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Air Pollution Monitoring in Remote Areas using Smart UAV based System

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Abstract: *Real time monitoring of air pollution and measurement of pollutant gases is very challenging task and needs more numbers of sensors and lots of observation. In this paper, Unmanned Aerial Vehicle (UAV) based system equipped with different micro sensor, is introduced for monitoring of air quality. It will offer a new approach in environmental pollution assessment instead of ground based monitoring system. Air pollution concentration data is collected by different sensors present in UAV, are effectively monitored in personal computer or mobile devices. The main objective of this paper is to elaborate the performance capability of UAV for effective monitoring of air pollution and measure health hazard air pollutants with high sensitivities in a particular area where human cannot reach. As it is quite recent field, a fruitful effort has dedicated to develop an integrated sensing system and optimization of its crucial features as dimension, weight and energy autonomy. The effectiveness of the developed system is evaluated by performing some field experiments using a hardware prototype UAV model.*

Keywords: Air Pollution measurement, Unmanned Aerial Vehicle, Smart sensing unit, Electronic Speed Controller, MCU unit

I. INTRODUCTION

As day by day air pollution is rapidly increasing due to old vehicles, more industrialization, presence of toxic gases in atmosphere. It will increase pollutant particles in air like PM0, PM1.5, Sulphur Oxide, Nitrogen Oxide, Carbon Monoxide and other volatile components. Long term air pollution will cause heart disease, lung cancer, respiratory disease like emphysema. So, air pollution monitoring is become an issue of utmost important in our society mainly in crowd areas as a leading risk factor [2]. Different environmental organizations and government institutions are set to primary goal to consider the monitoring of environmental pollutants [4]. Air quality measurement is very much important to make sure that governmental agencies, general public and any involved party is conscious of pollution level of district to take the required precautions for ensuring safety of populations [1]. Drone technology has gained popularity over the years, mainly introduced for air quality monitoring, population monitoring, surveillance of critical building etc. In technology field, UAV can be accepted very well with minimum risk and maximum efficiency. Mainly taking measurements close to pollutant sources always may not be possible and it could be too dangerous or risky for manned aircraft to fly close to the ground, there UAV can give a quick and real time response of health hazard gases before protection [3]. Fast and comprehensive data collection near pollution sources is not always feasible due to complexity of sites and physical barriers [2]. Again, if satellite and sensors are used it will become very much costlier. This reasons encourage the usage of small, lightweight UAVs for wide range of applications mainly atmosphere pollution measurement [6].

Many researchers are doing many researches on UAV and applied drone technology in different applications. Recently, UAV have become a cheap alternate to sense pollution intensity in a certain area due to their flexibility and ability to carry small sensing units [7]. Further these vehicles are remotely controlled, autonomous, semiautonomous or have a combination of these capabilities. In reference [8], Pollution driven UAV Control (PdUC) algorithm is used to perform air pollution monitoring based on Chemotaxis metaheuristic and Particle Swarm Optimization Strategy. In reference [9], development of an environmental drone for autonomous monitoring, analysis and countering of air pollution with low cost sensors to measure Air Quality Index (AQI) in a particular area. The collected data from drone is received by base

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station for AQI mapping with a standardized threshold value. In paper [10], a decision theoretic framework is used to design unsupervised algorithm that navigates the UAV for loss function minimization. Reference [11] suggests a new autonomous multi rotor aerial platform for real time monitoring of air quality in large cities. The proposed system is evaluated in several locations throughout a metropolitan city during different seasons. For accurate monitoring of air pollution, the UAV is assembled with multiple sensors and all the output data should be integrated to get actual information about pollution.

In this paper, a small, lightweight UAV based air pollution detection system is designed to measure pollutions in remote areas. Undoubtedly, it is a promising approach environmental pollution measurement using UAVs based system accurately. This system is developed with 32 bit MCU with smart gas sensing unit and centralized data monitoring capability.

The work is organized here in following sections: Section I introduces the work, Section II explains proposed embedded UAV based pollution detection system and Section III describes the experimentation part using a hardware prototype and Section IV concludes the paper.

II. UAV BASED POLLUTION MONITORING SYSTEM

UAVs are much more versatile and visible in operation compared to land based approach or other aerial vehicles like satellites and manned aircrafts. Air pollution measurement in remote locations is very sensitive situation where small, lightweight, accurate UAVs are required with reduced cost of the platforms and instrumentations.

2.1 Design of Unmanned Aerial Vehicle

Generally, UAV requires high development and maintenance cost. So, before commercial UAV design, cost optimization is an important issue. For Frame design of UAV, mainly, 'X' type frame is preferred for UAV because it is strong enough to withstand the deformation due to load. Basically diameter of circle of frame area for mini UAV is ranging from 0.25 m to 1 m. UAV flight controller receives signal from remote transmitter through which it can understand what should be the direction of drone. For this model, APM 2.8 flight controller with ATMEL mega 664 PA and 8 bit AVR RISC based microcontroller with 64K memory space is used for its more stability over other flight controllers

Here, APM 2.8 flight controller unit is used. This board is designed with ATMEL mega 664 PA and 8 bit AVR RISC based microcontroller along with 64K memory. This controller has more stability over other flight controllers due to its inbuilt gyroscope, 6050 MPU. The user defined signal from APM controller board is processed by ATMEL 664 PA IC and finally the control signals are getting as input in Electronic Speed Controllers (ESC). Four BLDC motors are placed at the four arm corners of frame. Due to its superior thrust to weight ratio, better speed torque characteristics and longer life BLDC motor is preferable. Four motors, named as "Front, Rare, Left, Right" are connected with ESCs and these ESCs are connected with KK 2.1.5 UAV controller board. Five motion operations like hovering, backward, forward, left, right directions are controlled by changing four motor speed given in TABLE I. The UAV is capable for maximum payload weight 250 g, with a total flight weight of about 1.5 kg. The diameter of the designed UAV is considered as 1m along with maximum flight time of 20 min at a maximum wind load of 8 m/s.

TABLE 1: Motion control by BLDC motors

Motions	Motors			
	Front	Rare	Left	Right
Forward	Speed decreasing	Speed increasing	-	-
Backward	Speed increasing	Speed decreasing	-	-
Left	-	-	Speed increasing	Speed decreasing
Right	-	-	Speed decreasing	Speed increasing
Hovering	Clockwise rotation	Clockwise rotation	Anticlockwise rotation	Anticlockwise rotation

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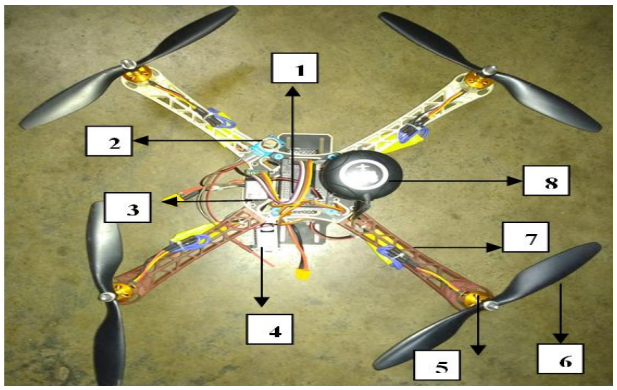
2.2 Development of Sensor Unit for Pollution Detection

The compact design and its excellent manoeuvrability with remote control mechanism UAV make possible precise navigation for entering small passages. For a significant weight reduction, lightweight lithium battery used and it will buffer the sensors until their next mission to achieve fast operational readiness. A powerful wireless link enables the communication and smooth data transmission between ground station with the UAV system. Depending on environmental scenario, five no. of sensors like MQ2, MQ7, MQ9, MQ135 are used to detect different pollutant hazards like CO, H_2S, Methane, CO_2, SO_2, PH_3, HCN, NO_2 etc. Due to low power consumption and high level of integrations, the authors use MQ series sensor with UAV for air condition monitoring. The sensitive material of that gas sensor is SnO_2, which has lower conductivity in clean air. This sensor has also very good character configuration like high sensitivity, low cost, long life. Simple drive circuit etc. Sensors are framed with MicroAL203 ceramic tube, measuring electrode and heater fixed into a crust made stainless steel net. Average power consumption is below 150 mW and it can be serviced up to 5 years. Gas sensors are connected with Node MCU microcontroller with in build Wi-Fi module. Via Wi Fi module the controller is linked with control room. After sensing unwanted gas particles, MQ sensors send raw data continuously to Node MCU unit. From there, via Wi Fi module output is available in smart phone screen by a mobile app named "blynk". The concentration is converted into Parts Per Million (PPM) reading using sensitivity calibration curve of gas sensor datasheet. Output can be observed in different patterns like graphs, raw data, indicator signals for above threshold values. Here, the authors choose graphical representation for measuring pollutants value very easily.

III. DEVELOPMENT OF HARDWARE MODEL AND EXPERIMENTATION

As mentioned in section II, a hardware prototype for small UAV system with sensor arrangement are designed in laboratory. Here, APM 2.8 flight controller is used for its advantages than other lower cost controller KK 2.1.5 like onboard barometric sensor for security purpose, interfacing facilities with off-board GPS and compass. The flight controller is connected with the fly sky receiver, which gets signal from RC transmitter by manual control. The twin blade propellers mounted on motor have 10 X 4.5'' length for excellent lift and thrust performance. The lithium polymer battery cells are used for power supply in the system. The overall parts of developed UAV are shown in Fig. 1.



1. APM 2.8 Controller
2. Gas sensing unit
3. Lipo Battery cell
4. Node MCU
5. BLDC motor
6. Propellers
7. Electronic Speed Controller
8. GPS module

Figure: Different parts of developed UAV model

As mentioned in section II, a hardware prototype for small UAV system with sensor arrangement are designed in laboratory.

3.1 Validation of Experiments in Laboratory

To validate the accuracy of pollution measurement system, experiments was performed in laboratory test chamber for different CO and LPG concentration. Two commercial gas sensors placed at different positions to detect the reference value of gases. Gas concentration is increased gradually and sensors are started to operate for reading after 1 min to provide some time to spread the gas in surrounding medium. Gas concentration is measured after every 3 mins interval throughout 40 mins. The final PPM value is measured for every time. For validation of the accuracy of UAV system, this value is compared with the ppm value obtained by UAV based gas detection system. Fig. 2 and Fig. 3 shows the result which will prove the accuracy of developed model. The UAV was in the air before the experiment started.

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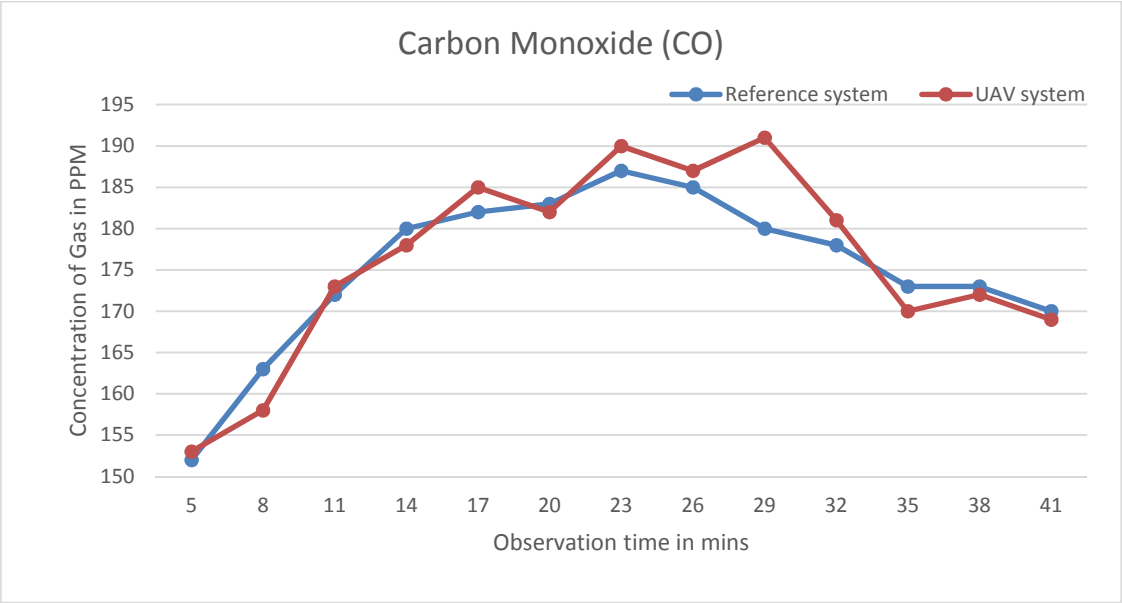

Fig. 2 Comparison between CO concentration measurement for reference device with UAV

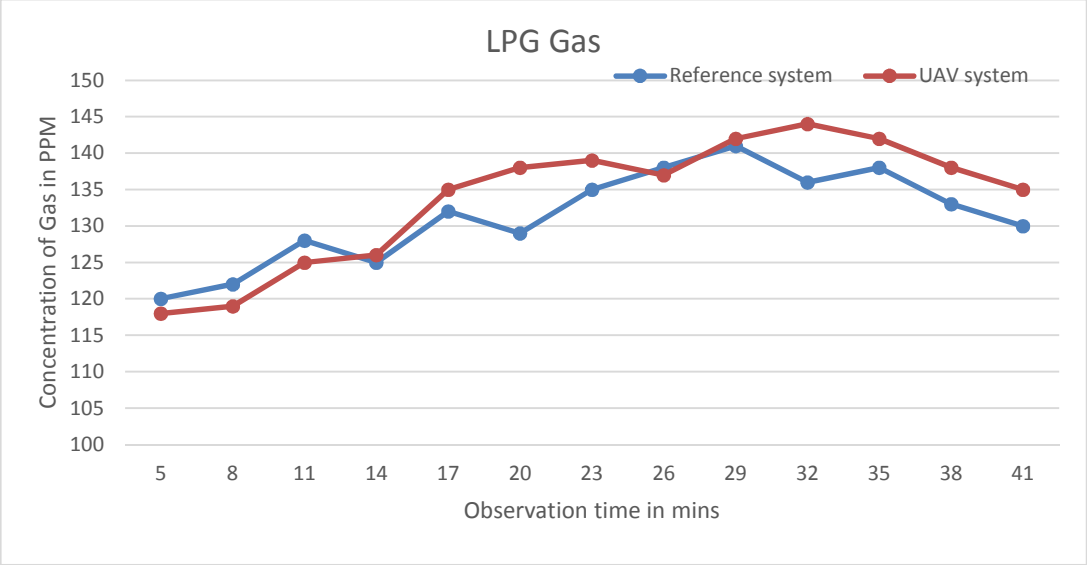

Fig. 3 Comparison between LPG concentration measurement for reference device with UAV

3.2 Experimentation in Outside Environment

The designed UAV model during flying in outside environment is shown in Fig. 4. UAVs are assembled with wide range of sensors to sense different pollutant particle and depending on that sensors, multiple data sets are collected with huge spatial and temporal resolution. To improve the information of air quality, in a short period of time air quality over a broad area is sampled using fixed wing drone mainly in pollution point sources such as industrial and constructional site. When different pollutants like CO, Methane, other combustion gases are present in atmosphere specially in remote area, UAV will monitor the condition and find pollution level. The developed model is tested in different polluted environments and gas concentration is measured in PPM. The Wi Fi range is supported here up to 500 meter. In Fig. 5, sensor output for CO gas is given. This is taken from PC via blynk app. In this graph, X axis indicates time scale and Y axis indicates gas concentration in PPM.

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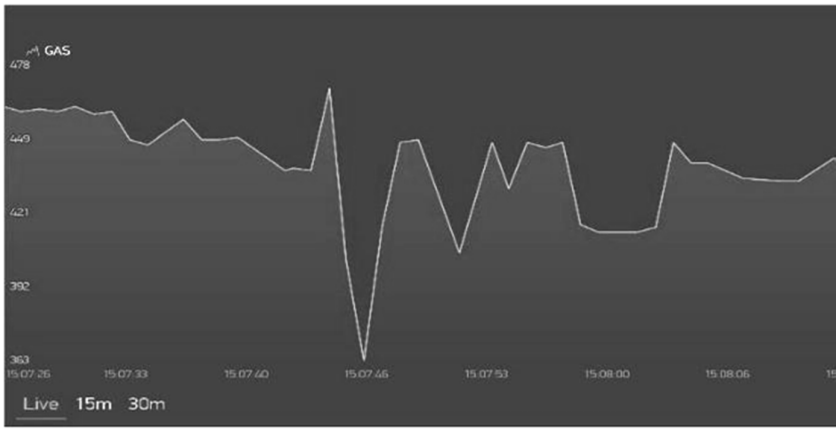

Fig. 5 Observed output from blynk app

IV. CONCLUSION

For analyse the adverse effect of atmospheric pollution on living beings, a detailed information on the characteristics of pollutant concentration is needed. Undoubtedly UAV monitoring system is expected to be an emergency and effective tool with the features of high resolution, flexibility, subjectivity, accuracy, quick response. The advanced UAV model presented here, is a low cost solution for taking the advantages of their abilities to manoeuvre in both horizontal and vertical dimensions and to hold its fixed position in air under high wind condition also. The presented model focuses on the both capabilities like classification and performance application. Moreover, this system will provide full 360 deg awareness of its surroundings. So it can be concluded that accurate continuous monitoring at any human inaccessible places or congested area are main benefit of developed UAV system.

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