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Internet of Things (IoT) Enabled Air Quality Monitoring System for Conventional and UAV Application

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ABSTRACT

The purpose of this research is to make a system to read the air quality by detecting the various gases existing in the air by using Arduino UNO and node MCU module for conventional as well as UAV applications. The emergence of the Internet of Things (IoT) has made it easier to read the various gases present in the environment using smartphones from the workplace. The use of an Arduino processor with a Node MCU to construct an air quality monitoring system is discussed in this paper. The Node MCU is used to transmit live data for CO, CO_2, and $PM_{2.5}$ concentrations that are sensed by sensors. This data can be monitored continuously by the user via the mobile phone. The calibration of sensors is highly important while reviewing and grasping the large literature on the subject of IoT-based air quality monitoring. The proposed low-cost live air quality monitoring system uses commercially available gas sensors to detect environmental gases such as CO, CO_2 and $PM_{2.5}$ to monitor air quality in an outdoor area. The proposed system is used to correctly evaluate the experimental outcomes. This proposed prototype model incorporates an open-source cloud facility with Arduino for air quality monitoring, confirming low cost, comfort, and convenience for a customizable air quality monitoring system. As a result, the suggested system can simply be converted to use in a UAV for monitoring air quality in the outdoors at various altitudes, and it can be scaled up in the future.

INTRODUCTION

Nowadays, environmental gas monitoring is critical for observing the concentrations of numerous dangerous gases in both indoor and outdoor environments, as well as for studying the state of the environment in today's society. The gases in the environment such as CO, CO_2, $PM_{2.5}$ cause more health-related issues for human beings. The low-cost pollution tracking system needs to be installed in many places to track the level of hazardous gases present in the environment. The aim of tracking the level of hazardous gas around the environment is to give useful information related to the impact of pollution on the people and also it is very much helpful to take remedial action to improve the quality of the environment. There is a plethora of conventional methods used to monitor the quality of environmental conditions (Sirsikar & Karemore 2015). The major goal of environmental parameter monitoring is to continuously observe the concentration of hazardous gases and to analyze the impact of environmental pollution due to the emission of gases from the vehicles and industries and to provide this information to the people to create awareness about global warming and health-related issues caused by the emission of hazardous gases such as CO, CO_2, nitric oxide, $PM_{2.5}$, PM_{10} and so on. The Korea Ministry of Environment (KMOE) prescribed the Indoor Air Quality (IAQ) act to minimize the effect of various gases present in the environment such as $PM_{2.5}$, particulate matter 10, and carbon monoxide from these listed pollutants. The Indoor Air Quality (IAQ) standard for the $PM_{2.5}$ level is around 150 $\mu.gm^{-3}$ (Dinh et al. 2014). The proposed environmental gas sensing system may help to reduce the rate of health-related problems due to the excess amount of hazardous gases present in the environment by identifying the high concentration regions in the environment. The presence of very small particles between 2.5 microns or less causes more health problems in the brain and lungs. In general, the suggested IoT-based real-time environmental gas monitoring system is used to map high concentration zones at a lower cost of installation.

RELATED WORK

With a limited number of air quality monitoring systems, the Internet of Things (IoT) was deployed in a smart environmental pollution monitoring system Shitole & Markande (2016). Okokpujie et al. (2016) presented a request and response protocol with a combination of address and data-centric protocol for air quality monitoring at home. Alvear et al.

(2017) presented a pollution-based UAV control system. The data is collected using an unmanned aerial vehicle equipped with a Pixhawk autopilot and a Raspberry Pi controller board, which is then compared to the simulation findings using OMNeT++. Wei-Ying et al. (2016) proposed a model that displayed the quantity of real-time air pollutants using several air quality sensors. Saha et al. (2017) proposed an IoT-based sensor-based air quality measurement. Short message service is shared with the public whenever the air quality level exceeds the threshold level of the standard air quality index. Sammarco et al. (2017) proposed an ambient real-time air quality monitoring system that consists of several air quality monitoring stations placed in various locations that are connected via wireless protocol using machine-to-machine communication. For air quality monitoring, supervisory control and data acquisition (SCADA) is used, which allows the user to monitor pollution data quickly using smart SCADA (Anil kumar et al. 2017). The Raspberry module is used to measure CO and other gases at normal levels, and the data may be viewed via a web page within the network range. However, using the parameters, accurate long-term prediction of air pollution data is not possible (Nayak et al. 2017). Balasubramanian & Manivannan (2016) proposed an IoT-based air quality monitoring system with alarm indication, in which the data can be accessed from a web server and the alarm will be activated if the air pollution level exceeds the threshold level, otherwise, the air pollution data will be indicated and accessed from the webserver. The MQ 135 sensor is used (Rukmani. et al. 2018) to measure various hazardous chemicals present in the environment, and an Arduino-based controller is used to control the entire process, as well as image processing and deep learning. Vinoth Kumar et al. (2017) proposed IoT based smart irrigation system using an Arduino processor in which various information is transmitted. Xioajun et al. (2015) proposed IoT based air quality monitoring system with a large number of sensors.

MATERIALS AND METHODS

The proposed system is used to assess the air quality in a given location where gas sensors detected air samples. Thus it consists of MG 811 (CO_2), MQ 7 (CO) and $PM_{2.5}$ sensor modules, Arduino UNO, Node MCU, and ground station to obtain live pollution data from the environment. CO_2 sensor MG 811 was calibrated with the known values from the various vehicles. The operating voltage for MG 811 was 6 V and the detection zone is about 0 to 10000 ppm. The MQ 7 sensor was used to monitor CO levels in the external environment, and it was calibrated using known values from various vehicles. The CO sensor's operating voltage is 5V dc, so the CO gas may be felt by the sensor, which has a range of 10 to 1000 ppm. The PM2.5 sensor is utilized in the proposed system to measure the particulate matter in the environment. The $PM_{2.5}$ sensor measures the concentration of small particles with a diameter of less than 2.5 microns. The $PM_{2.5}$ sensor's supply voltage and operating current are around 5 V dc and 20 mA, respectively. The $PM_{2.5}$ sensor has a sensitivity of 0.5 V (0.1 $mg.m^{-3}$), and all of these air quality sensors are sent into the Arduino UNO CPU to provide valuable data to the user. The controller's power source is around 5 volts. Because of its many capabilities and low cost, the Arduino UNO controller is used. The suggested system employs Node MCUs to transport data from one site to the control station. The Node MCU may be coupled with the Blynk app, which is highly beneficial for constructing IoT projects. With the Blynk app, the user can see live data monitoring on their mobile phone. Because a scalable unmanned aerial vehicle platform must be suitable for real-time monitoring of environmental pollution related parameters, the UAV for air quality monitoring plays a critical role in this application, and quad copter UAV is suitable for air quality measurement application due to its hovering capability, greater manoeuvrability, lower cost, ease-of-use, and higher payload capacity. As a result, this suggested air quality monitoring system is more suited for use by UAVs to detect the various gases present in the environment at different altitudes.

PROPOSED SYSTEM

In the proposed system low-cost air quality monitoring system for the outdoor environment is implemented using various air quality sensors, arduino UNO and node MCU module. Fig. 1, shows the proposed air pollution monitoring system.

Arduino UNO was used to convert the sensor signals into the respective gas concentration in ppm as well as in the unit of $mg.m^{-3}$. Because the node MCU module was used for wireless air quality monitoring, the arduino signal was further delivered and received to the user's mobile phone. Environmental parameter measuring and analysis systems that use wired networks have more design complexity and are more expensive than wireless environmental parameter

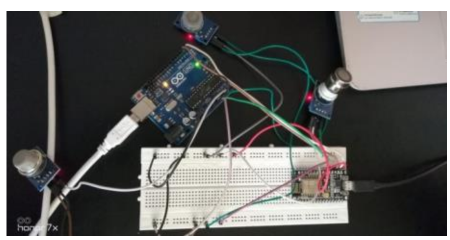

Fig 1: Proposed air pollution monitoring system.

measuring systems. This suggested system uses IoT approaches to monitor environmental indicators, resulting in a system with more functionality and a lower installation cost. Sensors to measure gases such as CO, CO2, and $PM_{2.5}$ are calibrated and integrated with an Arduino controller, after which the measured values from the sensors are converted to electrical quantities, such as voltage signals, which are then converted to the respective ppm units as $mg.m^{-3}$ units using codes uploaded in the Arduino, and finally transmitted to the user's mobile phone using a node MCU module and Wi-Fi protocol.

The sensor calibration and the sensor measurements are tested by using different gases emitted from various vehicles. Finally, the suggested system for real-time environmental gas measurement in an outdoor location was measured, and real-time live data was transferred and received by the user. For testing, the breadboard was used to connect the sensors like MQ 7, MG 811, $PM_{2.5}$ and other controller modules. Android type mobile phone is used in the proposed system and the live environmental parameter in ppm and $mg.m^{-3}$, as well as the corresponding sensor output in voltage, also can be displayed in the mobile phone which is connected to cloud database so that variations in the graph can be viewed based on various level of pollution concentration. Fig. 2, shows the block diagram for the proposed air quality monitoring system in which the CO sensor, CO_2, and $PM_{2.5}$ sensors were connected to the Arduino controller, and the output of the Arduino connected to the node MCU and from the node MCU, the live pollution data was transmitted.

RESULTS AND DISCUSSION

We focused on measuring gases such as CO, CO_2, and $PM_{2.5}$ that are emitted by automobiles. In the suggested system, measurements of various gases such as CO, CO_2, and $PM_{2.5}$ were made with various condition vehicles. The CO_2 sensor,

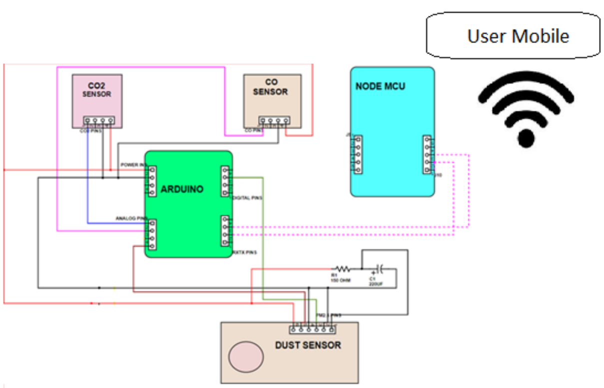

Fig. 2: Block diagram of proposed air quality monitoring system.

CO sensors, and $PM_{2.5}$ sensors were linked to the analog input pins of the controller throughout the experimental inquiry, which involved roughly 12 different motorcycles in various conditions. The vehicles were categorized based on their condition as well as the year of the purchase or the different old vehicles such as 1-year old vehicle category, 3-year old vehicle category, 6-year old vehicle category, and 12-year old vehicle category. From each category, three vehicles were chosen, and emitted gas measurements were taken using the proposed system. CO, CO_2, and $PM_{2.5}$ are some of the gases released by cars. Five pollutants were analyzed, and the results of the research revealed that the amount of pollution varies on the condition and age of the vehicles. The arduino controller was coded to output the calibrated sensor electrical signal voltage as well as the associated value of the pollutants in $mg.m^{-3}$ and ppm, which are also employed in the deep analysis. The system was then used to measure various pollutions present in the environment in real-time, and the measured data was then transmitted to the user mobile using IoT application with all the parameters in different units of measured pollutant gases, and the data collected from the proposed system was very useful to analyze in light of health issues and others. Hence, the system's installation cost is low. To investigate gas emissions from various vehicle conditions, sensors were attached to an Arduino controller that was combined with a node MCU. After processing the data with the Arduino UNO module, the measured pollutant values from the vehicles were transmitted to the user's mobile phone via the cloud, and then interpretations were made using the collected data. Case-1 category vehicles were purchased and used for less than or equal to one year. Vehicles in the case-2 category were purchased and used for about three years, vehicles in the case-3 category were purchased and used for about six years, and vehicles in the case-4 category were purchased and used for about ten years. In each category, three vehicles were used for testing purposes to measure the CO_2, CO, and $PM_{2.5}$ that were emitted from those different cases of a vehicle.

MEASUREMENT OF CO_2

The amount of CO_2 emitted from four distinct types of automobiles was measured. Fig. 2 depicts the testing of emitted gas detection for CO_2 gas, with a CO_2 gas sensor MG-811 put at the vehicle's gas emitted place. The sensor's function is to measure the concentration of CO_2 gas emitted from the vehicle; additionally, the sensor was connected to an Arduino UNO board to obtain the corresponding emitted gas concentration values in various units such as ppm, $mg.m^{-3}$, and the corresponding sensor output voltage in mV. Then the device was embedded with Node MCU and after further configuration, the system was ready to connect with the Smartphone to monitor the live data of the CO_2 gas. Table 1 shows the measured gas concentration values from the various conditions of vehicles to observe the dynamic range of measured values of gas concentrations including ppm, mg/mg^3 and mV.

In the first case, three different one-year-old vehicles were chosen for the test, and the emitted gases were measured. The results show that the CO_2 concentration varies in ppm from 744.882 ppm to 749.072 ppm, the CO_2 gas concentration in mg.m^{-3} varies from 853.244 mg.m^{-3} to 858.964 mg.m^{-3}, and the corresponding sensor output in mV varies from 436.873 mV to 439.331 mV. From the measurement of CO_2 gas, a small amount variation in emitted gas concentration was observed from the measurement.

In the second case of CO_2 measurement, three different 3-years old vehicles were chosen for the test, from the result the CO_2 gas ppm value varies from 769.570 ppm to 775.892 ppm, the CO_2 gas concentration in mg.m^{-3} varies from 904.319 mg.m^{-3} to 910 mg.m^{-3} and the corresponding sensor output values vary from 463.024 mV to 466.122 mV. It was observed that the variation of CO_2 gas concentration from case-1 to case-2 was quite large due to the conditions of vehicles.

In the third case, the emitted CO_2 gas was measured from three 6-years old vehicles for testing purposes, from the result, the concentration of CO_2 gas in ppm varies from 789.470 ppm to 794.75 ppm, the emitted CO_2 gas concentration in mg.m^{-3} varies from 904.319 mg.m^{-3} to 910.369 mg.m^{-3} and the corresponding sensor output voltages ranges from 463.024 mV to 466.122 mV, from the observation even though there is a little variation in the vehicles among the case-3 category, There is quite large variations observed from case-2 category vehicles to case-3 categories of vehicles. Three different ten years old vehicles were chosen in the case-4 category for the test to measure the emitted CO_2 concentration for the analysis purpose at last from the result the variation of CO_2 gas in ppm was from 808.382 ppm to 816.339 ppm, the concentration of CO_2 in mg.m^{-3} varies from 925.982 mg.m^{-3} to 935.09 mg.m^{-3}, and the corresponding sensor output voltage varies from 474.116 mV to 478.783 mV. The various cases of emitted CO_2 measurement give the observation of variations in the dynamic range of the measured values from the sensors using a controller.

Table 1: Measured CO_2 values from different vehicles.

Vehicle	Vehicle Period	Sensor output (mV)	Concentration of CO_2 (ppm)	Gas concentration (mg.m^{-3})
Vehicle-1	1 year old	436.873	744.882	853.244
Vehicle-2		438.266	747.256	855.964
Vehicle-3		439.331	749.072	858.044
Vehicle-4	3 years old	451.353	769.570	881.524
Vehicle-5		452.160	770.946	883.100
Vehicle-6		455.061	775.892	888.766
Vehicle-7	6 years old	463.024	789.470	904.319
Vehicle-8		464.409	791.831	907.023
Vehicle-9		466.122	794.752	910.369
Vehicle-10	10 years old	474.116	808.382	925.982
Vehicle-11		475.901	811.425	929.468
Vehicle-12		478.783	816.339	935.097

Fig. 3: Measurement of CO_2 from different vehicles.

Measurement of CO

Thus the measurement of CO from the various categories of vehicles was observed. The testing of emitted gas detection for CO gas is shown in Fig. 5 and Fig. 6. The figures depict the measured gas concentration values from various vehicle conditions to demonstrate the dynamic range of recorded gas concentration values, such as ppm, mg.mg^{-3}, and mV.

Three different 1-year old used vehicles were chosen for test in case-1 for the measurement of emitted CO from vehicles, and from the result, the CO gas concentration in

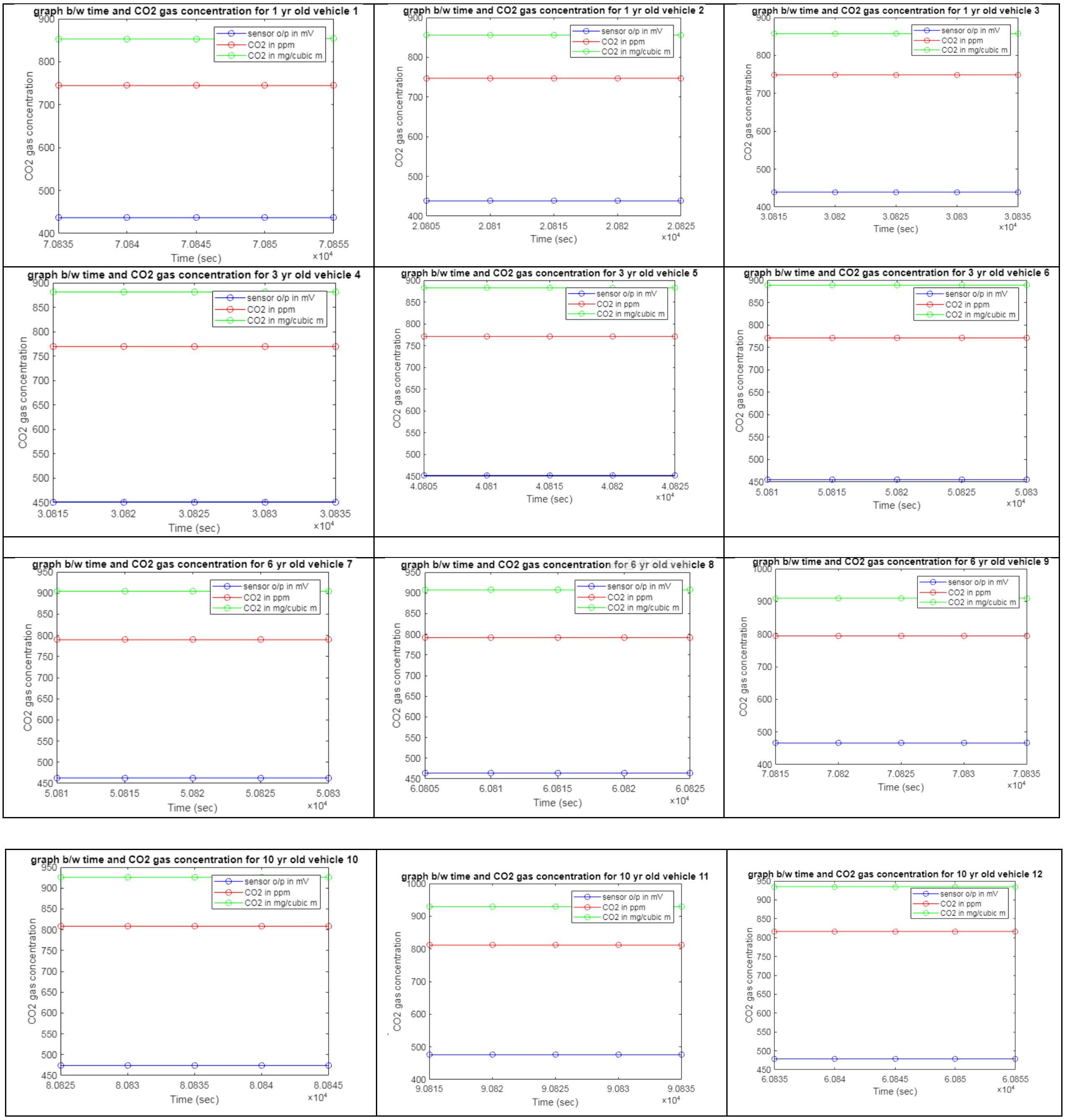

Fig. 4: Arduino UNO controller output for CO_2 from different vehicles.

Fig. 5: Measurement of CO from different vehicles.

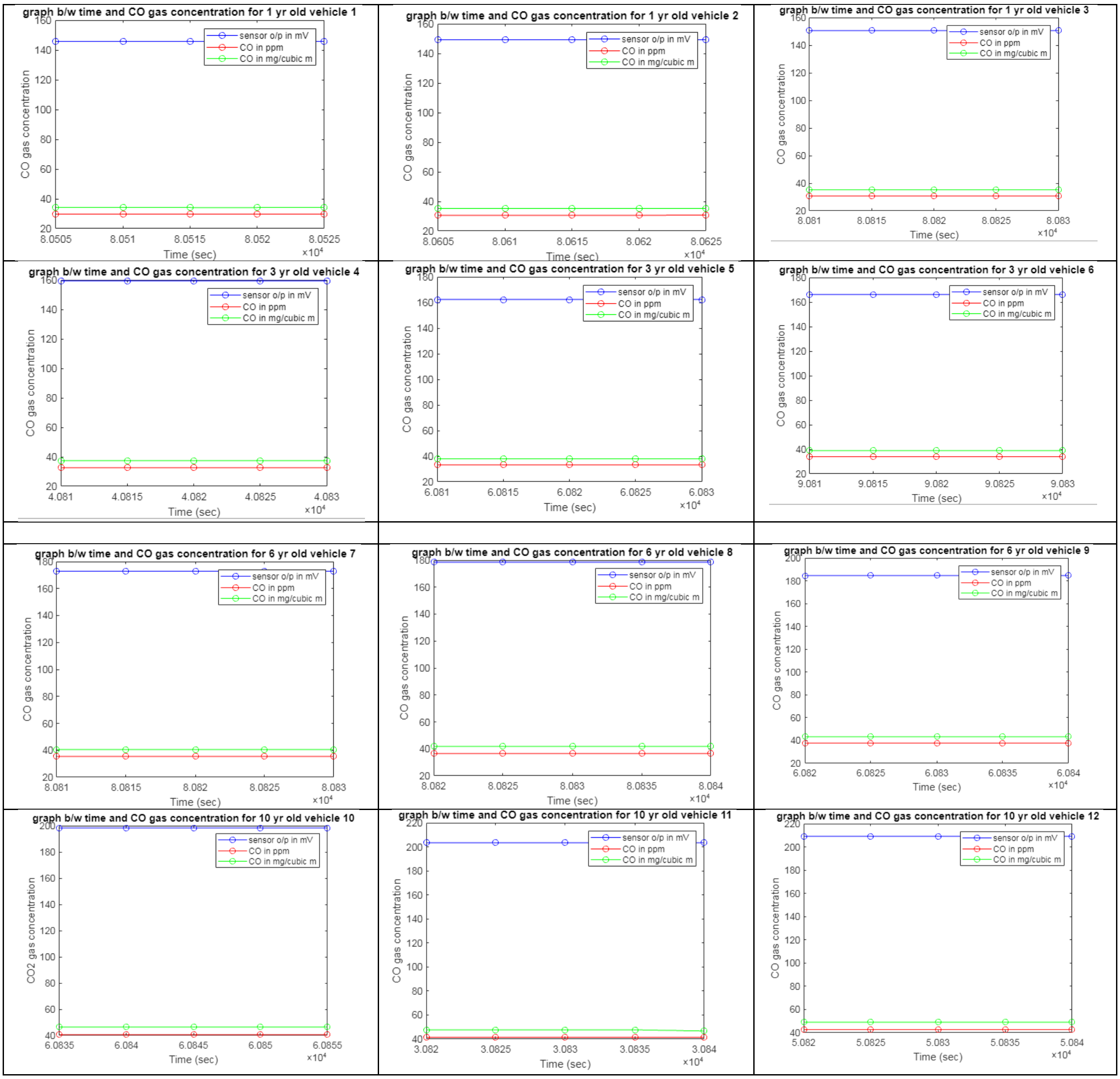

Fig 6: Arduino UNO controller output for CO from different vehicles.

ppm values varies from 29.833 ppm to 30.806 ppm, the CO gas concentration in mg.mg^{-3} varies from 34.173 to 35.288 mg.mg^{-3} and the corresponding sensor output voltage varies from 145.811 mV to 150.566 mV. For the case-1, it was observed that there is a small amount of variation in emitted gas concentration for CO. In the second case of CO measurement, three different three-years-old vehicles were chosen for the test to observe the dynamic range of sensor output, and from the result, the emitted CO gas concentration in ppm varies from 32.621 ppm to 33.996 ppm, the CO gas concentration in mg.mg^{-3} varies from 37.367 mg.mg^{-3} to 38.942 mg.mg^{-3} and the corresponding sensor output voltage variation in mV is from 159.418 mV to 166.131 mV. It was observed that the variation of emitted CO gas concentration from case-1 to case-2 is quite large due to the conditions of vehicles (Table 2).

In the third case of CO measurement, three different 6-years used old vehicles were chosen for the test, and from the result, it was observed that the variation of CO gas in ppm was from 35.380 ppm to 37.754 ppm, the emitted CO gas concentration in mg.mg^{-3} varies from 40.577 mg.mg^{-3} to 43.247 mg.mg^{-3} and the corresponding sensor output variation in mV vary from 172.902 mV to 184.503 mV. In the fourth case of CO measurement, three 10-years old used vehicles were chosen for the test to measure the emitted gas measurement, and from the result, it was observed that the CO gas concentration in ppm varies from 40.579 ppm to 42.792 ppm. The concentration of CO in mg.mg^{-3} varies from 46.483 mg.mg^{-3} to 49.018 mg.mg^{-3}, and the corresponding sensor output in voltage varies from 198.309 mV to 209.124 mV. It was observed that from the first case to the fourth case the output of the sensor varies with the category and condition of vehicles.

Measurement of Fine Particulate Matter $PM_{2.5}$

In the first case of $PM_{2.5}$ measurements, three different 1-year old vehicles were chosen for the test, thus the measurement of $PM_{2.5}$ from the various categories of vehicles was observed. The testing of emitted gas detection for $PM_{2.5}$ gas is shown in Fig. 7, where the $PM_{2.5}$ gas sensor was placed in the gas emitted place of the vehicles. The function of the sensor is to measure the concentration $PM_{2.5}$ gas emitted from the vehicle and after further configuration, the system was ready to connect to the Smartphone to monitor the live data of the $PM_{2.5}$ gas. Fig. 8, shows the measured gas concentration values from the various conditions of vehicles to observe the dynamic range of measured values of gas concentrations including ppm, mg.mg$^{-3,}$ and mV.

In case-1, the measured value of $PM_{2.5}$ in ppm varies from 0.0229 to 0.0235 ppm, the $PM_{2.5}$ concentrations in mg.m^{-3} varies from 0.0262 mg.m^{-3} to 0.0269 mg.m^{-3} and corresponding sensor output voltage varies from 0.367 mV to 0.371 mV. In the second case of $PM_{2.5}$ measurements, three different 3-years old used vehicles were chosen for the test. Results show that $PM_{2.5}$ concentrations in ppm varies from 0.0246 ppm to 0.0252 ppm, the $PM_{2.5}$ concentration in mg.m^{-3} varies from 0.0281 mg.m^{-3} to 0.0288 mg.m^{-3} and the corresponding sensor output voltage varies from 0.394 mV to 0.403 mV. In the third case of $PM_{2.5}$ measurements, three different 6-years old vehicles were chosen for the test. Results show that the concentration of $PM_{2.5}$ in ppm varies from 0.0254 ppm to 0.0261 ppm, the $PM_{2.5}$ concentrations in mg.m^{-3} varies from 0.0292 to 0.0299 mg.m^{-3} and the corresponding sensor output voltage varies from 0.408 mV to 0.418 mV. Due to the similar vehicle conditions, the

Table: 2 Measured CO values from different vehicles.

Vehicle	Vehicle Period	Sensor output (mV)	Concentration of CO (ppm)	Gas concentration.(mg/m^3)
Vehicle-1	1 year old	145.811	29.833	34.173
Vehicle-2		149.217	30.530	34.942
Vehicle-3		150.566	30.806	35.288
Vehicle-4	3 years old	159.418	32.621	37.367
Vehicle-5		162.233	33.197	38.027
Vehicle-6		166.138	33.996	38.942
Vehicle-7	6 years old	172.902	35.380	40.527
Vehicle-8		178.414	36.508	41.820
Vehicle-9		184.503	37.754	43.247
Vehicle-10	10 years old	198.309	40.579	46.483
Vehicle-11		203.338	41.608	47.661
Vehicle-12		209.124	42.792	49.018

Fig. 7: Arduino UNO controller output for $PM_{2.5}$ from different vehicles.

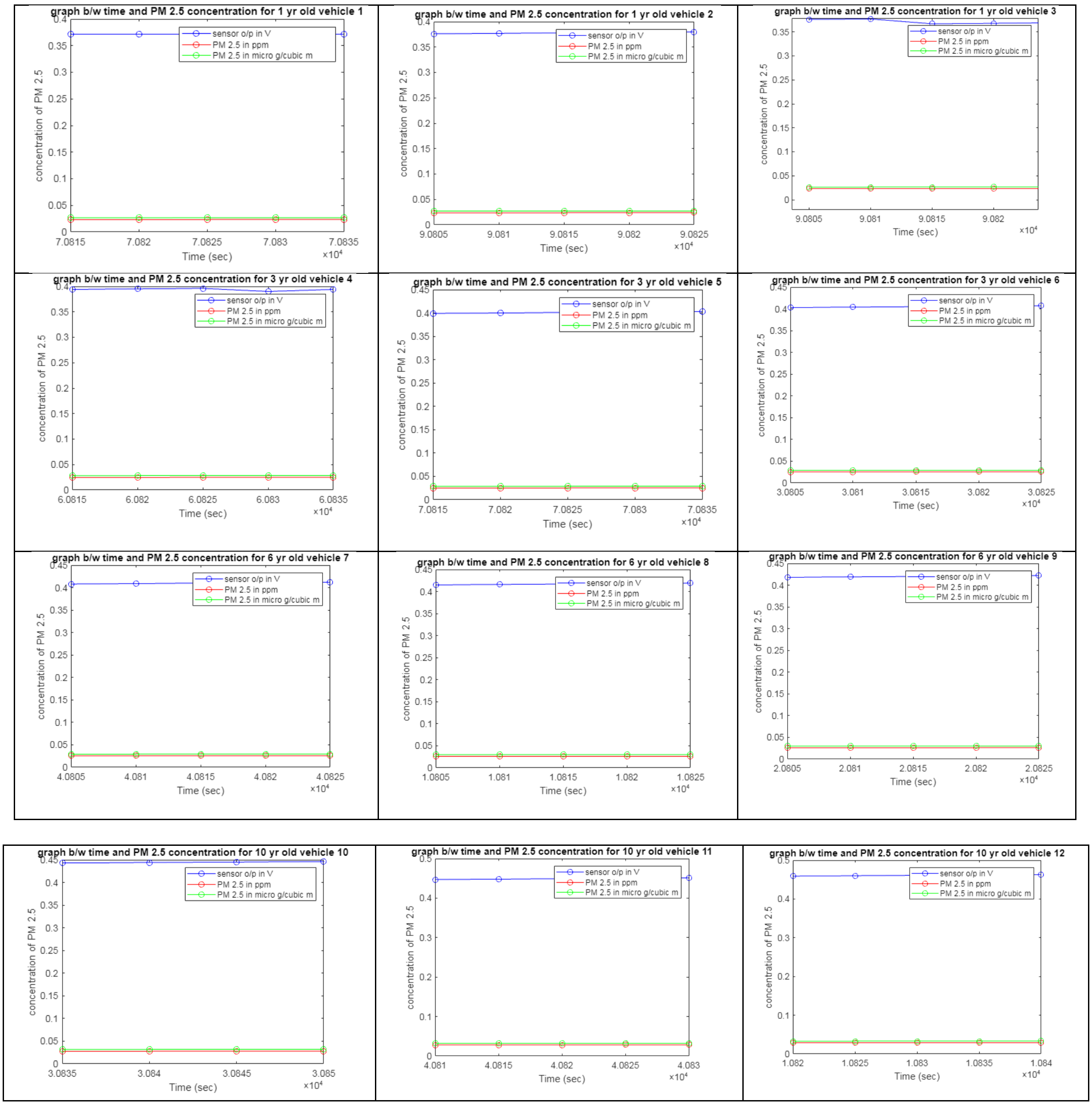

Fig 8: Measurement of $PM_{2.5}$ from different vehicles.

difference between the emitted $PM_{2.5}$ concentration values of this category of chosen vehicles was very small, and a significant difference was observed between the second case category of vehicles and the third case category of vehicles due to the different vehicle conditions between case-2 and case-3. In the fourth case of $PM_{2.5}$ measurements, three different 10-years old vehicles were chosen for the test. The result was observed that the variation in $PM_{2.5}$ in ppm varies from 0.0277 ppm to 0.0287 ppm. The $PM_{2.5}$ concentration in $mg.m^{-3}$ varies from 0.0317 $mg.m^{-3}$ to 0.0328 $mg.m^{-3}$ and the corresponding output voltage varies from 0.443 mV to 0.459 mV. From the measurement, considerable variation exists between those two cases (Table 3).

Environmental Parameter Measurement

In this proposed system, measurement of CO, CO_2 and $PM_{2.5}$ using different gas sensors was done and the sensor outputs were transmitted using node MCU, and the same module was used for live data monitoring. The analog values received from the sensors were processed by the controller via a Wi-Fi connection to the Internet. Once the values were obtained from the sensors, they were converted to various units of gas concentrations such as ppm, $mg.m^{-3}$, and sensor output in mV, which the user could monitor via their mobile phone. The air quality data such as CO, CO_2 and $PM_{2.5}$ were sensed by the sensors interfaced with the controller board and those were transmitted to the user's mobile phone. The user could monitor the live air quality data from their working place. As a result, the suggested air quality monitoring system's main feature is its low cost. The main goal of IoT was to have the values of real-time data updated to the user at any given time via the cloud.

The proposed system was used for real-time air pollution monitoring after completion of the various emitted gas measurement from the vehicles. Fig. 9, shows the live data for CO, CO_2, and $PM_{2.5}$ in ppm. Fig. 10, shows the live data for CO, CO_2, and $PM_{2.5}$ in $mg.m^{-3}$, and Fig. 11, shows the live data for CO, CO_2 and $PM_{2.5}$ in ppm. These pollutant

Table: 3 measured $PM_{2.5}$ values from different vehicles.

Vehicle	Vehicle Period	Sensor output (mV)	Concentration of $PM_{2.5}$ (ppm)	Gas concentration ($mg.m^{-3}$)
Vehicle-1	1 year old	0.371	0.0232	0.0265
Vehicle-2		0.376	0.0235	0.0269
Vehicle-3		0.367	0.0229	0.0262
Vehicle-4	3 years old	0.394	0.0246	0.0281
Vehicle-5		0.399	0.0249	0.0286
Vehicle-6		0.403	0.0252	0.0288
Vehicle-7	6 years old	0.408	0.0254	0.0292
Vehicle-8		0.415	0.0259	0.0297
Vehicle-9		0.418	0.0261	0.0299
Vehicle-10	10 years old	0.443	0.0277	0.0317
Vehicle-11		0.447	0.0279	0.0320
Vehicle-12		0.459	0.0287	0.0328

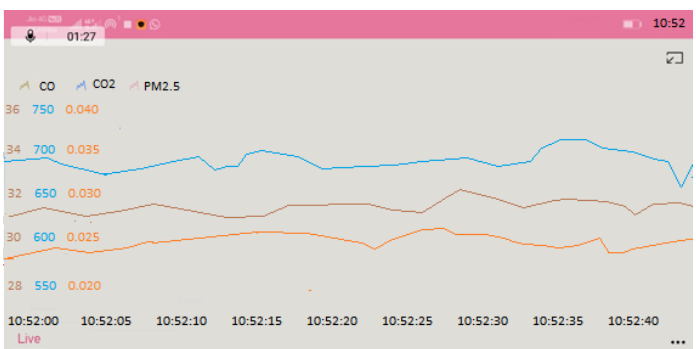

Fig. 9: Live data for CO, CO_2, $PM_{2.5}$ in ppm from node MCU.

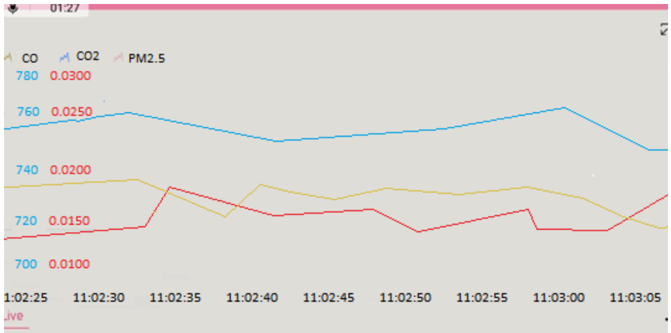

Fig. 10: Live data for CO, CO_2, $PM_{2.5}$ in $mg.m^{-3}$ from node MCU.

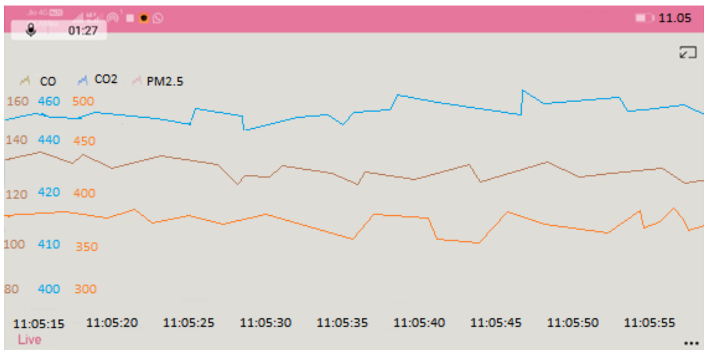

Fig. 11: Live data for CO, CO_2, $PM_{2.5}$ in mV from node MCU.

measurements were obtained from the proposed system and this system was more suitable for an unmanned aerial vehicle (UAV) for the measurement of various hazardous gasses present in the different altitudes of the environment.

CONCLUSION

The proposed system is integrated with various environmental parameter measuring sensors, controller, and node MCU modules for the transmission of data to the user. Further, this system can be utilized for the measurement of hazardous gases present in the various altitude of the environment using unmanned aerial vehicles (UAV). The cost of installing the system is low, and it has a high sensitivity for measuring various ambient gases in both the interior and outdoor environments. An aspect of IoT applications is the ability to monitor environmental pollutants using smartphones. It is very convenient for the user to monitor the pollutant gases present at various altitudes from the control station whenever the system is used with an unmanned aerial vehicle. By deploying our system in various locations, we can quickly obtain measurements of various gases present in the environment, which can then be updated on the cloud. Environmental parameters were also collected by the system, which was then stored in the cloud and analyzed to determine air quality in both urban and rural areas. This aids in determining and analyzing the principal cause of health-related difficulties caused by various levels of pollutants in the air, so that appropriate precautionary actions can be taken to overcome and reduce air pollution.

REFERENCES

Alvear, O., Zema, N.R. and Natalizio, E.2017. Using UAV-based systems to monitor air pollution in areas with poor accessibility. J. Adv. Transp., 16: 14.

Anil Kumar, U., Keerthi, G., Sumalatha, M. and Sushma, R. 2017. Iot based noise and air pollution monitoring system Using Raspberry Pi. Int. J. Adv. Technol. Eng. Sci., 5(3): 183-187.

Balasubramanian, C. and Manivannan, D. 2016. IoT enabled air quality monitoring system (AQMS) using raspberry Pi. Indian J. Sci. Technol., 9(39): 63-79.

Dinh, T.V., Son, Y.S., Chung, S.G., Lee, J.H. and Kim. J.C. 2014. Removal of particulate matter emitted from a subway tunnel using magnetic filters. Environ. Sci. Technol., 48(5): 2870-2876.

Nayak, R., Panigrahy, M.R., Rai, V.K. and Rao, T.A. 2017. IoT based air pollution monitoring system. Imp. J. Interdiscip. Res., 3(4): 111-121.

Okokpujie, K.O., Orimogunje, A., Noma-Osaghae, E. and Alashiri, O. 2017. An intelligent online diagnostic system with epidemic alert. Int. J. Innov. Sci. Res. Technol., 2: 327-331.

Rukmani, P., Teja, G.K. and Vinay, M.S. 2018. Industrial monitoring using image processing IoT and analyzing the sensor values using big data Procedia Comp. Sci., 133: 991-997.

Saha, D., Shinde, M. and Thadeshwar, S. 2017. Iot-based air quality monitoring system using wireless sensors deployed in public bus services. ICC '17: Proceedings of the Second International Conference on Internet of things, Data and Cloud Computing, Cambridge, UK, 22-23 March 2017, Association for Computing Machinery. New York, United States, pp. 1-6

Sammarco, M., Tse, R., Pau, G. and Marfia, G. 2017. Using geosocial search for urban air pollution monitoring. Pervasive Mobile Comp., 35: 414-426.

Shitole, P.V. and Markande, S.D. 2016. Review: Air quality monitoring system. Int. J. Adv. Res. Comp. Commun. Eng., 5(6): 56-73.

Sirsikar, S. and Karemore, P. 2015. Review paper on air pollution monitoring system. Int. J. Adv. Res. Comp. Commun. Eng., 4(1): 218-220

Vinoth Kumar, V., Ramasamy, R. Janarthanan, S. and VasimBabu, M. 2017. Implementation of IoT in smart irrigation system using Arduino processor, Int. J. Civil Eng. Tech., 61: 1304-1314.

Wei-Ying, Y., Leung, K.S., Leung, Y., Meng, M.L. and Terrence, M. 2016. The modular sensor system (MSS) for urban air pollution monitoring. Sensors, 18(1): 7. DOI:10.3390/s18010007.

Xiaojun, C., Xianpeng, L. and Peng, X. 2015. IOT-based air pollution monitoring and forecasting system. 2015 International Conference Computer and Computational Sciences (ICCCS) at IEEE, India, 27-29 January, IEEE, Piscataway, NJ, pp. 257-260.