# Environmental Risk Assessment Using Unmanned Aerial Vehicle

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## *Abstract*

*Now a day, Unmanned Aerial Vehicles (UAV) are significantly employed in various fields like military applications, regular civilian purposes, aerial photography, field surveillance, disaster relief etc. Among all, one of the most challenging application is environmental risk assessment i.e. recognition of gas leakage and monitoring of volatile chemical concentration in a particular area. It is a promising approach to control environmental pollution. In this paper, the authors developed an automatic environmental risk assessment system using Unmanned Aerial Vehicles. The proposed UAV based system designed with a 32-bit MCU along with smart gas sensing system, data storing and real time feedback capabilities. The UAV system comprises of four arms with four motors for lifting. Motors are connected to the ESC (Electronic Speed controller) for varying its speed. These ESC's are connected to APM 2.8 controller board which is connected to the fly sky receiver. As the field is quite recent, few efforts has been dedicated to develop integrated sensing system which focus on the optimization of crucial features as weight, dimensions and energy autonomy. To evaluate the effectiveness of the proposed system, some field experiments are performed using a prototype hardware UAV model.*

***Keywords:*** *Unmanned Aerial Vehicle, Electronic Speed Controller, MCU unit, Gas Sensing Unit*

## 1. Introduction

Unmanned Aerial Vehicles (UAV) or drones are becoming more popular in today's world for its large variety of applications from reconnaissance to inspection, mapping to surveillance [1, 2]. Though modern technology is quickly adopting and improving UAVs, its developments began a decade ago. The first manned airplane flight occurred in 1903 [3]. In 1940, an impactful design called the "Queen Bee" was developed in Great Britain, which was the capability to reach a height of 17,000 feet and fly for 300 miles at a speed over 100 mph. This drone was playing the most prominent role in World War II when the Interstate BQ-4 was effectively employed in combat in 1942 [4]. Again, in 1944, the United States reached 18 hits on targeted Japanese units with this drone. Advancement was done by Germany, which Adolf Hitler claimed to use for non-military targets. It was the capability to fly at 470 mph along with 2,000-pound load carrying capacity. Among its various applications, robot based automatically generated gas concentration map is considered as recent research topic for both environmental pollution monitoring and surveillance of critical buildings [5, 6]. As gas emissions are including under environmental security problem, so more efforts should be done for immediate safety issues and also for saving the life of peoples mainly those working on gas plants and pipelines. Not only health hazard, due to high cost gas leakage, thousands of rupees literally vanishing into thin air. In this field, UAVs can perform very well with minimum risk and maximum efficiency. Mainly the places, where one is not able to enterdue to the potential risks of inhalation and even of an explosion, there UAV can give a quick and real-time response of gas leakage scenario before rescue operation. In this paper the gas sensing system focuses on drone mapping along with gas concentration analysis by measuring the volatiles diffused in a particular area. The main constraints on using a commercial gas sensor are high power consumption. As, commercial gas sensors are mainly designed with aluminum platform, this leads to high power consumption and do not integrate with other devices. To avoid this, a custom MQ9 gas sensor has been implemented in the sensing module of this UAV system. MQ9 sensors, stands for the sensitivity towards the gas, are very well known for their ability for its reliable performance in harsh applications. This class of sensors is particularly suitable for localization the source of gas leakage, where gas sensitivity is main concern. These sensors are developed with micromachining (MEMS) techniques which provide multi parametric systems equipped with transducer for air velocity and gas detection along with minimum power requirements. Also, it is possible to implement different sensing layers to detect difference gases like CO, methane and other volatile organic compounds. This work is organized as follows, Section 2 describes related work done in this topic, Section 3 describes proposed embedded UAV system and Section 4 explains the experimentation part using a hardware prototype. Section 5 concludes the paper.

## 2. Related Work

During many years, many researchers are doing their research on low cost UAVs and the interest increases among the scientific community towards the application of drone technology in different scenarios. In reference [7, 8], gas concentration mapping in different areas using 3D imaging techniques have been explained. In reference [9], environmental monitoring by locating gas emitting sources using micro drone have been described. Reference [10] shows the monitoring of gas emission at landfill sites with mobile robots and gas source is localized by biologically inspired algorithm. Information of local wind for gas distribution mapping in outdoor environments using mobile robot has been presented in reference [11]. But the main problem with this current works is low size to pay load ratio, limited flight autonomy. Along with, another problem is high power consumption of sensing units. To overcome this, Chemo optical sensors can be adopted [12, 13]. But, this device is very expensive and periodic refill and maintenances are required. So, Chemo resistive sensors such as MOX sensors offer fast response without maintenance along with long term stability but here power consumption is very less. So, it greatly increases the lifetime of battery powered embedded electronic devices.

## 3. Proposed UHV System

Generally, UAV is such a device which intended for flighting in the air with no on board pilot and programmed for autonomous flight. It requires high development and maintenance cost. So, before designing a commercial UAV, cost optimization is a vital issue. Also UAV dimension varies from small insect size to big size professional vehicles, depending upon its application. The proposed UAV system for environmental risk assessment is divided in three parts, Frames with UAV controllers, motors for motion control, Gas sensing unit. All parts are described below:

### 3.1. Frames with UAV Controller

One important issue for design of an UAV is the frame design. Mainly, ‘X’ type frame is preferred for UAV because it is strong enough to withstand the deformation due to load. Length of the Frame depends on diameter of the circle of frame area or the motor to motor distance [14]. Basically, diameter of the circle of frame area for mini UAV ranges between 1/4m and 1m.UAV flight controller circuit translate the information from the drone remote controller to action. It works by receive a signal from remote transmitter by which it can understand what should be the direction of the drone. Here, APM 2.8 flight controller unit is used. It is a board with ATMEL mega 664 PA, 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).

### 3.2. Motors for Motion Control

An UAV produces a group of forces and torques acting on it while it flies. Drag, lift, weight and thrust are main four forces necessary for an UAV to fly. To make UAV in flying condition, these forces need to be balance. If, F is force, m is mass and a is indicating acceleration, then according to Newton’s 2nd law of motion, $F = ma$.

To fly with constant velocity, acceleration should be equal to zero i.e. sum of all forces equal to zero. For steady and constant motion, UAV complete a force balance in the horizontal direction.

$F_{thrust} - F_{drug} = 0$(1)

So, for constant velocity, UAV is either moving or at rest. An analysis in vertical direction will also provide similar results,

$F_{lift} - F_{weight} = 0$(2)

For steady level operation, lift must equal the weight and thrust must equal the drag. The UAV is designed with four BLDC motors placed in the corners of four arms. BLDC motors have superior thrust to weight ratio, electronic commutation capability, better speed torque characteristics, longer life etc. Motors are connected to the ESCs, which is further connected with KK 2.1.5 UAV controller board. ESCs are used for motion controls of UAV. The four motor arrangements are shown in figure 1.

To make the UAV commercially perfect, five motion operations like hovering, forward, backward, left and right directions to be controlled properly. Forward motion is controlled by increasing the speed of rear motor and decreasing the speed of front motor. Similarly, backward motion is controlled by increasing the speed of front motor and decreasing the speed of rare motor. For left motion, left motor speed has to be increased and right motor speed should be decreased. Similarly, for right motion, opposite operation will be performed.

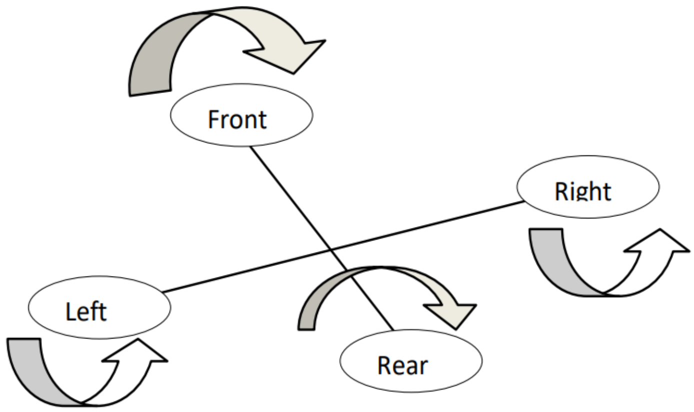


**Fig. 1. Arrangement of BLDC motors in UAV**

The hovering or static position of UAV is performed by two pairs of rotors are rotating in clockwise and counterclockwise respectively with same speed. By two rotors rotating in clockwise and counter-clockwise position, the total sum of reaction torque is zero and this allowed UAV in hovering position. The lift capability of the flight system, can be calculated as,

$$Lift(Kg) = \frac{W \times D^4 \times (^{\rho \times 24}/_{C_f \times 29.9})}{2.2} \tag{3}$$

Here, $W$ represents unknown weight of UAV, $D$ represents the diameter of propeller, $N$ is the speed in rpm, $\rho$ indicates air density in kg/m3 and $C_f$ is lift coefficient. The above equation gives us information about pair of DC motors with speed and load carrying capacity of UAV.

### 3.3. Gas Sensing Unit

For the detection and monitoring of harmful substances within our environment such as carbon monoxide, carbon dioxide and methane, Gas sensors are treated as essential elements of environmental risk assessment. Due to its high level of integration and low power consumption characteristics, the authors use MQ9 sensor with UAV for air condition monitoring. The sensitive material of that gas sensor is SnO2, which has lower conductivity in clean air. In fig. 2, the image of a MQ9 sensor is given.


**Fig. 2. MQ9 Sensor for Gas Detection**

The sensor conductivity is higher, when gas concentration rises. MQ9 gas sensor is high sensitive to detect Carbon Monoxide (CO), Methane ($CH_2$), Propane ($CH_3$), LPG and other combustion gases. This sensor has also very good character configuration like high sensitivity, low cost, long life. Simple drive circuit etc. The image of MQ9 gas sensor is given below. The sensor composed with Micro AL203 ceramic tube, Tin Dioxide ($SnO_2$), measuring electrode and heater are fixed into a crust made by stainless steel net. The enveloped MQ9 has six pins. Among them, four pins are used to fetch signals and other two pins are used to provide heating current. Here total power consumption is below 130 mW. Moreover, this sensor has excellent long term stability. Its service life can be up to 5 years under using conditions. To increase its accuracy, sensitivity adjustment will be required. The resistance values of MQ9 is difference to various kinds various concentration of gases. In this work, detector is calibrated for 200 PPM for CO, 5000 PPM for $CH_4$ and 1000 PPM for LPG concentration in air. The load resistance value is taken about 30 ohms. When accuracy measuring, a proper alarm point for gas detector should be determined after consideration of the influence of temperature and humidity. In this work, MQ9 gas sensor is connected with Node MCU microcontroller. Node MCU has inbuilt Wi-Fi module. And via wi-fi module the controller module is linked with control room. MQ sensor senses the gas particles from remote location, where humans are not being safe and measures the concentration of unwanted gas particles. Then sensor sends continuously the raw data to Node MCU unit. Form Node MCU, via Wi-Fi module, output is available in computer or smart phone screen using blynk app and gas concentration is converted into a Parts Per Million ("PPM") reading using the sensitivity calibration curve of the gas sensor datasheet. Using blynk app, the output can be observed by different patterns like raw value, graphical value, indication signal etc. In this work, the authors choose the graphical representation to identify leakage gas very easily.

## 4. Development of Hardware Prototype

In this work, a hardware model of UAV with gas detection system is developed. The block diagram of developed hardware is given in fig. 3.

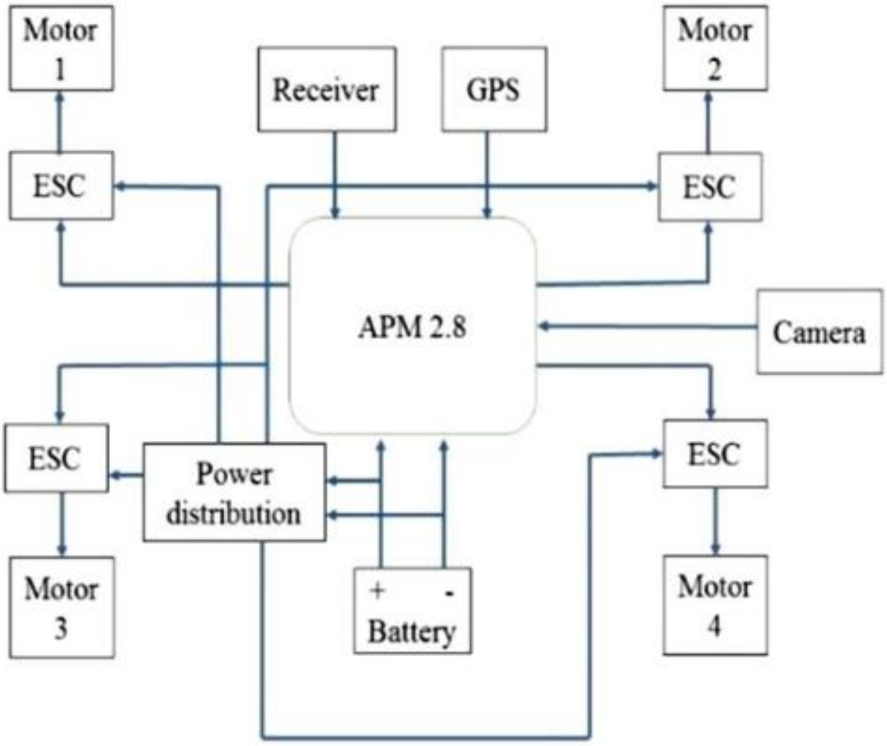


**Fig. 3. Block diagram of developed UAV**

UAV comprises off four arms and four motors for lifting. As mentioned in section 3.2, here BLDC motors are used. The motors are connected with Electronic Speed Controller (ESC), by which motor speed can be controlled. Four ESCs are connected with APM 2.8 flight controller. APM 2.8 controller has many advantages than other lower cost controllers like KK 2.1.5. APM controller has an onboard barometric sensor for security purpose and has interfacing facilities for an off-board GPS and compass. The flight controller is connected with the fly sky receiver, which gets signal from RC transmitter by manual control. For gas leakage detection, MQ 9 sensor is connected with UAV using Node MCU.

This make the UAV system environment friendly, as it can measure the air pollution level for any remote place. The twin blade propellers mounted on motor have 10 X 4.5” length. This will allow 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. 4.

Different parts:

| | |
|---|---|
| 1. APM 2.8 controller | 2. MQ 9 gas sensor |
| 3. Lipo Battery Cell | 4. Node MCU |
| 5. BLDC motor | 6. Propellers |
| 7. Electronic Speed Controller | 8. GPS module |

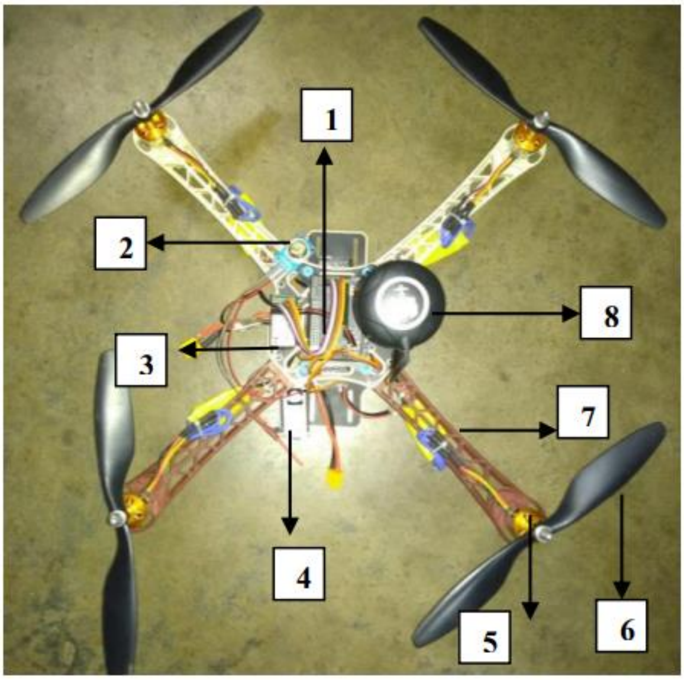


**Fig. 4. Parts of developed UAV model**

For overall weight analysis of UAV, weight of BLDC motors, battery, ESC and UAV controller boards should be considered. Other minor components like wires, adhesive tapes can be neglected. The developed UAV image during flying condition is shown in fig. 5.

**Fig. 5. UAV model during flying condition**

When there is a possibility of presence of Carbon Monoxide, Methane or any combustion gases, this UAV system is used to monitor the air condition specially where humans not able to reach and find the pollution level using gas sensor. This developed model is tested in various polluted environments; gas concentration is measured in PPM and monitored in Mobile or PC screen. The wi-fi range is supported here is 500 m. In fig. 6, a part of sensor output is given, which is taken from PC via blynk app. Here X axis gives the time when gas concentration is measured and Y axis gives actual gas concentration in PPM.

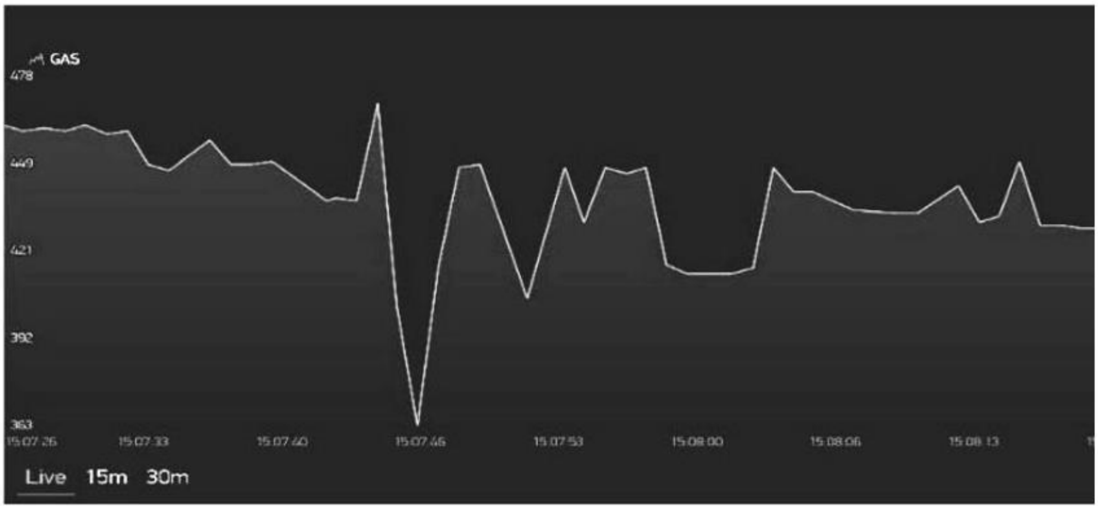


**Fig. 6. Gas concentration measurement using blynk app**

## 5. Conclusion

In this paper, authors develop a UAV model mainly used to monitor the gas concentration in polluted environment. Many gases are higher than air, meaning that in an indoor the gas will rise and be thicker nearer the ceiling. Then, ground based testing not provides accurate result. The this UAV system can cover every corner without the need of scaffolding, cherry pickers or other support. The UAV will also provide 360o awareness of its surroundings. So, accessing any human inaccessible places and continuous monitoring the air condition of congested area are the main benefits of this developed UAV system.

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