

# Low-cost and Efficient Quadrotor for Medicine Delivery and IoT based Air Quality Monitoring

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*Received 17 February 2024; revised 28 June 2024; accepted 16 September 2024*

The emerging field of multi-rotor Unmanned Aerial Vehicles (UAVs) has witnessed a surge in research and development efforts in the recent years. Among UAVs, quadrotors have been used extensively for several applications such as precision agriculture, drone light shows, surveillance, mapping, medicine delivery, and air quality monitoring. This paper presents a multifunctional quadrotor platform designed to address the growing demand for versatile and efficient Unmanned Aerial Vehicles (UAVs). This setup can be beneficial in building a multi-functional drones that are low-cost while maintaining their efficiency. Equipped with advanced features such as a LiDAR sensor for obstacle avoidance within a 2m proximity and an IoT-enabled air quality monitoring on Thing Speak with 6s refresh rate, the quadrotor offers enhanced safety, real-time data collection, and adaptability to various applications. The quadrotor hardware uses a PixHawk 2.4.8 flight controller with local monitoring of the flight data done using Mission Planner. The proposed quadrotor hardware has been used for two applications: i) Medicine Delivery and ii) IoT based Air Quality Monitoring. The same quadrotor has been used for both applications. A comparison with the prior work mentioned in the literature has been done for both the applications. The following parameters have been considered for the comparison: i) maximum flight time, ii) application area iii) weight, iv) type of drone, v) number of drones used and vi) battery used. The quadrotor's adaptation as a multifunctional drone makes it a promising tool for various and varied industries instead of the existing concept of a single drone for a single application.

**Keywords:** Arduino, Drone air monitoring, Drone delivery, ThingSpeak, Unmanned aerial vehicle

## Introduction

Over the years, quadrotors have been used for a variety of tasks, including surveillance<sup>1</sup>, crop monitoring<sup>2</sup>, pesticide spraying<sup>3</sup>, medicine delivery, border patrolling<sup>4</sup>, air quality and weather monitoring. It can also be used for inspections of oil and gas pipelines.<sup>5</sup> During emergencies, quadrotors can be used to establish a communication medium for disaster struck areas.<sup>6</sup> The ability to hover and take off from any type of surface adds to their list of advantages.

Medicine delivery and air quality monitoring are some of the key application areas where quadrotors can be used. Inventory in big warehouses can be done using a quadrotor. Unmanned aerial vehicles (UAVs) utilizing a quadcopter design offer a versatile platform due to their scalable size and configuration. Primarily, these UAVs aim to alleviate human risk and workload across various industries. They can be used to monitor the air quality in the areas where pollution is prevalent.<sup>7</sup> Drones can collect data and send it online

using cloud-based services to make the data available to multiple users and multiple devices.

Quadrotors can be selected based on the following parameters: i) weight, ii) operating height, iii) payload capacity, iv) flight time, and v) battery energy usage. This paper focuses on two applications: i) IoT-based Air Quality Monitoring and ii) Medicine delivery.

## Literature Review

A lot of researchers and companies are trying to build good solutions for problems such as pesticide spraying, fruit picking, surveillance, border patrolling and remote sensing using drones. As a result, this technology is advancing rapidly. The quadrotor frame has a flight controller which acts as the brain of the aerial robot. Different microcontroller based flight controllers can be used for a quadrotor system such as KK 2.5.5, Arduino Uno, Arduino Nano, Raspberry Pi, APM flight controller and PixHawk flight controller. Different flight controllers can be used based on the application of the quadrotor. Tahtawi & Yusuf<sup>8</sup> presented a flight controller built on an Arduino Uno microcontroller board for a quadrotor. Good quality and inexpensive components such as propellers, radio

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control and controllers were selected. The working of the flight controller was validated by calculating the overshoot and settling time of the flight controller.

The quadrotor system can be used to obtain visual data. A novel target acquisition method was used by Coelho *et al.*<sup>9</sup> using a vision system for object tracking. Their approach was 20 times quicker than the OpenCV-based techniques that were published in the literature. The system's ground station and quadrotor system were connected through an Xbee module, and the quadrotor used PID control to obtain a stable flight.

During the pandemic, the idea of a quadrotor delivering goods and medicine services gained a lot of popularity. The safety of the delivery agent could be ensured using drones. Companies such as Zipline uses a fixed wing drones to deliver blood, medical equipment, vaccines in remote and inaccessible areas in Ghana, Rwanda, Nigeria, USA and Japan. Quadrotors does not require a runway like fixed wing UAVs and can be used in congested cities. Purahong *et al.*<sup>10</sup> proposed a novel approach to emergency cardiac care by developing a medical drone specifically designed to deliver a defibrillator for cardiac arrest victims. The drone can land within 1.5 metres from the patient's location. A first aid packages were also delivered using this drone service. Shastry *et al.*<sup>11</sup> developed a quadrotor simulation model for product delivery. A variable-pitch propeller was selected to generate more thrust. The drone was able to even fly in inverted position. The drone was able to track trajectories even for sinusoidal paths. Khandagale *et al.*<sup>12</sup> designed a medicine delivery quadrotor using KK 2.5.5 Flight controller. ESP8266 was used to provide internet connectivity. The computational power of the quadrotor can be increased by using an advanced flight controller.

The air pollution is on the rise in the recent years due to various factors such as increase in the construction sites, vehicles, and factories. The quadrotors can be used as mobile sensors to pinpoint the exact location of the air pollution causing elements. The release of that particular air pollution causing element can be avoided. Liu *et al.*<sup>7</sup> created a quadrotor system to reduce the impact of the air flow disruption. Temperature correction and sensor calibration were done using polynomial piecewise regression and linear regression, respectively. The device was able to locate a vehicle's exhaust position. This lowered the labour costs and equipment

requirements for air pollution monitoring. Yungaicela-Naula *et al.*<sup>13</sup> used simulated annealing meta-heuristic method to define a path for the UAV-based air quality monitoring system. This allowed for rapid, automated, and simple detection of the pollution source both indoors and outdoors. A low-cost quadrotor was designed by Cozma *et al.*<sup>14</sup> to collect data at different heights. Various environmental factors were also considered while designing the hardware. However, only CO and Nitrous oxide were detected. Kuantame *et al.*<sup>15</sup> used Analysis of Variance Methods (ANOVA) to detect the carbon monoxide source and other pollutant compounds. The air quality sensor data was sampled with the help of a quadrotor. Luo *et al.*<sup>16</sup> proposed a method for tracking air quality using Zigbee. Data was gathered from several terminal modules and sent to the monitoring centre via the Internet. If the readings were higher than the threshold values, real-time changes were applied.

Internet of Things (IoT) based sensors can be used to send the data online for remote monitoring. The transfer of live data can be beneficial for implementing rapid actions. Hoque *et al.*<sup>17</sup> proposed a Drone-based IoT services for areas where network access posed a problem and the deployment of IoT devices was not feasible. IoT nodes were deployed in an airborne, dynamic, and inexpensive manner. The suggested model was able to create a low cost and superior connection model. Lu & Xing<sup>18</sup> designed a simulation model based on Newton-Euler Eqs. in Unity 3D. Disturbances caused by environment factors such as weather were also considered. The integration of IoT with drones was studied. H. Ali *et al.*<sup>19</sup> presented the integration of IoT with the quadrotor for use in industrial monitoring and security monitoring. A camera was mounted on a quadrotor along with a mobile IoT application sensor for online remote monitoring and surveillance.

#### Research Gap and Inspiration

In the literature review of the associated work, there are quadrotor systems that are used in various applications. Research on IoT based air quality monitoring using quadrotors is progressing rapidly. Different hardware and simulation models are being evaluated for their efficiency. In this paper, the hardware model of the quadrotor is used for two applications: i) IoT based Air Quality Monitoring and ii) Medicine Delivery. The use of quadrotor for multiple applications would increase the number of

sensors attached to the same body frame. This gives an inspiration to study the effect of weight and battery on the flight time of the designed quadrotor system when used for two applications. Since quadrotors can operate in remote and inaccessible areas, deploying a single multi-purpose robot could eliminate the need for separate, specialized drones for each application. A multi-utilitarian robot could significantly reduce the cost of manufacturing separate drones for each application.

### Contribution

The contribution of the paper is as follows:

A quadrotor hardware is built using PixHawk Flight Controller (version 2.4.8).

- i. The quadrotor frame is made from epoxy glass.
- ii. The quadrotor is modified for two applications: Medicine Delivery and IoT based Air Quality Monitoring.
- iii. The medicine box of dimensions 4x4 inches is attached at the bottom of the quadrotor frame. The opening and closing of this medicine box is controlled by a remote control.
- iv. The IoT sensor used for Air Quality Monitoring are MQ3, MQ135 and DHT11. These sensors collect data and send it online to ThingSpeak Platform. The data is updated every 6s. The data is displayed in the form of graphs on ThingSpeak.
- v. The quadrotor is capable of avoiding any obstacles by using a LiDAR sensor.

The detailed description of the proposed system is shown in Fig. 1. The quadrotor system has two main parts: i) quadrotor hardware and ii) ground station. As shown in Fig. 1, two softwares are used: i) Mission Planner ii) ThingSpeak. The Mission planner data can

only be viewed at the Ground station within the range of the Telemetry module. The data displayed on the Thing Speak can be viewed anywhere in the world.

This paper attempts to understand the effect of i) weight and ii) type of battery on the flight time of a multi-utilitarian quadrotor. Some of these factors that usually influence the flight time are as follows:

- Low battery failsafe settings
- Size and Weight of the load
- Type of Battery and its lifespan
- Condition of Rotor and propellers
- Density of the altitude
- Environmental factors, path planning and manoeuvring.

### Mathematical Model and Quadrotor Hardware Design

The dynamic model of quadrotor can be described with a set of mathematical Eqs. that are based on Newton-Euler Eqs. and are used to design the flight controllers. A quadrotor has four rotors, each attached to one end of an arm. The basic components of the quadrotor are as follows: i) Brushless DC (BLDC) motors, ii) Electronic Speed Controllers (ESCs), iii) propellers, iv) Flight Controller, v) battery, vi) remote control, vii) transmitter unit and viii) power distribution board. The quadrotor has six Degrees of Freedom (DoF) and only four rotors to control the parameters of the quadrotor. This makes the quadrotor underactuated<sup>20</sup> and non-linear in nature. The Fig. 2 shows representation of the forces generated by the propellers. Each arm generates a force pointing upwards, labelled  $F_1$ ,  $F_2$ ,  $F_3$ , and  $F_4$ , respectively.<sup>21</sup>

The inertial frame is represented by  $O(XYZ)$  and the body fixed frame is represented by  $o(xyz)$ . It is

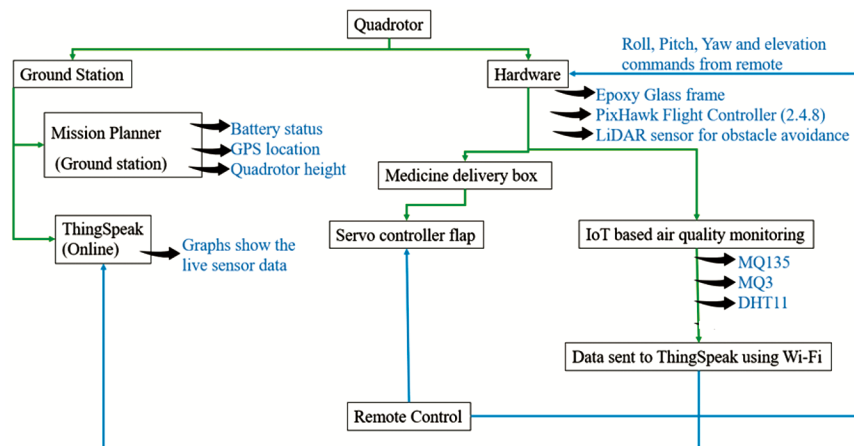


Fig. 1— Block Diagram of the proposed quadrotor system components

assumed that the quadrotor is a rigid body and the body fixed frame is attached to the quadrotor's body. The rotation angles of the quadrotor are represented by  $\varphi$  (**roll**),  $\Theta$  (pitch), and  $\psi$  (yaw) along the x, y, and z axes, respectively. The quadrotor system<sup>22-24</sup> is described by the mathematical Eqs. (1) – (6) given below:

$$\ddot{x} = -\frac{U_1}{m}(\cos\varphi\sin\theta\cos\psi + \sin\varphi\sin\psi) \quad \dots (1)$$

$$\ddot{y} = -\frac{U_1}{m}(\cos\varphi\sin\theta\cos\psi - \sin\varphi\sin\psi) \quad \dots (2)$$

$$\ddot{z} = g - \frac{U_1}{m}(\cos\varphi\cos\theta) \quad \dots (3)$$

$$\ddot{\varphi} = \frac{I_{yy}-I_{zz}}{I_{xx}}\dot{\theta}\dot{\psi} + \frac{1}{I_{xx}}U_2 + \frac{-J_r}{I_{xx}}\dot{\Omega}\dot{\theta} \quad \dots (4)$$

$$\ddot{\theta} = \frac{I_{zz}-I_{xx}}{I_{yy}}\dot{\varphi}\dot{\psi} + \frac{1}{I_{yy}}U_3 + \frac{-J_r}{I_{yy}}\dot{\Omega}\dot{\varphi} \quad \dots (5)$$

$$\ddot{\psi} = \frac{I_{xx}-I_{yy}}{I_{zz}}\dot{\varphi}\dot{\theta} + \frac{1}{I_{zz}}U_4 \quad \dots (6)$$

where  $\ddot{x}$ ,  $\ddot{y}$  and  $\ddot{z}$  define the Eq. of the motion along axes x, y and z. The rotational angles can be obtained

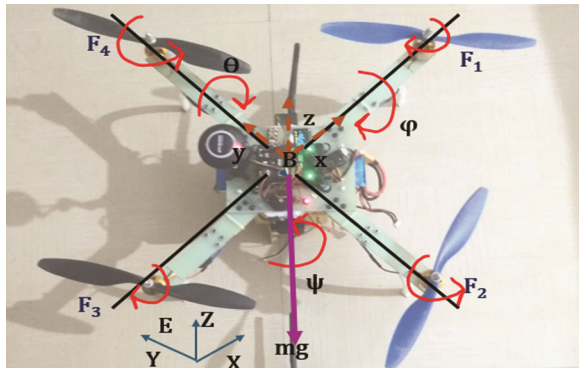


Fig. 2 — Representation of different forces on the Quadrotor system

from  $\ddot{\varphi}$ ,  $\ddot{\theta}$  and  $\ddot{\psi}$ . The mass of the quadrotor is denoted by  $m$  and  $U_1$ ,  $U_2$ ,  $U_3$  and  $U_4$  denote the control signal to the quadrotor system. The parameters  $I_{xx}$ ,  $I_{yy}$  and  $I_{zz}$  denote the moment of Inertia along x, y and z axis.

The Eq. for the thrust generated by a quadrotor can be represented by Eq. (7):

$$T = F_1 + F_2 + F_3 + F_4 \quad \dots (7)$$

where,  $T$  denotes the total thrust generated by the quadrotor and  $F_i$  denotes the force generated at each arm of the quadrotor ( $i = 1$  to 4). These mathematical equations help in designing a simulation model of the quadrotor. This paper focuses on the hardware model of the quadrotor which can be defined using the same mathematical model.

The quadrotor frame can be designed from materials like carbon fibre, plastic, wood, aluminium and Glass epoxy. In this paper, the hardware model of a quadrotor has been built using an epoxy glass frame in 'X' configuration. This allows the user to modify the hardware for any application in less cost.

Flight controller acts as the brain of the quadrotor. PixHawk 2.4.8 Flight Controller has been used. The flight controller sends signal to ESC which are in turn connected to the motor and a propeller. A BLDC motor has been used for the proposed hardware as they provide higher efficiency, require low maintenance, and are light weight as compared to brushed motors. This leads to longer flight time and better maneuverability. The block diagram of the quadrotor hardware is displayed in Fig. 3.

As shown in the Fig. 3, Global Positioning System (Ublox M8N GPS module) has been used. A remote

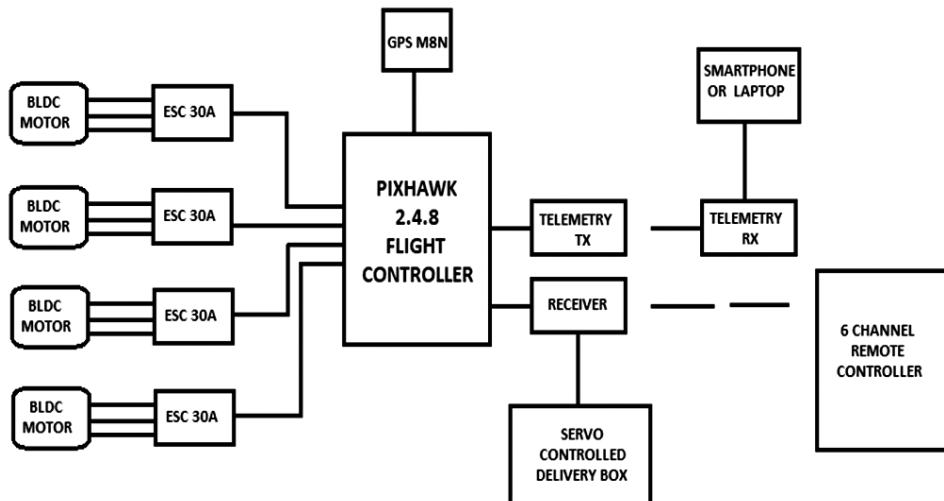


Fig. 3 — Block diagram of the quadrotor system

Component Name	Quantity	Specifications
BLDC motors A221213D	4	1000 rpm per volt
ESCs	4	Regulated power supply of 5V, Maximum current of 2A
Propellers	4	10-inch diameter, 4.5 pitch
Flight controller	1	PixHawk 2.4.8
GPS	1	In-built compass, navigation rate upto 10Hz
Telemetry transmitter	1	1–1.5 Km range, 1.2GHz
Battery	1	Rechargeable 3S LiPo
Power Distribution (PDB)	1	Current up to 20A per output

control, FlySKy remote control (FS- CT6B), with a 1 km operational range has been used to remotely control and guide the quadrotor flight. The remote control can vary the quadrotor's i) vertical thrust, ii) roll, iii) pitch, and iv) yaw movements. The change in the direction of the quadrotor can be attributed to the change in these rotational angles.

The flight data can be viewed at the ground station using a Telemetry module. The following data has been transmitted: i) current location obtained from the GPS, ii) battery status, iii) height of quadrotor during its flight, and iv) heading angle. This data is transmitted at a baud rate of 57600bps. The transmitted data can be viewed on a laptop using an open source software known as Mission Planner. A list of all the components that have been used in the proposed hardware are given in Table 1.

The proposed quadrotor has been displayed in Fig. 4. Pixhawk flight controller has been used which uses Extended Kalman filter (EKF) to determine the precise location of the quadrotor by using information from multiple sensors like: i) gyroscope, ii) magnetometer, iii) accelerometer, iv) GPS, and v) compass.

The proposed quadrotor has been further developed for two applications: i) Medicine Delivery and ii) IoT based Air Quality Monitoring. The same hardware setup has been used for both applications with minor modifications.

### Quadrotor Applications

Quadrotors are versatile UAVs, proving their value in search and rescue missions, environmental monitoring, and infrastructure inspection. Their exceptional maneuverability and advanced sensor technology also enhance efficiency in agriculture and delivery services. Across various industries, quadrotors can access hard to reach areas and transform the workflow.

#### Medicine Delivery

A medicine box of dimensions 4x4 inches has been mounted at the bottom of the quadrotor frame. Epoxy

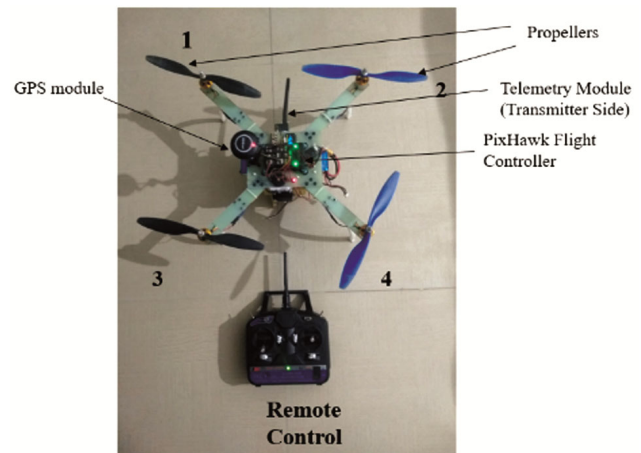


Fig. 4 — Quadrotor with GPS and telemetry system

sheets have been used for the medicine box. FlySKy FS-CT6B remote controller has been used to control a servo motor (Futaba S3003) which opens and closes the flap of the medicine box. The FlySky remote controller with 6 channels has been used. The first four channels have been used to give commands to change the roll, pitch, yaw and thrust. Channel 5 of the remote control has been used to operate the servo motor. An image of the proposed quadrotor hovering has been shown in Fig. 5 (a). The medicine box can be observed at the bottom of the quad frame.

Smooth semi-autonomous and autonomous traversal requires avoiding obstacle. In order to achieve obstacle avoidance, a LiDAR sensor (Benewake Tfmimi plus) has been used. It has a maximum detection and avoidance range of 12 metre outdoors and 7 meters indoors.<sup>25</sup> The parameters of the LiDAR sensor have been set using the Mission Planner software. These parameter values are then written on the PixHawk flight controller. The LiDAR sensor's detection range has been set to 2 metres using Mission Planner software. LiDAR sensor releases a train of laser pulses. The Eq. to measure the distance between the quadrotor and obstacle is given below:

$$d = \frac{(s \times t)}{2} \quad \dots (8)$$

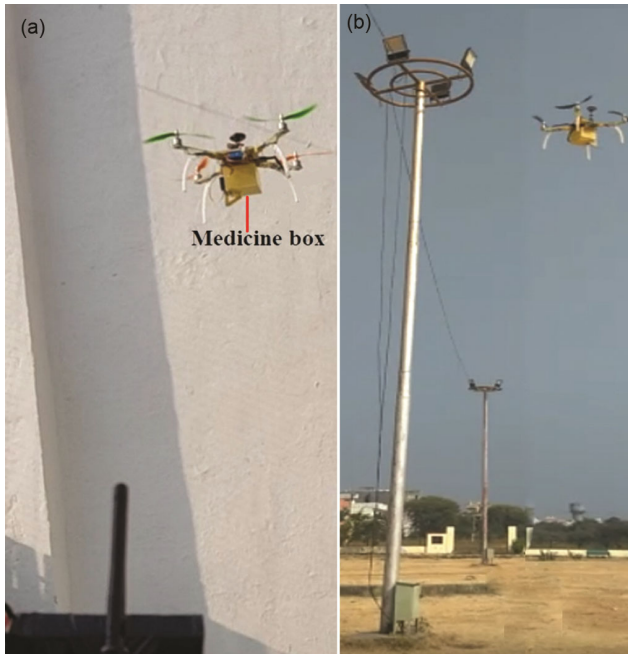


Fig. 5 — Proposed quadrotor: (a) with Medicine box for delivery, (b) in flight

where,  $d$  is the distance between the quadrotor and the obstacle,  $s$  is the speed of light and  $t$  is the time of the flight.

Mission planner has been used to configure all the internal and external sensor attached to the Pixhawk flight controller. This software also displays vital quadrotor information. The flight test for the proposed quadrotor has been done in an open ground of area  $76.2 \times 18$  m. The efficiency of the LiDAR sensor has also been tested. The average flight time for each flight has been recorded. An image of the quadrotor in open ground has been displayed in Fig. 5 (b).

Next, the same quadrotor hardware has been modified for IoT based Air Quality Monitoring application. The IoT based sensors are installed on the sides of the medicine box at the bottom of the quadrotor frame.

#### IoT based Air Quality Monitoring

The rise in the number of industries has led to a decline in the air quality over the years. This has led to many health issues like breathing difficulties, which may potentially be malignant. Every year, the air quality in India drops during the winters, which causes haze that reduces visibility. But an active monitoring of the pollution causing elements is required to curb the decline in the air quality. The hardware of quadrotor used for medicine delivery has been modified to monitor air quality using the Internet

Table 2 — Sensors used for air quality monitoring

Sensors	Quantities Measured
DHT11	Temperature and Humidity
MQ135	NH <sub>3</sub> , NO <sub>x</sub> , alcohol, Benzene, smoke, CO <sub>2</sub>
MQ3	Alcohol and Benzene

of Things (IoT) based sensors. The use of quadrotor for collection of air quality data enables a pilot to gather data at different altitudes and locations. The collected data is sent online on ThingSpeak cloud server. The detailed description of the sensors attached on the quadrotor system is given in Table 2.

The different sensors mentioned in Table 2 are attached on the side of the medicine box sides. These sensors are programmed using an Arduino Uno microcontroller board. Connection between Arduino Uno and PixHawk flight controller is made at TELEM 2 port. Live sensor data is sent online via Wi-Fi using NodeMCU (ESP8266) which is connected with Arduino UNO. The values captured by the sensors: i) MQ135, ii) MQ3 and iii) DHT11 (temperature and humidity sensor) are sent on a cloud-based platform known as ThingSpeak. With IoT-based air quality monitoring of the quadrotor system, the data captured can be used to take strict and quick measures to avoid any type of incidents and ensure human safety. The Fig. 6(a) shows all the sensor used for air Quality monitoring and Fig. 6(b) shows the IoT sensors mounted on the medicine box of the quadrotor.

The quadrotor communicates with different components using different technologies like i) serial communication, ii) Telemetry, iii) Wi-Fi and iv) Radio frequency for remote control. This is displayed in Fig. 7 in detail as a block diagram. The data collected by the IoT sensors is sent to ThingSpeak with a refresh time of 6s. The graphs are displayed on Thingspeak website whereas the quadrotor data like height, battery is displayed on the Ground station using Mission Planner (Ardupilot) at the Ground Station.

#### Results and Discussion

Quadrotor hardware is built using a PixHawk 2.4.8 flight controller. The Ground Station can monitor the data obtained from GPS module, Compass (Ublox M8N), and Telemetry module mounted on the quadrotor using mission planner software. The Mission Planner screen displaying all the necessary data of the quadrotor has been shown in Fig. 8.

A medicine box for medicine delivery has been attached at the bottom of the quadrotor frame. A servo motor has been used to operate the flap of the medicine box which is controlled by FlySky remote control (FlySky FS-CT6B). The Fig. 9 (a & b) display the quadrotor hovering at one place and the lid has been opened and closed using the remote control.

Next, the quadrotor system has been modified by connecting IoT based sensors. Arduino Uno is used to make a connection between the IoT sensors and the

PixHawk flight controller. The Ground station provides Wi-Fi hotspot which gives internet connectivity to NodeMCU (ESP8266) with a range of about 40m. The IoT based sensors use the Wi-Fi signal to send the live data online on ThingSpeak website. The data is updated every 6s. The data collected by the IoT sensors on quadrotor system has been collected on different days and has been compiled in Table 3. IoT based sensors used are: i) Smoke (MQ135), ii) Alcohol (MQ3) and iii)

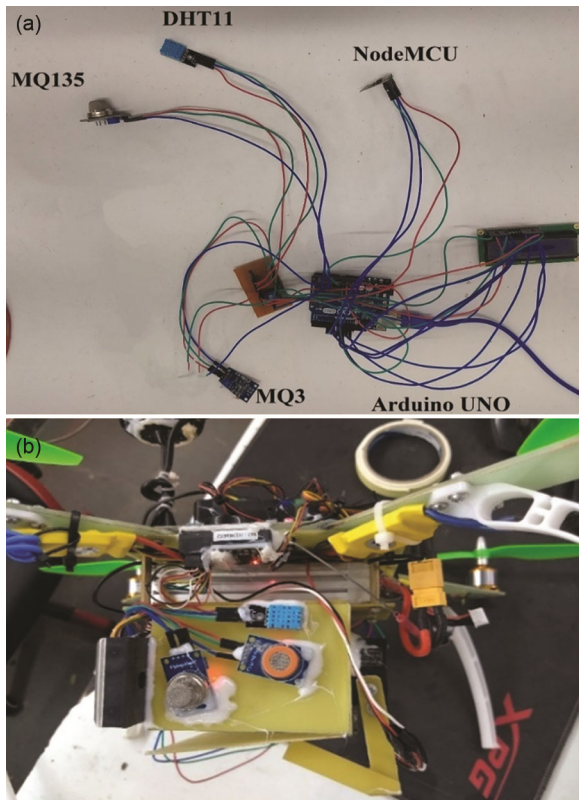


Fig. 6 — Sensors of the Quadrotor: (a) connected with Arduino Uno, (b) installed on the medicine box

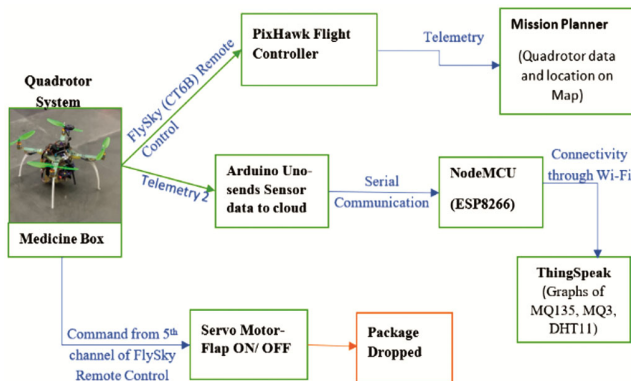


Fig. 7 — Block Diagram of working of Quadrotor with respect to communication between the various components

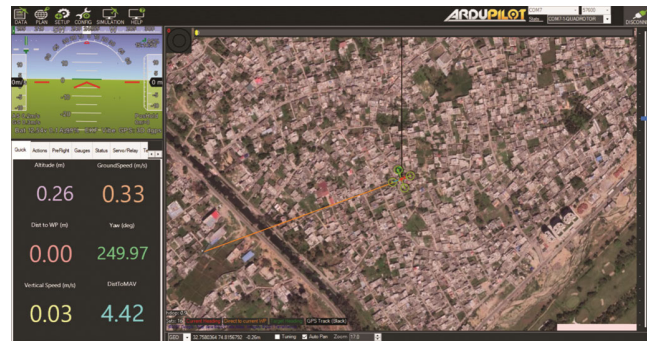


Fig. 8 — Quadcopter status on mission planner

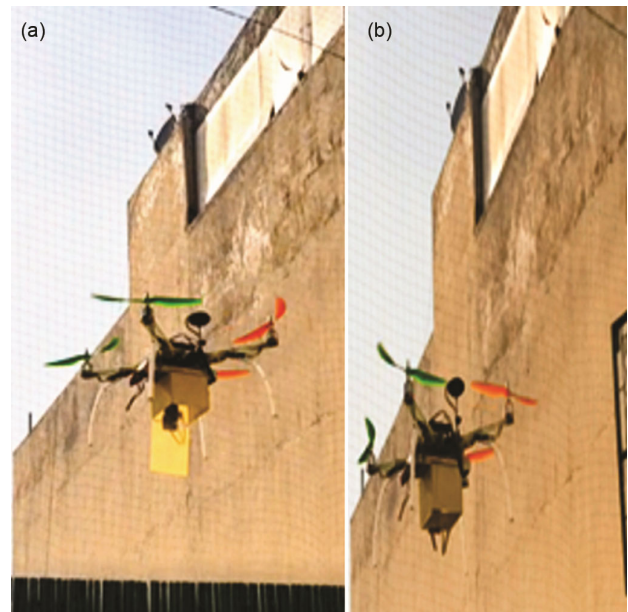


Fig. 9 — Quadrotor carrying medicine box: (a) lid is open, (b) lid is close

Table 3 — Sensor values recorded and uploaded on ThingSpeak for air quality monitoring

Sensor	Day 1	Day 2	Day 3	Day 4
Smoke (MQ135)	124	78	80	78
Humidity (%)	47	66	63	63
Temperature(°C)	33	34	33	32
Alcohol (MQ3)	292	218	228	217

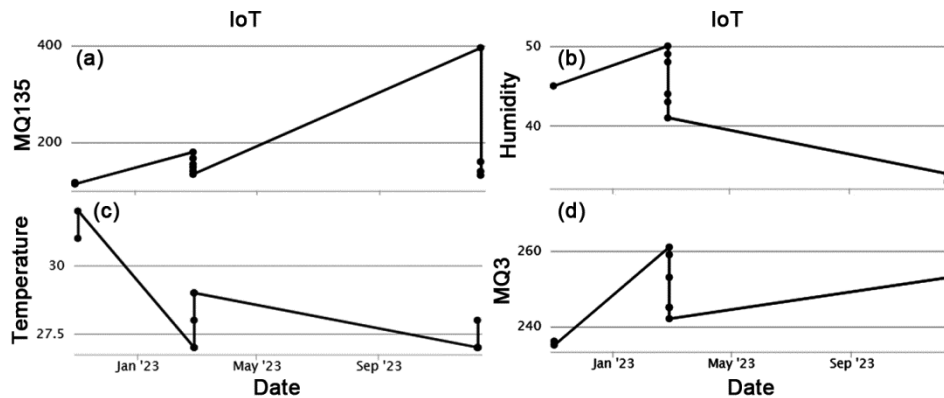


Fig. 10 — Live Data of sensor displayed on ThingSpeak: (a) Smoke sensor (MQ135), (b) Humidity sensor (DHT11), (c) Temperature sensor (DHT11), and (d) Alcohol Sensor (MQ3)

Table 4 — Flight time of quadrotor using different batteries

Capacity (mAh)	Voltage (V)	Weight (g)	C Rating	Flight time estimate (minimum)	Approximate Battery Cost (Rupees)
5500 (6S1P)	22.2	718	45C	33	10–12k
5500 (4S1P)	14.8	600	25C	33	9–10k
5000 (4S1P)	14.8	540	60C	30	8k
4500 (3S)	11.1	382	30C	26	5k
2200 (3S)	11.1	175	25C	13.2	2-3k

Humidity and Temperature sensor – DHT11. The live data is displayed on the Thingspeak in the form of graphs as shown in Figs. 10(a–d).

The quadrotor flight test has been carried out in an open field, and an average of flight time of 14 to 15 minutes has been recorded for the proposed quadrotor. Different Lithium Polymer (LiPo) batteries of different mAh have been used for both applications including 2200mAh, 4200mAh, and 5200mAh. The specifications of the batteries along with the flight time and cost have been given in Table 4.

In Table 4, ‘C’ represents the capacity of energy the battery can safely discharge. The ‘S’ indicates that LiPo cells are connected in series and ‘P’ represents the LiPo cell are connected in parallel. The estimated hover flight time for batteries with different capacities (mAh) are described in Table 4. The efficiency of these estimations can vary due to environmental conditions and payload during a flight. The condition and lifespan of the battery can also have an effect on the flight time of the quadrotor.

The performance of the system is compiled in Table 5 on the basis of its flight time, weight, and connectivity. The quadrotor system is a multifunction drone that can reduce the cost of developing two separate drones for different applications by reusing the same quadrotor.

The weight of the quadrotor increases due to the increase in the external sensors for IoT based air

Table 5 — Quadrotor values for Medicine Delivery and IoT based Air Quality Monitoring

Quadrotor Application	Medicine Delivery Quadrotor	IoT based Air Quality Monitoring Quadrotor
Weight	Approx.1400gm	1600gm
Flight Time	Minimum 15 min	Minimum 10mins
Wi-Fi Range	—	40m
Telemetry Range	1km	—

quality monitoring. These sensors also draw current from the battery that can also cause decrease in the flight time. In order to ensure that the quadrotor does not run out of battery charge during its flight, few precautions have been taken. Low Battery has been set at around 10V to ensure that the failsafe is kept at approximately 20% of the power supply. The quadrotor is instructed to Return to Launch (RTL) if the failsafe voltage value is encountered. A comparison of the proposed quadrotor system has been done with the literature and has been presented in Table 6.

Apart from the battery, the quadrotor frame and the motor selection can also increase the cost of the quadrotor. The frame used in the proposed Quadrotor is made of glass fibre which is cheaper than the carbon fibre frame. The chosen material for the quadrotor frame provides ease of modification in the quadrotor system. The motors selected are of 1000KV which according to the weight of the proposed system

Table 6 — Comparison with Published Papers

Drone	Max. Flight Time	Application	Weight	Type of Drone	Number of Drones used	Battery Used	Remarks
Proposed Quadrotor	30 min (Average time- 15 mins for medicine delivery and 10 mins with IoT based sensors)	Medicine Delivery IoT based Air Quality Monitoring	1.6 kg	Micro	Single Quadrotor Hardware for both applications	LiPo batteries of different mAh has been used	Inexpensive multi-functional drone
Cozma <i>et. al.</i> <sup>14</sup>	50 min	Air Pollution Monitoring	3.9kg	Small	Hexacopter with separate battery for IoT sensors	16000mAh	Battery 6-8 times more expensive
Hoque <i>et. al.</i> <sup>17</sup>	30 min	Precision Agriculture and Air Quality Monitoring as a Service	1.175kg	Micro	50-500 drones are used across the Drone centres	5200mAh	Separate setups used for different applications
Lu and Zing <sup>18</sup>	—	Quadrotor is used as a sensor for data collection for IoT Applications	1.5kg	Micro	Simulation model is made using Unity3D software	—	Only simulation of quadrotor done for data collection
Purahong <i>et al.</i> <sup>10</sup>	24 min	Delivery of Defibrillator	5kg	Small	Hexacopter	—	Heavier weight of the quadrotor system
Tahtawi & Yusuf <sup>8</sup>	—	—	3.85Kg	Small	Quadrotor	2200mAh	Heavier quadrotor with battery of less capacity has been used
Kuantama <i>et. al.</i> <sup>15</sup>	< 40 min	Air Scanning using Sniffer Quadrotor	1.9 kg	Micro	Quadrotor	18.4 V Lipo battery	Quadrotor is used for only one application.

is capable to generate enough thrust for lift off. Each BLDC motor provides upto 800gms of thrust with a 3S LiPo battery, 30A ESC and 10-inch propellers. A quadrotor with propellers powered by four BLDC motors can generate overall 3.2 Kg of thrust (800 grams times 4 is equal to 3.2 Kg which is greater than the total weight of the quadrotor and the payload). The battery selection for a Quadrotor system increases the cost of the system drastically. The battery with more power capacity has more weight which in turn increases the weight of the Quadrotor as well as its cost. The cost and weight of the proposed Quadrotor is lesser than the systems mentioned in Table 6.

## Conclusions

This paper demonstrates the potential of an affordable quadrotor system for IoT-based air quality monitoring and medicine delivery. The system's mobility and precision make it suitable for these applications. The factors like weight and battery type that influence flight time have been investigated. The proposed system's cost-effectiveness offers significant benefits for individuals and organizations since a multifunction drone can be used across various applications with minute changes. Future improvements include increasing payload, sensor variety, and autonomy through features like path planning and Artificial Intelligence. Moreover, battery

management system can be used to enhance performance and flight time.

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