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Quadcopter for Surveillance Application – A Review

[1]A.A. Bhujbal, [2]P. P. Khedkar, [3]Y. S. Agrawal,[4] A. N. Dambalkar,
[5]Prof. S. B. Pawar
[1,2,3,4,5]*(Mechanical, RSSOER JSPM NTC, Savitribai Phule Pune University, India)*

Abstract: *The Unmanned Aerial Vehicles (UAVs) has an ability to operate in dangerous locations while keeping their human operators at a safe distance. Due to which they have immense applications in the area of surveillance and emergency rescue. Quadcopter is a multi copter that is lifted and propelled by four rotors. In Quadcopters the lift is generated by a set of revolving narrow-chord airfoils. Quadcopters generally use symmetrically pitched blades for better stability. Control of vehicle motion is achieved by altering the pitch and/or rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics. It is controlled by radio transmission or operates under the guidance of limited autonomous protocols. This paper is a presentation of the design methodology and realization of the Quadcopter, a normal model aircraft based on a four-propeller design*

Keywords: *UAV, Quadcopter, Rotor, Roll, Pitch, Thrust, Power, ESC*

I. Introduction

There has been a rise in use of Unmanned Aerial Vehicle (UAV) in recent years even in the developing countries like India. They are being used in surveillance applications like traffic monitoring, border surveillance, environmental monitoring, target tracking and may other application.

A Quadcopter also known as Quadrotor or Quadrotor Helicopter is a type of UAV which can be controlled by remote controllers or computers. As the name suggests Quadcopter is a UAV with four motors which are mounted on frame. The frame is in a shape of 'X' or plus sign (+). Each motor has a propeller fixed on it which rotates clockwise and anticlockwise to produce balance torque as shown in FIG.1. When this balance torque advances to safe thrust level it lifts itself. The propellers used in Quadcopter are symmetrically pitched hence generating more torque and less turbulence due to which motors don't have to work as hard. The weight needs to be low enough so the Quad copter's upward thrust creates a force great enough for flight to occur. Control of vehicle motion is achieved by altering the pitch and/or rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics. The motors speed of rotation and direction of rotation change according to the user's desire to move the device in a particular direction. The rotation of motors change as per the transmitted signal sent from the transmitter

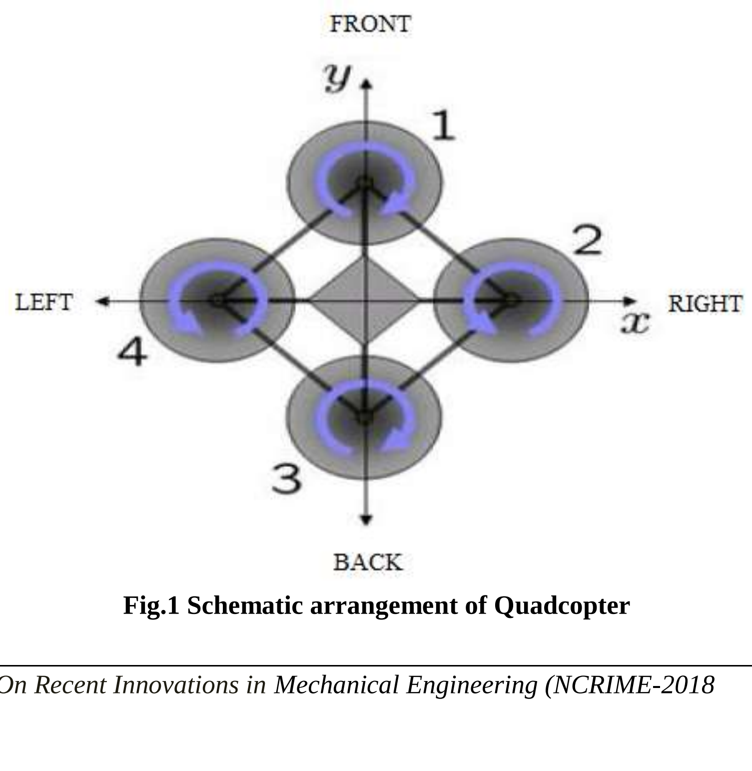

Fig.1 Schematic arrangement of Quadcopter

II. Components

Quadcopter Frame

The frame of the Quadcopter provides the physical structure for the entire aircraft. It joins the motors to the rest of the aircraft and houses all of the other components. The frame must be large enough to allow all four propellers to spin without collision, but must not be too large and therefore too heavy for the motors. For our Quadcopter we chose a Hobby king SK450 frame which measures at 450mm across opposite motors.

Motors

The motors spin the propellers to provide the Quadcopter with lifting thrust. Quadcopters almost exclusively use brushless DC motors, as they provide thrust-to-weight ratios superior to brushed DC motors. However, they require more complex speed controllers. Hobby motors are typically given two ratings: Kv ratings and current ratings. The Kv rating indicates how fast the motor will spin (RPM) for 1V of applied voltage. The current rating indicates the max current that the motor may safely draw. For our project, we selected 1000Kv, 15A max.

Fig.2 Brushless Motor

Propellers

Propellers come in many sizes and materials. They are measured by their diameter and their pitch, in the format (diameter) x (pitch). Pitch is a measurement of how far a propeller will “travel” in one revolution. Prop selection is important to yield appropriate thrust while not overheating the motors. For our project, we selected 9x4.7 carbon fiber props which yield 1.4lbs of max thrust while drawing 10.2A.With four motors, the max thrust for the quad is approximately 5.5 lbs. Our quad has an all-up-weight of 2.0 lbs (925 g), resulting in an overall thrust-to-weight ratio of 2.75. This allows the quad to hover just below half-throttle.

Fig.3 Propellers

Speed Controllers

Every motor needs an individual electronic speed controller (ESC for short). These speed controllers accept commands in the form of PWM signals and output the appropriate motor speed accordingly. Every ESC has a current rating, which indicated the maximum current that it may provide the motor without overheating. Appropriate ESCs must be chosen to ensure that they can provide enough current for the motors. We selected 20A Afro ESC for our project, as they are well reviewed for use with Quadcopters and have a sufficient current rating

Battery

The battery provides electrical power to the motors and all electronic components of the aircraft. Lithium Polymer (LiPo) batteries are used almost exclusively, because they have high specific energy. Hobby LiPo batteries have a capacity rating and discharge rating. The capacity rating, in milliamp-hours (mAh) indicates how much current the battery may output for one hour. Discharge rating, indicated by the letter “C”, show how fast the battery may be safely discharged. To determine max allowed current, multiply the C value with the capacity. For this project, we selected Turing 3000mAh 20Cbatteries

Fig.4 Battery

Radio Receiver

The radio receiver (Rx) receives radio signals from an RC transmitter and converts them into control signals for each control channel (throttle, yaw, roll & pitch). Modern RC receivers operate on a 2.4 GHz radio frequency, while older Rx units often used 72 MHz frequencies. Rx units may have as few as 4 channels, but many have more channels for additional control options.

Flight Controller

The flight controller is the "brain" of the Quadcopter, and performs the necessary operations to keep the Quadcopter stable and controllable. It accepts user control commands from the Rx, combines them with readings from the attitude sensor(s), and calculates the necessary motor output.

III. Quadcopter Dynamics

We will start deriving quadcopter dynamics by introducing the two orthogonal frames in which it will operate. The inertial frame is defined with respect to the ground, with gravity pointing in the negative Z-axis (Fig. 5) .Where exactly x and y point is irrelevant for math derivations, but for practical purposes, our algorithms and systems assume x being along the parallel latitude lines, and y being along themeridian longitude lines.The body frame is defined by the orientation of the quadcopter, with the rotor pointing in the positive Z-axis and the arms pointing in the positive/negative X and Y directions (Fig. 5).

We define the position and velocity of the quadcopter in the inertial frame as:

$$x = (x, y, z) \text{ and}$$
$$x' = (x', y', z')$$

respectively. Similarly, we define the roll, pitch, and yaw angles in the body frame as:

$$q = (f, q, y)$$

with corresponding angular velocities

$$q' = (f', q', y').$$

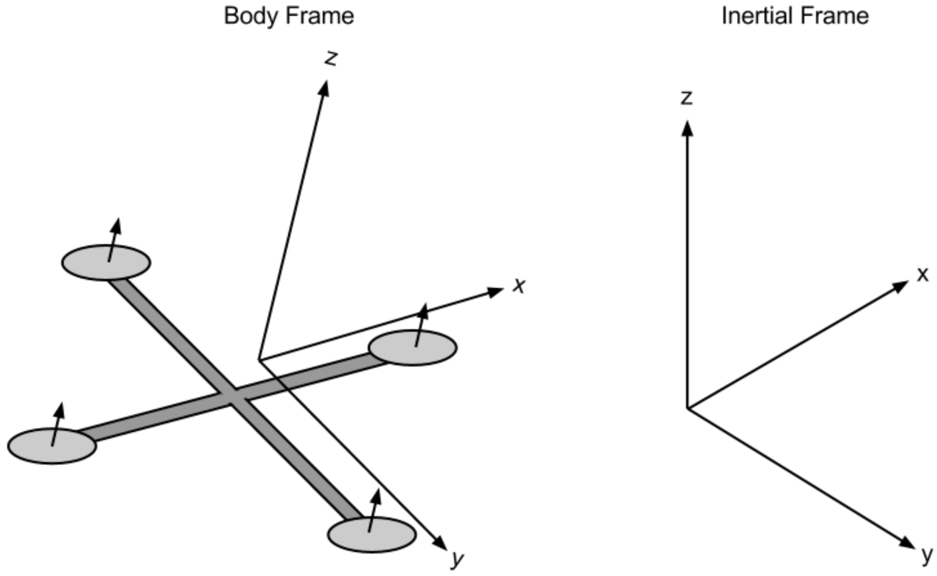

Fig.5 Orthogonal Frame

Control Techniques

Accelerometers will measure the angle of Quadrotor in terms of X, Y and Z axis and accordingly adjust the RPM of each motor in order to self stabilize by it-self. The stability is provided by setting the direction of rotation clockwise of one set of opposite motors and counter-clockwise of other set of motors which nullifies the net moment and gyroscopic effects.

By using this principle one is able to adjust the speed and can get desired speed of each individual motor in order to get desired yaw, pitch and roll. RPM of the shaft of a motor is a function of voltage provided to that motor. Roll and pitch can be controlled by changing the speed of the appropriate motor, while yaw control involves proper balancing of all four motor results in to change in moment and force applied to take appropriate turn. Controlling of quadrotor involves different four states.

Upward and Downward Motion (Z direction)

The force required for this motion is known as lift force and generated by thrust produced by four propellers rotating at same speed. In order for the Quadcopter to gain altitude, all four of the motors must increase the speed of simultaneously. Conversely to descend down, all four of the motors must decrease the speed of its rotation simultaneously.

Yaw Motion (□)

The ‘yaw’ or ‘rudder’ is a rotation movement of Quadcopter. In Quadcopter 2 CW and 2 CCW rotating propellers are used. The propellers with the same rotational motion are installed opposite to each other. Yaw motion is attained by increasing or decreasing speed of two diametrically opposing motors. By decreasing the speed of opposing motors the torque produced by other pair will increase allowing the Quadcopter to rotate in that direction.

Pitch Motion (□)

The ‘pitch’ control tells the Quadcopter whether to fly forward or backward. This motion can be attained by generating couple of forces from the set of motors in the direction of the movement. For example the speed of the motors at the rear of the Quadcopter must increase, relative to the speed of motors in front. This pitches the nose (front) of the quadcopter down resulting in the forward movement.

Roll Motion (□)

The ‘roll’ control tells the Quadcopter to move side to side. This motion can be attained by generating couple of forces from the set of motors in the direction other than the direction of motion. It is similar to pitch motion. The speed of the motors at the left of the quadcopter must increase or the speed of the right side motors must decrease to move it in right side.

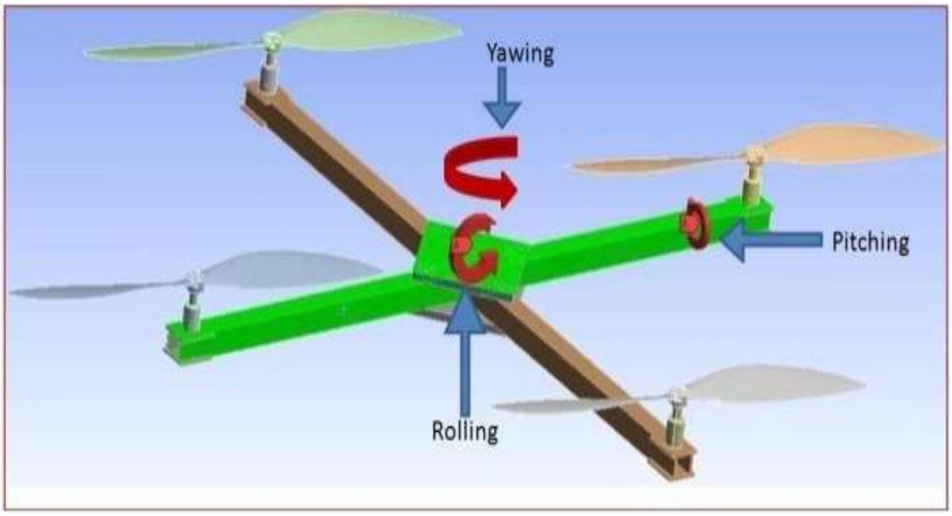

Fig.6 Gyroscopic Effects

IV. Principle of Working

There are 2 main configurations: X or +. X config is more popular as you can keep the propellers out of the camera's view (for FPV and aerial filming). Some people fly the plus (+) config because it's more instinctual, and flies like an airplane. It's easier to figure out the orientation.

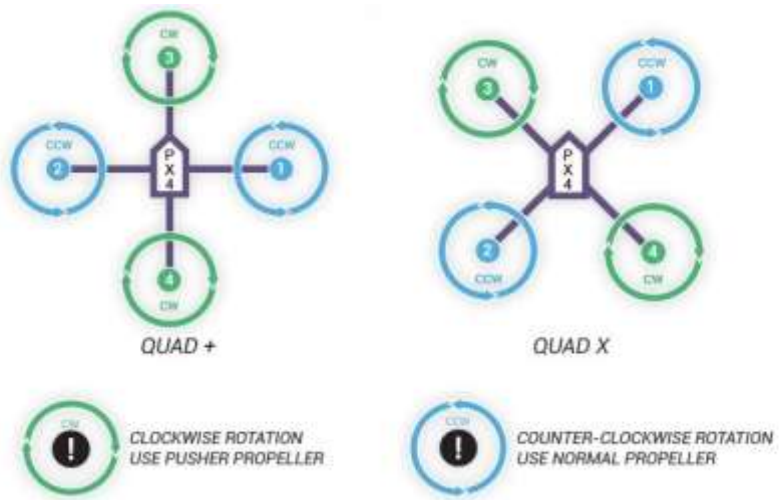

Fig.7: + and x Configuration

In "+" configuration two motors of Quadcopter rotate clockwise and other two motors rotate anti-clockwise. And the opposite motor rotate in the same direction Quadcopter operating motherboards front will be pointing rotor-3 shown in fig. In "x" configuration is almost same to "+" configuration. Only difference is Quadcopter operating motherboard front will be point to the direction between rotor-1 and rotor-3 shown in fig.

The entire configuration requires the opposite rotors spin in the same direction while adjacent rotors spin in opposite directions. The direction of each motor's rotation is such that it counteracts the torque generated by the motor that is placed at the opposite side. This is how the quadcopter keeps from spinning due to torque effect

Take-off and Landing Motion

In order for the quadcopter to gain altitude, all four of the motors must increase the speed of rotation simultaneously. On the other hand, to descend down, all four of the motors must decrease speed of its rotation simultaneously.

This is what happens when you increase or decrease the elevator control on your transmitter – the speed of the motors changes simultaneously.

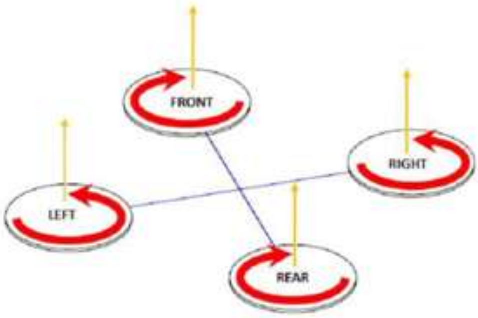

Fig.8.1: Take-Off Motion

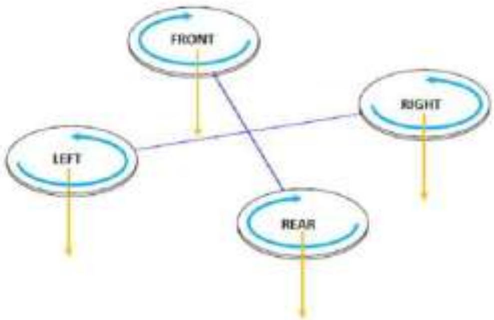

Fig.8.2: Landing Motion

Forward and Backward Motion

In order to move forward, the speed of the motors at the rear of the quadcopter must increase, relative to the speed of the motors on the front. This pushes the nose (front) of the quadcopter down, resulting in the forward movement. This is achieved by either increasing the speed of the rear motors or decreasing the speed of the front motors.

On the other hand, in order to move backwards, the speed of the motors at the front of the quadcopter must increase relative to the speed of the motors at the back.

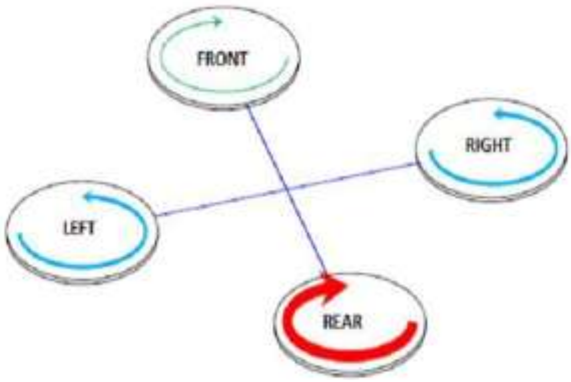

Fig.9.1: Forward Motion

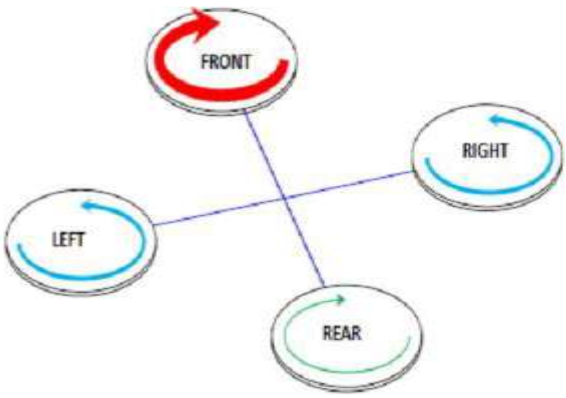

Fig.9.2: Backward Motion

V. Basic Formulae

Thrust

Thrust is the force that is orthogonal to the propeller and generated by rotor speed at certain velocity.

$$T = \rho A V_i$$

Where,
ρ = Air density
A = Cross-sectional area of the propeller
V_i = Velocity of rotors

Power

The power is used to keep the Quadcopter aloft. Power is equivalent to thrust times air velocity.

$$P = T \times V_h$$

Where,
T = Thrust required
V_h = Surrounding air velocity

VI. Application

- Surveillance: A drone allows recording and monitoring from the sky, and therefore, they are suitable to monitor public events, protests, or any suspicious happening without being heard and seen. A great tool for the police!

- Search and rescue: Drones are very useful in searching and rescuing operations. For example, they are used in firefighting to determine the amount of the certain gasses in air (CO, CO_2, and the like) using the special measuring equipment.

- Security: Many authorities use drones to protect people during various emergencies. For instance, they are able to help coordinate a variety of security operations and can preserve evidence alike.

- Inspections: Many systems such as power lines, wind turbines, and pipelines can be checked by drones.

VII. Conclusion

Our main goal is a Quadcopter which can be used for multipurpose application in market, military, commercial and industrial applications like Traffic monitoring and management, Search and rescue operation, Crowd management, post natural disaster. Given the stable platform produced by this group, further research and development can and should be done to improve the functionality of our design.

This project can go further in variety of research work to integrate various technologies with Quadcopter to get various useful outputs.

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