The Structure and Mechanisms of Quadrotor Drones and Their Applications for Hobbyists

Drone is a common name for unmanned aerial vehicles (UAVs). A UAV is a robotic aircraft that has an onboard computer, which gives it the ability to fly via remote control or autonomously. The most technologically advanced drones are best known for their military applications, such as reconnaissance and counterterrorism operations. However, there are also smaller commercial versions that are available to the public. One type of commercial drone is the quadrotor, which is a small drone that hovers and flies using four rotors. A popular quadrotor hobbyists like to fly is the Parrot AR.Drone, which is shown in Figure 1. In the following sections, I will describe the structure and components of quadrotors, how they fly, and several applications for hobbyists.

Structure of the Quadrotor

A quadrotor set has four main parts: the body, frame, propeller, and controller.

Body

The body of the quadrotor houses all the internal components, the most important of which are the battery power supply and computer control system. It also contains sensors, such as gyroscopes and accelerometers, which are necessary for stabilizing flight. More advanced drones include a mounted camera and a Wi-Fi transmitter.

Frame

The frame of the drone is designed to be strong and lightweight. Composite materials consisting of nylon and carbon fiber are used for the body’s shell as well as the frame bars, which hold the propellers. At the end of the frame bars, there are also landing gears so that the drone can land safely.

Propellers

The propellers produce the lifting force needed to fly in midair. These propellers are powered by electric motors, which are wired to the battery inside the drone’s body. Some quadrotors’ propellers are not shielded, such as the Parrot drone in Figure 1. This means they can be damaged if they hit an object.

Figure 1: The Parrot AR.Drone is a popular commercial quadrotor.1

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1 http://upload.wikimedia.org/wikipedia/commons/f/f5/Ardrone-img5-front.jpg
Other versions, however, do offer protection covers for the propellers if the consumer is interested in this feature.

**Controller**

Many quadrotors are controlled by simple radio controllers with an antenna, buttons and joysticks. Some quadrotors have a Wi-Fi transmitter, which provides a special option to control them with an iPhone or iPad. The main function of the controller is to adjust the speeds of each propeller, which pilots the drone, as described in the next section.

**Principles of Flight**

Figure 2 shows a schematic diagram of a quadrotor. The body is centered at the origin with the drone’s head on the +y-axis (not shown). The four rotors are positioned at the x and y axes. To produce stable flight, one pair of rotors needs to rotate clockwise (1, 3) and the other pair counterclockwise (2, 4). The reason for this is to counter the internal torques produced within the quadrotor.\(^2\) For example, assume all of the rotors rotate clockwise, which means they have negative torque. Since these rotational forces are internal (or within the drone) and also negative, angular momentum conservation induces a positive torque on the drone’s body (the total torque of the body and propellers is therefore zero).\(^3\) This makes the drone rotate counterclockwise, which is unstable. By having a pair of clockwise and counterclockwise rotors, they induce two torques on the drone’s body that oppose and therefore cancel each other. Under this rotor configuration, three main modes of motion can be used to pilot the quadrotor: lift, yaw, and pitch.

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\(^2\) Torque is a rotational force that rotates objects. By convention, a positive torque rotates objects counterclockwise and a negative torque clockwise.

\(^3\) The principle of the conservation of angular momentum states that if there are no external rotational forces on the drone, then the sum of internal rotational forces must equal zero.

Lift

Lift is the ability to fly upwards. In order for the quadrotor to move vertically, all four propellers need to rotate at the exact same speed. As mentioned earlier, this not only produces a downward thrust but also keeps the drone rotationally stable. The drone can ascend, descend, or hover depending on the magnitude of thrust.

Yaw

In the schematic diagram, yaw is pure rotation about the center of the xy-plane. In order for a quadrotor to rotate clockwise, the negative torque induced on the body needs to be greater than the positive torque. Therefore, the counterclockwise rotors (2, 4), which induce negative torque, must rotate faster while the clockwise rotors (1, 3) must rotate slower, and vice versa for counterclockwise yaw.

Pitch

Pitch is rotation other than about the center of the xy-plane. Instead, pitch is the rotation about the x-axis or y-axis (or both) and is therefore different than yaw. Pitch allows the drone to tilt in a particular direction; as a result, the thrust from the propellers can shift the drone forward, backward, left or right. The following subsection describes several ways to pitch the quadrotor:

1. Forward and backward
   • If rotor 3 rotates faster and rotor 1 slower, this imbalance in thrust causes the quadrotor to rotate and move forward. The drone can shift backwards if rotor 1 rotates faster and rotor 3 slower. Since both of these rotors rotate clockwise, this pitch method will not produce a yaw motion.

2. Left and right:
   • To pitch left or right, rotors 2 and 4 are used instead. To shift left, rotor 2 rotates faster and rotor 4 slower, and vice versa for pitching right. Because this pair rotates counterclockwise, there is also no additional yaw.
Hobbyist Applications

You and your friends can do all sorts of fun things with these quadrotor drones, such as performing tricks and recording live videos.

Tricks

1. Obstacles
   - Quadrotors are small enough to fly through windows, hallways, and other obstacles. Figure 3 shows a hula hoop obstacle course that the drone must navigate.

2. Flips
   - A drone pilot can use the lift and pitch controls together to perform 360° flips.

3. Circles
   - A user can use the pitch controls to pilot the quadrotor in circular paths in midair.

Live Video

Most quadrotors have a camera mount and Wi-Fi transmitter, which allow hobbyists to capture live video and stream it to their iPhones or iPads. You can use your iPhone not only to control the quadrotor but also see what it is seeing at the same time. It is a fun way to explore landscapes if the quadrotor is flying at high altitudes, as shown in Figure 4. You can then post the video on YouTube to show beautiful aerial sceneries to viewers.

Conclusion

To summarize, I have described the components that make up the quadrotor, such as the body and propellers, and the principles of flight: lift, yaw, and pitch. Hobbyists should familiarize themselves with the drone and understand how they work before flying them. Have fun with your new quadrotors!

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5 http://i1.ytimg.com/vi/geqip_0Vjec/maxresdefault.jpg
6 http://johnberryphotography.com/2014/quadcopter-aerial-photos/