Aerial Surveillance Quadcopter

Shadaj Tiwari[1], Saumya Gupta [2], Shivangi Aggarwal [3] and Satyam Kaushik [4]

[1,2,3,4] ABES Engineering College, *NH-09, Ghaziabad, India*

Abstract

Quadcopters or drones are unmanned aerial vehicles, which can normally be well-defined as devices proposed to be used to fly in the air with no onboard pilot. They can be used for different applications such as providing surveillance for military operations, an inspection of railway tracks, in the field of medicine, and many more. Their usage has considerably increased as they have multiple functions and are reliable. Drones or unmanned aerial vehicles can provide real-time control and monitoring of a particular crowd or an area by the security services. The high maneuverability and mobility of drones or unmanned aerial vehicles help in performing surveillance in areas where the threat is high. They are used for surveillance in real-time. The Defense forces use drones or unmanned aerial vehicles for most of their operations. This paper proposes the design and implementation of a quadcopter controlled by wireless and used for surveillance. The paper also discusses the practical aspects of drone surveillance as well as the possible implementation of real-time flight control systems to enhance drone performance.

Keywords

Unmanned Aerial Vehicles (UAVs), surveillance

1. Introduction

Consumer unmanned aerial vehicles are being used for anything from photography to security devices to e-commerce delivery [1]. The authors of [2] describe constructing and controlling a stabilized quadcopter for high performance and to provide optimum output. They also discussed controlling the quadcopter with an RC remote control which is very common and is mostly preferred for these kinds of projects. They also emphasize the usage of Bluetooth to remotely control a quadcopter which reduces the cost of the project and also makes it user-friendly and easy to use. In [3] it is discussed how to control a drone in real-time along with performing some sophisticated tasks that are many desirable tasks for drones to perform. Controlling a drone can be a tough task when it comes to maneuvering it in situations that are not normal. This results in complex control, and faster and proper execution of instructions. [4] states how improvements in the structure can affect the overall flight dynamics of the quadcopter. The results also show how these small changes in the design model can affect the results. The use of UAVs is predicted to arise in the future, fueling its expansion. The rise of the UAV market is likely to create new exciting commercial prospects for cellular operators. As new demands develop, UAV technology is constantly evolving, and UAV solutions are being provided at a quicker rate [6]. Specific UAV uses influence drone characteristics. A survey of the most current uses of UAVs in the cryosphere was carried out. In terms of gathering and capturing images & collecting sensory data, UAVs outperform traditional spaceborne or airborne remote sensing devices.

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EMAIL: shadajtiwari01@gmail.com (A.1)

The authors of [7] demonstrate the adaptable and fast-growing use of UAV solutions in everyday situations They suggest leveraging IoT-based drone technology to develop a system that can. identify coronavirus automatically using a thermal imaging camera with very less human contact. Defending the public against dangers is a difficult and time-consuming task [8]. Threats can range from small threats like affecting a person to large threats that can lead to a very large-scale calamity/failure where UAVs can be a real solution therefore this paper presents related research on drones or unmanned aerial vehicles that are used for surveillance in real-time. These systems can provide real-time control and monitoring of a particular crowd or an area by the security services to perform security checks and surveillance to safeguard the premise from any threat. Along with all the uses in performing surveillance, the designed drone is capable of hovering, moving, gliding, and diving in mid-air, it is capable of lifting lightweight articles that are not more than 1kg in weight. This allows the drone to not only safeguard the premise but also to assist the security personnel in emergencies or at times when the team or premise is under attack. This paper focuses on discussing the practical aspects of drone surveillance as well as the possible implementation of real-time flight control systems to enhance. drones' performance.

2. Quadcopter Modelling & Design

Quadcopters are dynamically described as a highly non-linear helicopter with the following characteristics: It is a 12-state helicopter (six attitude states and six-position and linear velocity states); it has six degrees of freedom (3 translational velocities and three rotational velocities), and it is actuated by four independent rotors. Various scholars infer from this description that the resulting helicopter's dynamics are a severely under-actuated and highly nonlinear helicopter with erratic aerodynamic uncertainty (because it controls inputs using four rotors to control its 6-DOF) The Fig.1. shows the Quadcopter spatial free-body diagram where roll, pitch, and yaw angles are depicted. The arrows show that rotors 1 and 3 revolve clockwise, whereas rotors 2 and 4 rotate counter-clockwise. The thrusts generated by the rotors around their center of rotation are T1, T2, T3, and T4. The torques applied to the quadcopter (counter torques) as a result of the rotors rotating are r1 ,r2,r3, and r4.

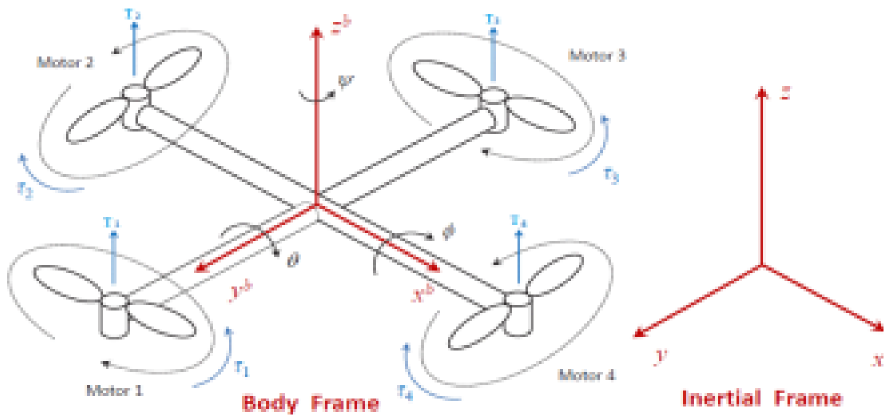

Figure 1: Quadcopter spatial free-body diagram

Different mathematical strategies for modeling the helicopter based on the first principal approximation have been presented in various literature and research papers. They are derived from both the Newton-Euler equations and the Euler-Lagrange equations for generating the helicopter's model equations. Newton-Euler– according to this approach quadcopter is assumed to be a rigid body and thus Newton-Euler equations can be used to describe its dynamics. Euler-Lagrange– This approach is based on energy and kinematics, with equations derived from Newton's second law. Both techniques produce the same effects and are favored because of their efficacy.

2.1.UAVs types and characteristics:

1. Payload: It refers to the weight a drone can carry. It measures the lifting capability of the drone. The larger the payload, the more equipped a drone can be. Generally, payloads include video cameras, and sensors, which could be used for surveillance and other commercial purposes.

2. Flying Mechanism: According to their flying mechanisms, drones can be characterized into three types: multi-rotor drones, Fixed-wing drones, Hybrid fixed/rotary wing drones. 3. Range and Altitude: The range refers to the distance from which a drone can be controlled. The range varies for different sizes of drones. Altitude refers to the max height drone can reach regardless of country-specific regulations. Aerial platforms can be classified into two types depending on their altitude: Low-altitude platforms (LAPs), High-altitude platforms (HAPs) .

4. Speed and Flight Time: Small drones fly at speeds of less than 15 m/s [27], whereas large drones can achieve speeds of up to 100 m/s. If the trajectory requires frequent turns its speed needs to be considered carefully when flying with maximum energy.

5. Power Supply: The power supply directly indicates endurance. While most commercial drones are powered by rechargeable batteries, some larger drones can fly for longer periods of time using fuels such as gas. Drones that are powered by solar energy are also a viable option.

2.2.Working Principle of Quadcopter

How could a quadcopter drift or fly toward any path, raise or dive with the flip of a regulator stick? Robots may likewise fly independently utilizing pre-modified waypoint route programming and travel any course from A to B. So let us examine the quadcopter innovation that empowers this. Its separation from the propeller, along with the turn and speed of the robot's engines, empowers it to fly and explore. The flight regulator of the quadcopter gives push, RPM (Revolutions each Minute), and course information to the vehicles through their advanced speed control circuits (ESC). The flight regulator will total IMU, Gyro, and GPS information prior to guiding push and rotor speed to the quadcopter vehicles. Even though today's drone and quadcopter technology is cutting-edge, they nevertheless rely on the age-old fundamentals of aircraft flight, gravity, action and reaction. The four forces that affect all flight are considered while manufacturing quadcopters, propellers, and motor designs. (Weight, lift, push, and drag) are also important considerations. While aircraft aerodynamics is utilized for propeller arrangement and the velocity of air above, under, and around the quadcopter, mathematics is also employed to compute quadcopter motor thrust. The movement in the controller is essentially far away, delivering signals to the central flight controller. This information is transmitted by the central flight controller to Electronic Speed Controllers (ESCs) for each engine, which commands the engines to increase or reduce speed.

2.3.Hardware components of Quadcopter

Depending on the application quadcopters can have very different hardware components. The main components include sensors, battery, microcontroller, frame, blades, motors, Global Positioning System (GPS), and telemetry devices.

- Brushless Direct Current Motor: A2212 motor is a 2200kV Brush-less Direct Current motor that is specially made to power Quadcopters and Drones. This motor is used because of its ability to provide proper and constant current due to which the routers experience high stability. This also helps in reducing the vibrations caused at the ends due to the moment of routers. The reduced vibrations at the end of each arm of the frame help the quadcopter to fly at a constant speed, rotate at a particular point, and provide a highly stable flight.

- Lithium Polymer Rechargeable Battery: The 11.1V 2200mAH Lipo battery is capable to provide a maximum continuous discharge rate of up to 25C. It provides continuous power with a high rate and reliability. It is also lighter in terms of weight and shorter in length when compared to other power sources.
- Microcontroller: The Uno R3 ATmega328p Development Board is the cheap and high-efficiency version of Uno R3 Arduino. It is assembled with the CH340 USB to Serial converter chip. It is a highly stable microcontroller that uses a very minimum
- Triple Axis Gyro Accelerometer Module: MPU6050 module is a micro electro mechanical system. It consists of an MPU 6050 that has a 3 Axis gyroscope and 3-axis accelerometer. It helps in the measurement of orientation, displacement, acceleration, velocity, and other motion-like features. This modulation has features.that are easily accessible as its easy availability, it can be used with any microcontroller. It has a 6-bit analog to digital converter hardware and this feature, captures three-dimensional motion at the same time and is provided to the microcontroller for real-time analysis. It also has an onboard digital motion processor which is used to solve complex calculations thus making it easier to calculate the dimensions and various motion-like features. It provides high accuracy and helps the quadcopter in maintaining a proper altitude and helps it to fly in a given direction related to the earth
- Quadcopter Frame: The main structure is made of glass fiber while the arms are made from highly strong carbon fiber material. It is a 30 x 8 x 16cm drone frame that is 650g in weight. This frame is mostly used in drones which require stability along with high maneuverability. This frame provides high stability and the ability to fly the quadcopter in close and compact spaces where it is difficult for humans to reach.

Figure 2: QuadcopterFrame

- Electronic Speed Controller: Electronic Speed Controller is used for quadcopters and drones that provide faster, smoother, and better motor speed control and provides better flight performance. It is connected to the flight controller and the brushless DC motor. It takes the signal from the flight controller; power is supplied from the battery and this makes the brushless motor rotate as per the input signal from the Controller. It is responsible to change the speed of a brushless motor by changing the amount of power intake according to the signals received from the receiver.

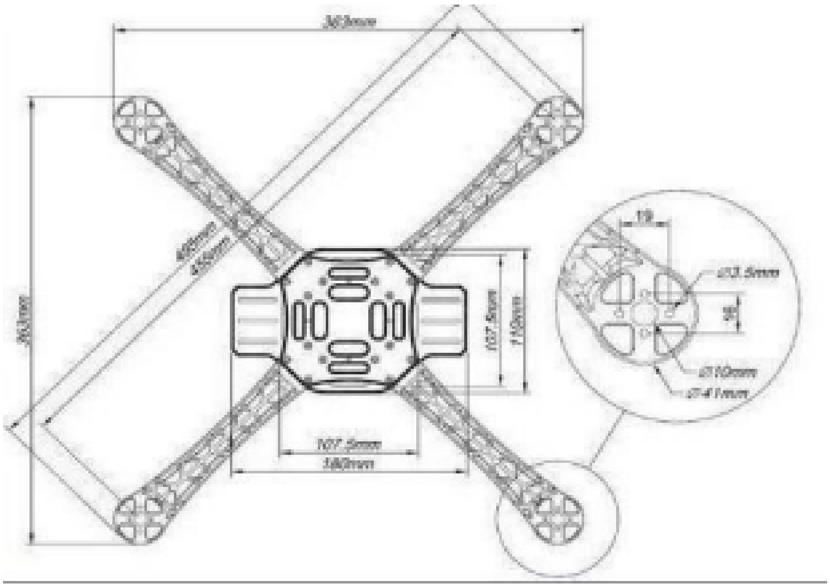

Figure 3: Sketch design of a Quadcopter

- Propeller: A set of 2 x 1045 Propellers. The quadcopter consists of four propellers, 2 of them rotate in a clockwise direction and 2 of them rotate in a counter-clockwise direction. This propeller is specially designed for quadcopters to provide a high amount of thrust to change direction in any of the axes and also to provide high stability at the end of each arm of the frame to make the flight highly stable and easy to maneuver. The pic angle of these propellers is suitable for quadcopters to maintain performance with minimum use of power from the battery.

Figure 4: Propeller

- Amount of power to control the quadcopter. It also controls the camera module, MPU 6050 sensor, and other parts of the Quadcopter and ensures a stable, proper, and smooth flight.
- Camera Module: The ESP32-CAM is a small size, low power consumption camera module that works on ESP32. It has a camera lens and an onboard SD Card slot.

3. Working

As soon as the user provides a signal to the flight controller using the transmitter and receiver, the quadcopter achieves its ideal state. In this ideal state, the quadcopter is on ground and all the propellers are rotating at very low speed The user then provides instructions in the form of signals to the receiver using the transmitter which is connected to the flight controller to take off and achieve a height which is safe to fly and maneuver with respect to the location. The MPU 6050 gyroscope and accelerometer starts to provide information about the height, speed and stability of the quadcopter to the controller. The controller then collaborates the data coming from the MPU 6050 and the data coming from the transmitter and receiver. The ESP 32 cam module also starts to provide live feed of the area wirelessly to the user. Based on the live feed, the quadcopter is moved with respect to the X, Y and Z axis.

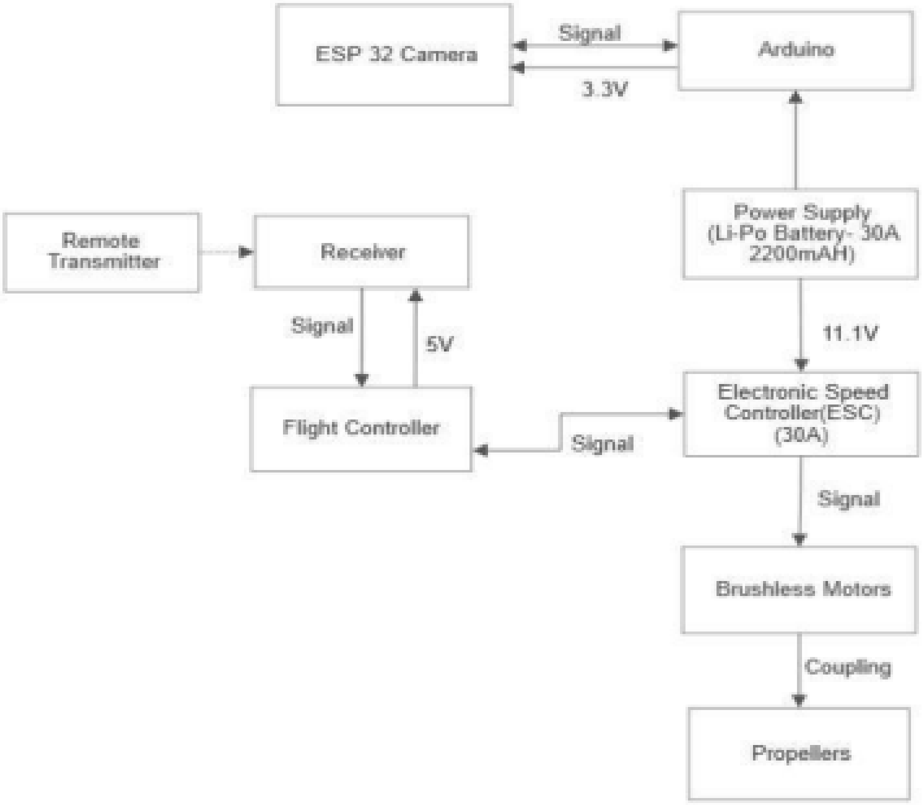

Figure 5: Block diagram

4. Results & Discussion

After assembling all the parts and successfully testing each part individually, several Flight tests were done. The results are as follows:

Test Flight 1: Successful lift-off and drone attained a height of 27 feet. The drone encountered a lot of vibrations on its arms which were reduced by adding some weights on one arm to balance the overall weight.

Test Flight 2: Successful lift-off and drone attend height of 34 feet. The problem of overheating of components was observed which was solved by changing the connection wires. Test flight 3: Successful lift off and do not reach the height of 46 feet. A live video feed was received at the remote-control station.

Test flight 4: This flight was conducted to check the stability of the drone in windy weather. The IMU system worked perfectly and the flight was stable and the live video feed was received at the remote control.

Test flight 5: During this flight, the overall working of the system was observed and it was concluded that the system was working fine and providing proper outputs.

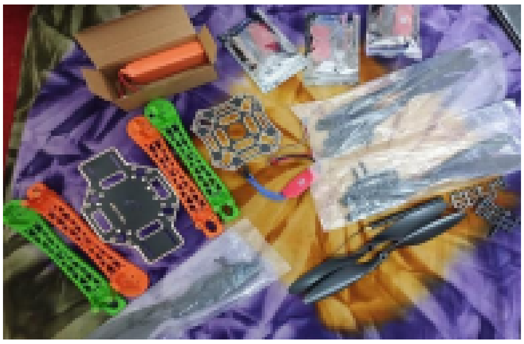

Figure 6: Hardware components of the Quadcopter

Figure 7: Assembled Quadcopter

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AccX:  17068.00 AccY:  320.00 AccZ:  -636.00 GyX:  -313.00 GyY:  238.00 GyZ:  59.00 Temp:  26.04
AccX:  17088.00 AccY:  252.00 AccZ:  -596.00 GyX:  -331.00 GyY:  251.00 GyZ:  76.00 Temp:  26.04
AccX:  17104.00 AccY:  212.00 AccZ:  -588.00 GyX:  -349.00 GyY:  218.00 GyZ:  52.00 Temp:  26.04
AccX:  17028.00 AccY:  208.00 AccZ:  -644.00 GyX:  -332.00 GyY:  249.00 GyZ:  77.00 Temp:  26.08
AccX:  17128.00 AccY:  252.00 AccZ:  -656.00 GyX:  -327.00 GyY:  244.00 GyZ:  64.00 Temp:  26.04
AccX:  17060.00 AccY:  224.00 AccZ:  -492.00 GyX:  -316.00 GyY:  212.00 GyZ:  85.00 Temp:  26.08
AccX:  17096.00 AccY:  296.00 AccZ:  -596.00 GyX:  -327.00 GyY:  234.00 GyZ:  47.00 Temp:  26.08
AccX:  17132.00 AccY:  288.00 AccZ:  -576.00 GyX:  -340.00 GyY:  232.00 GyZ:  65.00 Temp:  26.04
AccX:  17024.00 AccY:  192.00 AccZ:  -568.00 GyX:  -336.00 GyY:  225.00 GyZ:  69.00 Temp:  25.99
AccX:  17220.00 AccY:  268.00 AccZ:  -532.00 GyX:  -319.00 GyY:  276.00 GyZ:  40.00 Temp:  26.04
AccX:  17032.00 AccY:  324.00 AccZ:  -476.00 GyX:  -336.00 GyY:  228.00 GyZ:  63.00 Temp:  26.08
AccX:  17084.00 AccY:  196.00 AccZ:  -656.00 GyX:  -335.00 GyY:  212.00 GyZ:  69.00 Temp:  26.13
AccX:  17044.00 AccY:  224.00 AccZ:  -508.00 GyX:  -332.00 GyY:  222.00 GyZ:  64.00 Temp:  25.94
AccX:  17020.00 AccY:  300.00 AccZ:  -580.00 GyX:  -329.00 GyY:  224.00 GyZ:  63.00 Temp:  26.13
AccX:  17032.00 AccY:  216.00 AccZ:  -484.00 GyX:  -310.00 GyY:  220.00 GyZ:  74.00 Temp:  25.99
AccX:  17044.00 AccY:  104.00 AccZ:  -700.00 GyX:  -315.00 GyY:  246.00 GyZ:  81.00 Temp:  26.04
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Autoscroll Show timestamp

Figure 8: Readings of Gyroscope

The above results show the initial reading that the flight controller received from the 3 axis Gyroscope. These readings show the individual inclination of all the axis's i.e. X axis, Y axis & Z axis.

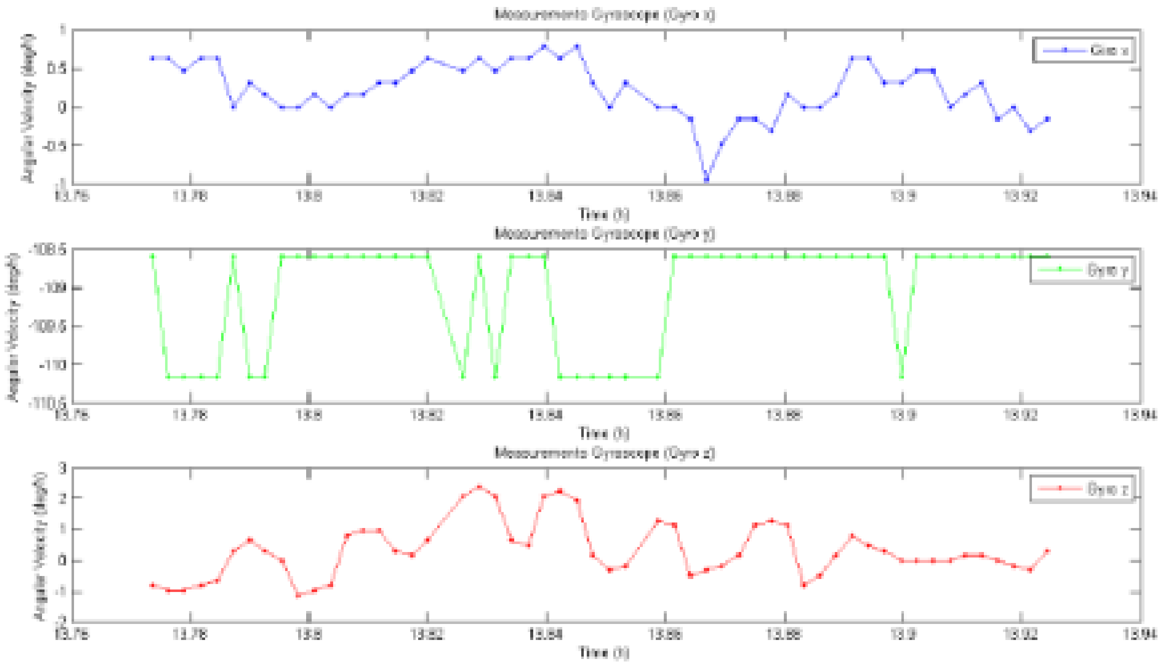

Figure 9: Plot of Gyroscope Reading

Fig 8. Shows the graph of the readings that the flight controller received from the 3-axis gyroscope. This graph depicts the X axis, Y axis and Z axis. The straight lines in these graphs shows that the quadcopter maintained a proper altitude during the respective time frame and axis. The upside and downside graph shows how the quadcopter was maneuvered during that very time frame with respect to all the axes.

5. Safety & precautions for flying Quadcopter

When flying a quadcopter the following six simple safety precautions need to be taken care of: ● Select the suitable setting: To start, consider flying a robot in an open external climate instead of inside to verify that the day ought to be less blustery and the region has lesser trees. ● Keep an eye on your surroundings: Keep track of other people, objects, trees, and highways to ensure a safe flight route and landing. Do not fly near an airport or over a huge crowd. Be cautious of strong antennae and power wires.

● Acquire approval: Request authorization in the event that you are on another person's property or in a public area to stay away from intrusion of protection or different punishments. ● Examine the battery: To avoid an emergency landing, make sure your battery is completely charged. If you travel in the winter, your battery will deplete faster than it would in the summer.

Take control: Perhaps the earliest thing you ought to comprehend prior to flying the robot is the way to utilize the crisis arrival button. Assuming you make a critical blunder while flying, it ensures that the robot lands securely. Nonetheless, you ought to just enact the crisis land capacity in crisis circumstances. Real emergencies, similar to the engines, will fizzle and your robot will crash (which could truly hurt those beneath). Keep an immediate view with your robot and screen its level.

6. Applications

Some of the applications of quadcopters are as below:

- Aerial Photography: Nowadays, quadcopters are used to capture the footage instead of helicopters as they are cheaper than helicopters and also congested areas are no problem. Movies having sci-fi scenes and fast-paced action scenes are filmed easily. These are also used in sports videography and photography, journalism, real estate, and live broadcasts.
- Shipping and Delivering: Many companies like Zomato, Swiggy, and Amazon have started using quadcopters for their delivery purpose as it decreases the manpower and also resolves the traffic problem. This saves a lot of time as there is no traffic in the air.
- Disaster Management: In any man-made or natural disaster, quadcopters gather information and also help in looking out for the victims. It may be equipped with an HD camera, radar, or sensor which gives the rescue team a helping hand in saving victims in any region and also save the resources used on the manually piloted helicopter
- Search and Rescue: Sensors like thermal sensors help in rescuing at mountain regions or also provide night vision function for dark rescue. It provides transporting medical supplies for emergencies for lost persons by carrying them while searching for the victim.
- Wildlife Monitoring: Quadcopters help in monitoring the wildlife to defending against poachers. People try to harm the wildlife by cutting trees and killing animals to earn some money. For the safety of wildlife quadcopters help in keeping the track of the poachers entering the wildlife region.
- Law Enforcement: Quadcopters are used for maintaining the law. It is used for the surveillance of a large crowd.

7. Conclusion

A quadcopter is a versatile vehicle that may be used for a variety of purposes. This paper outlined the fundamental design and application ideas that are now in use. Quadcopters can be used in areas that are difficult to reach for humans and require a lot of hindrances to be crossed. They can be used to catch speeding drivers' license plates and their vehicles, identify cash machine theft, battle fly-posting, fly-tipping, and waste management. Future studies will focus on search and rescue. An attempt will be made in the future to build a system for designating the safest paths in the event of a natural disaster. In addition to natural catastrophes and accidents, this system may be used in cases of climate changes that impact the safety and health of the people, or in circumstances where it threatens the operation of various economic systems.

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