They can be mounted on lamp posts and send data wirelessly to a remote server, so that traffic can be managed using this information. Through a smartphone application, this system also offers information about air quality, enabling us to choose routes with good quality. Ref. [8] identified that the primary source of air pollution is transportation. To reduce air pollution, electric cars and bicycles can replace other types of transportation. This study shows how crucial it is to predict air pollution levels so that individuals can change their travel routes. An inexpensive, alternative IoT-based air quality monitor is described in [9]. It tracks air pollution in real time and communicates data quickly over a low-power wide area network. A wide network of these monitors may provide a significant quantity of data, which can be analyzed in the cloud in real time and connected with the time of day, month, year, weather, and other aspects. The microcontroller and sensors communicate through the microcontroller, which collects data from the sensors, processes it, and communicates it to an online server using an IoT [10].

The system uses IoT to identify the most dangerous airborne contaminants as well as louder noise levels. It also provides real-time updates on the degree of pollution. In summary, an air pollution surveillance system is essential for safeguarding the environment, the public's health, and advancing sustainable development. It gives individuals and governments the power to make decisions that improve living standards and the quality of the environment. It can be helpful in reducing traffic pollution. Different sensors can be used for different ranges and accuracy. The solution presented here consists of a single air quality monitoring sensor which can sense ammonia, sulfur, benzene, carbon dioxide, smoke, and other similar harmful gases, a Wi-Fi module, and an alert system. This helps in keeping track of air quality, and in the case of excess pollutants, it helps in informing the pollution control board. An air pollution surveillance system can be used for real-time analysis. The Kalman filter was employed to increase the measuring device's accuracy since it can make predictions even in the event that sensor data is missing. This paper is categorized as proposed system, modeling of the air pollution surveillance system and experimentation with validation of the proposed work.

2. Proposed Air Pollution Surveillance System

The proposed air pollution surveillance system is shown in Figure 1. The power supply is given to the Arduino UNO. The MQ-135 sensor detects ammonia, sulfur, benzene, carbon dioxide, smoke, and other similar harmful gases and sends them to the Arduino UNO. It is connected with the wi-fi module, as shown in Figure 1, which sends data when the pollution rate received from the gas sensor is high. Then the data is sent to the pollution control board through a hybrid cloud that combines both public and private cloud resources, which takes steps and takes action towards reducing pollution in the air. Since the Kalman filter can make predictions even in the case of missing sensor data, it is used to boost the accuracy of the measuring instrument as shown in Figure 2 and the pollutants measured, range is given in Table 1.

Alarm system algorithm:

Initialize the hardware components and serial communication.

Continuously read the analog value from the sensor.

If the analog value is greater than the threshold:

- Activate the alarm (red LED and buzzer).
- Display "ALERT" and "EVACUATE" on the LCD.

If the analog value is not greater than the threshold:

- Deactivate the alarm (turn off the red LED and buzzer).
- Display nothing or a different message on the LCD.
- Repeat the process in a loop.

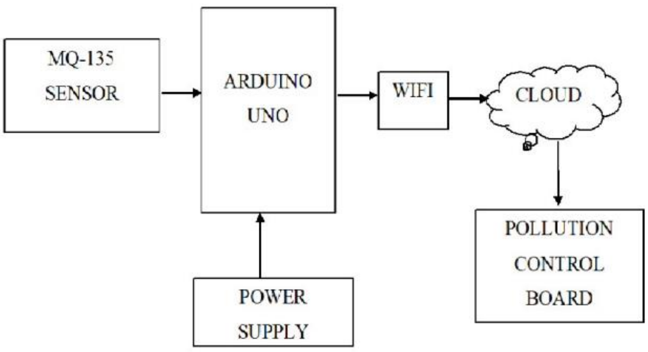

Figure 1. Air pollution surveillance system.

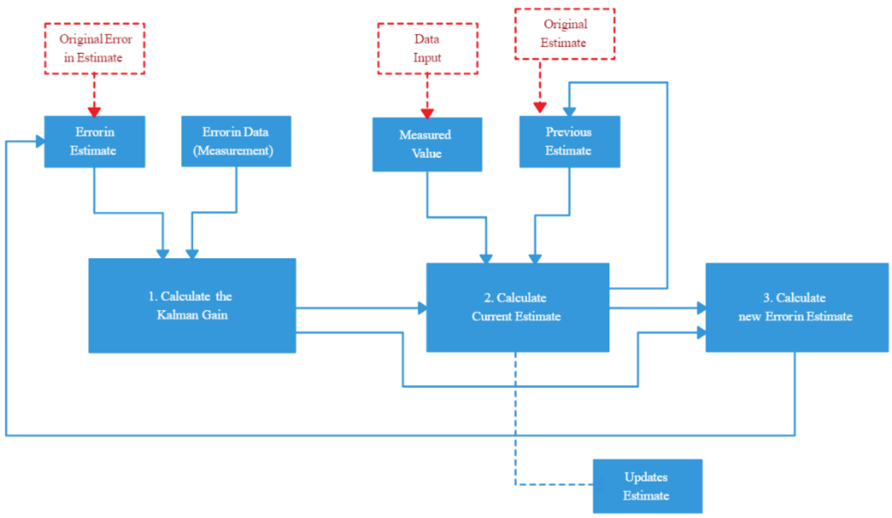

Figure 2. Process of Kalman filter.

Table 1. Pollutants measured and range.

Measurement Item	Unit	Normal	Bad
CO	ppm	0.0~9.0	9.1~15.0
NH_3	ppm	0~5	6~40
SO_2	ppm	0.0~0.1	0.2~20.0
NO_2	ppm	0.0~0.1	0.2~20.0
O_3	ppm	0.0	0.1~0.15

3. Modeling of Air Pollution Surveillance System

As shown in Figure 3, Connections are provided in accordance with the circuit. Data is sent from the MQ-135 to alarm system which sounds and the alert message is shown on the LCD when the level of smoke or pollution is excessive. The pollution control board receives the data on a continuous basis along with its PPM value. The LCD shows a safe message when the pollution level is below the set threshold. When the circuit is closed, the safe green LED illuminates.

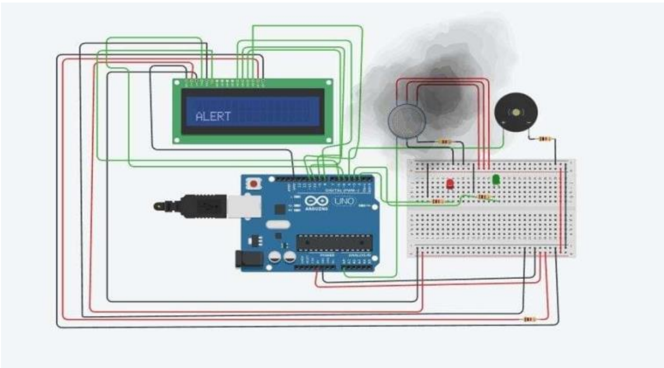

Figure 3. APSS-Simulation.

The simulation of the proposed air pollution surveillance system is shown in Figure 2. The air pollution surveillance system, which provides the required alert in the form of an LED and LCD, is shown in Figure 4.

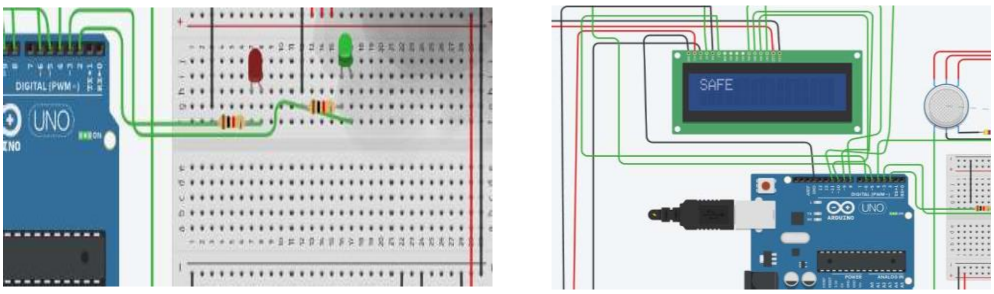

Figure 4. Result of APSS for LED and LCD.

4. Experimentation of Air Pollution Surveillance System

In the developed APSS shown in Figure 5, components such as the Mq-135 gas sensor, Arduino UNO, Wi-fi Module, LCD display, alert system, and LED lights are used. Gases like CO_2, smoke, alcohol, benzene, and NH3 are detected using the MQ-135 gas sensor. The gas sensor continuously monitors the quality of the air at PPM. When the PPM goes higher than 1000, the LCD shows an alert message; otherwise, the safe message is displayed. The LED shows green during the safe message, and the red LED is turned on when the alert message is displayed. The data from the gas sensor is sent through the Wi-Fi module to the pollution control board. The data is shown as PPM to the pollution control board. The alert system gives a sound when the PPM goes to the danger level, and the alert message is also sent to the pollution control board. This helps the pollution control board take the required actions to control the pollution.

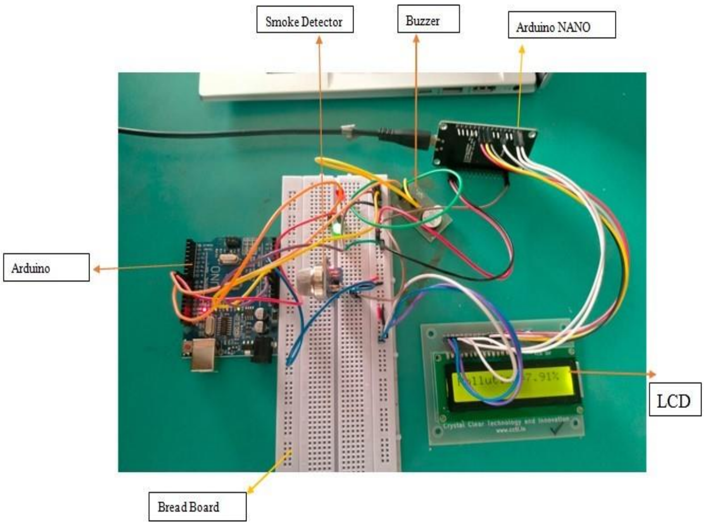

Figure 5. Result of APSS.

The people can also connect to the Wi-Fi module and know the air quality of their locality, which helps them take the necessary measures. The data is displayed continuously with their PPM levels. There cursive mathematical process known as the Kalman filter determines the state of dynamic from a set of noisy measurements taken over time. It can be used to monitor and forecast pollutant concentrations in the context of air pollution monitoring using sensor data. The Arduino is connected to the LCD display, a bread board fixed with LEDs and an MQ-135 gas sensor, a Wi-Fi module, and an alert system.

On observing the range of each pollutant in the cement or petrochemical industry taken as a sample, the measured pollutants and their range, ppm levels are shown in Figure 6. To analyze the data's observed via developed APSS, a regression model is created to forecast air quality using sensor data while taking into account variables including weather information, traffic patterns, and pollutants. Additionally, air quality categories (such as good, moderate, and harmful) are classified using classification algorithms based on preset thresholds. By continuously monitoring the PPM levels, the air quality can be detected, a safe environment can be implemented, and diseases such as cancer, asthma, kidney, liver, skin diseases, neurological disorders, etc. can be reduced due to air pollution. The people also receive an alert sound when they are connected through the Wi-Fi module when the PPM level goes high, which shows the level of PPM and a message such as safe or alert. In such a way, a modern gas sensing unit is developed (Figure 5). By analyzing the model in a industry before and after using Kalman filter there is at least 5% increase in accuracy and showed a better performance. The results gained during the analysis is shown in Figure 6 which shows a bar graph between the gases sensed by the sensor and their range, Figure 7 shows the accuracy changes before and after Kalman filter in the gases CO_2 and NO_2 respectively.

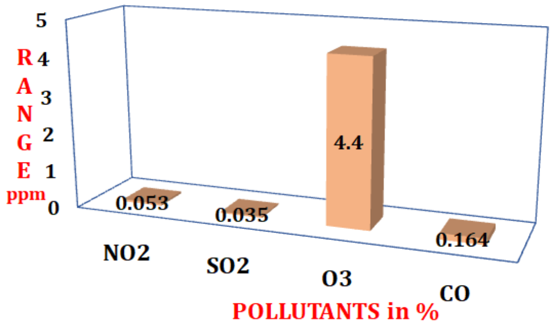

Figure 6. Pollutants range from a cement or petrochemical industry.

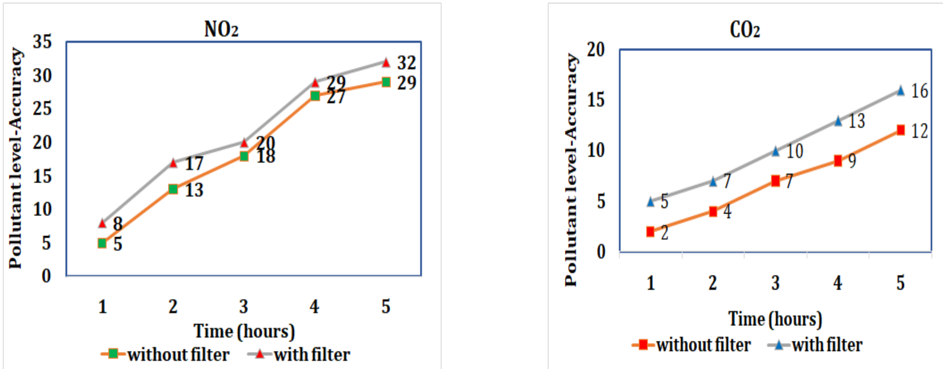

Figure 7. Accuracy of NO_2 & CO_2 measurement before & after filter.

5. Conclusions

The proposed APSS is cost-effective and handy. The fascinating feature of the proposed model is that it reports pollution to the pollution control board, which helps to avoid polluted areas as soon as they get polluted.

- A key aspect was to monitor pollution levels to create a profile of a city or region and predict risks at individual levels. This awareness can also lead people to make direct contributions to reduce pollution levels.
- This system can be upgraded by adding more sensors, so it is portable.
- There is no need for any application to be installed; the system sends directly to the pollution control board.
- The process of the Kalman filter makes the system reliable as it has processing feature based upon previous values.
- It is found that the accuracy is increased after implementing Kalman filter.
- The proposed system was tested successfully, and it is able to sense the gases of range 10 to 1000 ppm, process them with Kalman filter and making it most reliable and accruable helps in sending quality data of air. This system can be used as a warning system when the air quality gets severe, and measures could be taken to prevent it.

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