IoT based smoke and gas leaks detection and ventilation system

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***Abstract*— To monitor the indoor air content, the proposed approach detects the presence of high concentration of smoke and gas and alert the user about them with the help of hardware components and cloud computing. The study proposed an aggregated Two-layer Dense Neural Network model for predicting the precision of the sensor measurements. The proposed system tackles the problem of the lack of proper methods to prevent hazards caused by smoke leaks. The method monitors and alerts users about harmful components whereas this paper proposes ventilation system to prevent hazardous situations.**

Keywords—IoT Infrastructure, cloud computing, Monitoring, Ventilation, Internet of Things.

I. Introduction

The massive Internet of Things (IoT) is foretold to introduce a surplus of applications for a completely connected world. The increasingly degrading quality of air in several regions of the biosphere is a reliable impact of human difficulties of accelerating globalization and urbanization. Pollution is a mixture of solid particles and gases in the air which occurs when some harmful additive quantities of substances are introduced into atmosphere. Air pollution levels in cities exceed legal and World Health Organization (WHO) limits for particulate matter and gaseous pollutants which are found in concentrations that are hazardous to health. The discharge of pollutants into the air can be made by car emissions, chemicals from factories, specks of dust, pollens and mold spores. Regular acquaintance with high pollution intensities increases the number of humans affected by respiratory disorders such as asthma, chronic obstructive lung disease, and increased mortality. Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016; this mortality is due to exposure to fine particulate matter of 2.5 microns or less in diameter (PM2.5), which cause cardiovascular and respiratory disease, and cancers [1].

The ambient air quality measurement is determined by the air quality index (AQI) which translates numerical data into a descriptive rating scale and allow citizens of all ages to know the level of pollution in the air they breathe. The Air Quality Index is predicated on the measurement of particulate matter (PM2.5 and PM10), Ozone (O3), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2), Carbon Monoxide (CO), Ammonia (NH3), Sulphur (S), Benzene (C6H6), Carbon Dioxide (CO2) emissions. An air quality index is a scale used to show how polluted the air is, along with the risks associated with each rating [2]. An AQI is calculated based on medical research for the acceptable levels of major air pollutants to inform the public about air quality in a comprehensible manner so that they take action to protect their health and to help countries develop and assess policies for better air quality [3]. In India, there are many households which do not have a proper ventilation system in case of gas and smoke leakage. The proposed system wants to solve this problem by creating an automatic ventilation system for such households which is cost-efficient. Such system does not exist in majority of household, and even if it does, it's very expensive.

II. Related Work

Jagriti Saini et al. proposed the main idea to discuss the use of wireless technologies for the development of cyber-physical systems for real-time monitoring[4]. The paper presents some new ideas and scopes within the field of IAQ monitoring for researchers. The authors provide details about how various factors such as VOCs, PM10, PM2.5, CO, SO2, NO, O3, temperature, and RH affect IAQ. Furthermore, authors have highlighted the technical aspects of the studies performed by early researchers in this field.

Ruochong Xu et al. developed a simplified indoor-outdoor mass-balance equation to simulate the indoor concentrations, so that the predictions fitted the observed data for most of the testing period. Their study enhances the understanding regarding the indoor-outdoor relationships between gaseous and particulate matter concentrations in polluted areas [5].

Leeban Moses et al. developed a low-cost wireless air pollution monitoring system. Their work deliberates the implementation of cloud based IoT system for air quality monitoring [6]. Their study helps to understand the various uses and implementation of cloud-based IoT systems. The proposed paper uses a similar method to monitor the sensor values.

James F. Montgomery et al. proposed a brief term of intensive pollutant monitoring in open office space. Their results show how hybrid ventilation system has the most flexibility in meeting IAQ needs [7]. Their study gives a better understanding of the ventilation system in various conditions and helps to design an efficient ventilation system for the proposed system.

III. Solution Approach

A. *Ventilation System infrastructure and hardware setup*

When smoke accumulates within the house, it can not only affect your home's structure and your personal belongings but also your health. Once you have this issue, it is vital to address it quickly and appropriately. The same goes for gas leaks because natural gas is flammable, which means that if there is a flame or even a spark, it can cause a fire, or explosion, or be unhealthy for your body and can be fatal in some cases.

Fig 1. shows proposed ventilation system infrastructure. Once the buzzer rings and detect a high concentration of smoke and gas in the air these pollutants need to be ventilated out of the house. This is achieved using a relay system that controls two fans out of which one pushes indoor air(with high smoke and gas concentration) outside the house and the other fan to get fresh air indoors from outside. Also, both the fans can be programmed to push indoor air outside in case of high concentration.

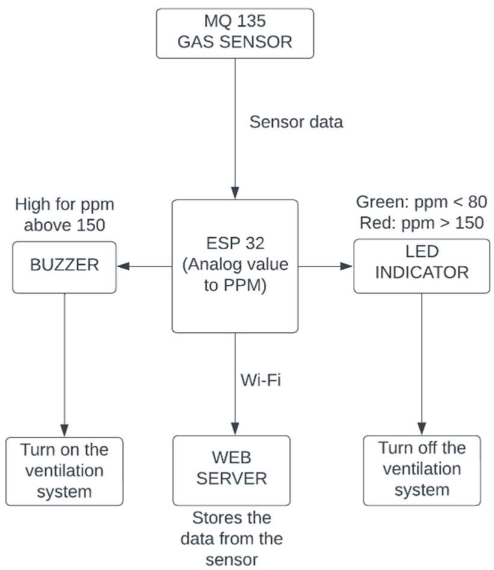

Fig 1. Shows the proposed system. ESP32 shows the microcontroller used in the system. WEB SERVER represent the cloud server used for storing and representing the data.

B. *Sensor Architecture*

The system is programmed to detect smoke and gas leaks using the MQ135 Sensor. MQ135 is a sensor with lower conductivity of clean air. When the target explosive gas exists, then the sensor's conductivity increases, increasing more along with the increase in gas concentration levels. By using simple electronic circuits, it converts the charge of conductivity to the corresponding output of gas concentration. The MQ135 gas sensor features high sensitivity to ammonia, sulfide, benzene steam, smoke, and other harmful gas. This sensor is connected to ESP32 which is programmed to trace the pollution levels and alert us when it reaches harmful levels using LEDs and a buzzer. The typical levels shown by the sensor in indoor clean sir varies from 0 - 80 which is indicated using green LED. When the level goes above 80 the red LED turns ON indicating a moderate level of smoke/gas in the air and if the level goes above 150 then the buzzer goes off indicating a high level of smoke and gas in the air.

C. *Real-time monitoring using cloud computing*

The server uses API to receive data from the system. The system sends the info to the server at a fixed interval of time through the internet. The ESP32 connects to an available WiFi field that successively is connected to your internet. The data is stored in the server database and displayed in the form of a real-time graph. This system uses Thingspeak[1] to monitor these levels. ThingSpeak™ is an IoT analytics platform service that permits you to aggregate, visualize and analyze live data streams with the cloud. ThingSpeak™ provides instant visualizations of data posted by your devices to ThingSpeak.

Fig 2. Shows the recorded reading which are present on the server in the form of graphs.

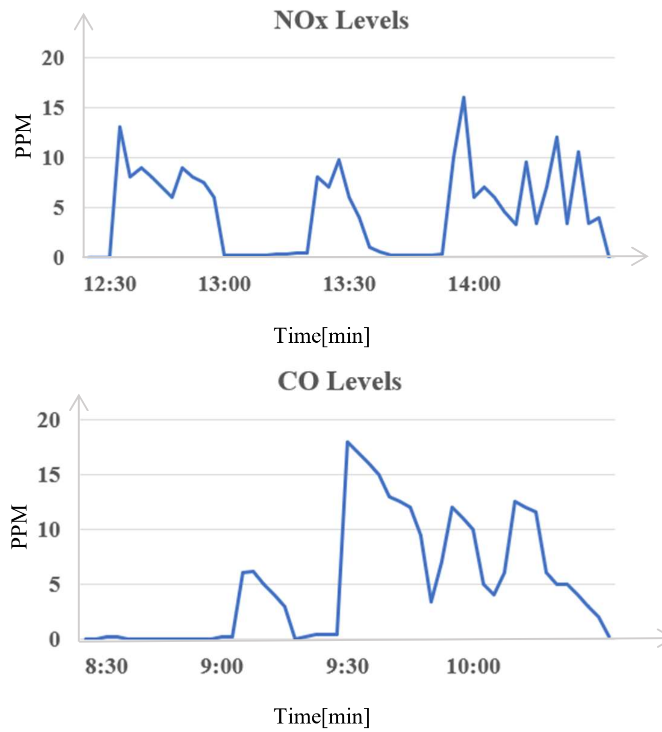

Fig 2. Reading recorded by the sensor for two values target gases – NOx and CO. Data is retrieved from the ThingSpeak™ sever.

IV. Implementation

The proposed system uses ESP32 (WiFi) Module. ESP32, like Arduino, is a development board, but far superior to Arduino UNO and ESP8266. MicroPython is a tiny open-source Python programming language interpreter that runs on small embedded development boards. The microcontroller performs the task of getting the data from the IoT sensor, controlling the components of the hardware setup, establishing the connection between the Thingspeak server, and sending the data to the server.

Initially, the system needs approx 10 minutes to calibrate the MQ135 sensor after which the system can accurately measure the air quality levels after which the system with help of LEDs and a buzzer shows the range of the air quality. If the concentration of smoke and gas goes above a specific level then the system alerts the user by turning on the red LED and the buzzer and it will automatically switch on the ventilation system with the help of a relay module connected to the microcontroller.

V. Machine Learning

The system shows how much the sensor gives accurate results or how accurately they can predict in critical conditions

[1] https://thingspeak.com/

with the help of machine learning. This project focuses on LSTM because it provides us with a large range of parameters such as learning rates, and input and output biases. Hence, no need for fine adjustments. The complexity to update each weight is reduced to O(1) with LSTMs, similar to that of Back Propagation Through Time (BPTT), which is an advantage. For this, Edge Impulse[2] was used which provides simple and easy-to-use training and deployment tools for various kinds of ML models and even helps the user to deploy this model for embedded systems.

A. Sensor Dataset:

The MQ135 sensor experimental data is gathered from the Thingspeak web server for both conditions (one with smoke/gas leak presences and one for ambient air). Fig 3. shows the dataset used for training the Machine Learning model. For this it was required collection of data for three minutes of training data for two classes: true smoke and one for ambient air. The data sheet is then uploaded to the server for generating features.

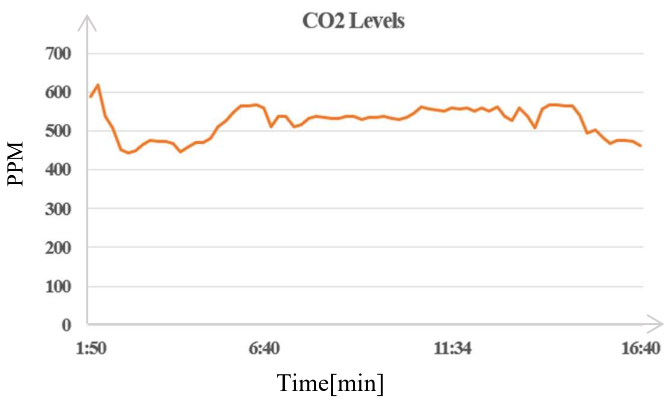

Fig 3. Test Data

B. Accuracy of MQ135 Sensor:

Two-layer Dense Neural Network is used for predicting the accuracy of the sensor. It was required to normalize the values of the sensor to the range [0-1], as neural networks perform better on normalized data. Normalized data is then fed into a two-layer Dense Neural Network. Even with limited number of samples, the prediction gave 87.1% training accuracy.

This result provides that the system can accurately detect a dangerous or critical situation.

Components	Quantity	Price of 1(USD)	Total Price (USD)
Buzzer	1	1.24	1.24
ESP 32	1	3.28	3.28
MQ 135	1	6.87	6.87
LED Indicator	1	0.13	0.13
Computer Fans	2	2.25	5.01
			= 14.02 USD

Fig 4. Total estimated Hardware cost of the proposed system

VI. Result

As discussed smoke and gas leaks can cause economical damage and severe effect on health. Therefore, a system is required that will prevent this effectively at a considerably low cost. Fig 4. shows the total estimate cost of the proposed system. In various methods they only alert the user about such incidents but this paper put out forward a method of preventing this incident by its ventilation system. The proposed method can be implemented in place with individuals sensitive to air pollutants and areas which are prone to such incidents which don't have such prevention methods like school and college laboratories, restaurants. The proposed method within the paper makes it flexible enough to add multiple sensors to provide more prevention methods.

The future scope includes use of multiple gases and fire sensor, and image recognition to detect the presence of any individuals within the vicinity of the incident.

Project Demo: https://youtu.be/UqYCoNWsQuc

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