Drone Motion Manual

Theory

Introduction:

Drones or UAV come in two variants – fixed wing and rotary drones. Rotary drones or multirotor drones consist of three rotor tri-copter, four rotor quadcopter and six rotor hexcopter. Each rotor type has a specific usage and is useful for specific applications. The commonly used type of multirotor is the quadcopter. In drones, each motor spins in the opposite direction of the adjacent motor as shown in Figure 1. This allows it to achieve vertical lift.

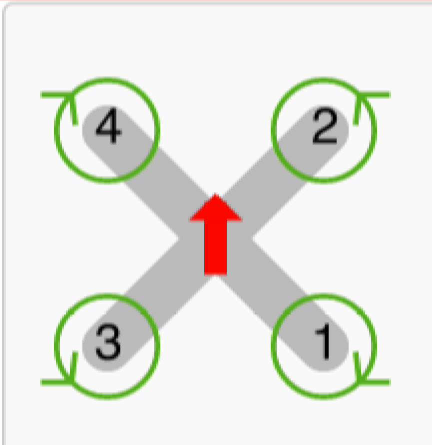

Figure 1: Motor Directions
Image Source

In order to maintain its 'pose' in flight and stay stable, a drone heavily relies on sensors that constantly monitor the drone's 'attitude'. These sensors provide feedback to the drone using which the flight controller makes corrections in the motor spin speed and thus adjusting and shifting the drone in flight so that it remains stable.

Sensors:

Accelerometer and Gyroscope: The accelerometer sensor is used to sense the acceleration of the drone in the X, Y and Z axis. The gyroscope is used to measure tilt in the roll, pitch and yaw of the drone. The MPU6050 sensor is a combination of accelerometer and gyroscope. It measures the acceleration in all the 6 Degrees of Freedom (DoF). It is widely used in pose estimation robots like a self-balancing robot or hand gesture controlled robot.

Barometer: Barometers are used to measure the air pressure and hence help flight controllers to predict the height of the drone from the ground. Barometers generally come handy when the drone is at large enough heights.

Ultrasonic: Ultrasonic sensors help give precise height of the drone from the ground. Ultrasonic sensors are extremely useful when flying a drone within 50cm from the ground. Beyond that height it is recommended to rely on the barometer for estimating the drone height with respect to the ground.

Drone Motion:
Drones' thrust, roll, pitch and yaw is changed by manipulating the angular velocity of the motors. Following details how to move the drone by manipulating the angular velocity of the motors:
i. Thrust/Throttle - In order to change the drones height, we can decrease or increase the velocity of all 4 motors. Reducing the velocity of all the motors lowers the drone height, while increasing the velocity increases the height of the drone with respect to the ground.
ii. Pitch - By changing the motor speed of the front and back motors, we can move the drone forward and backward. Increasing the speed of the forward motors moves the drone back while increasing the speed of the back motors moves the drone backward.
iii. Roll - To move the drone left or right, we simply manipulate the left and right motors. By increasing the speed of the two left motors the drone bends to the right. By increasing the speed of the two right motors the drone bends to the left.
iv. Yaw - By changing the speed of the alternate motors, the drone yaws to the left or right respectively.

A quadcopters motion in 3D space is explained visually in Figure 2.

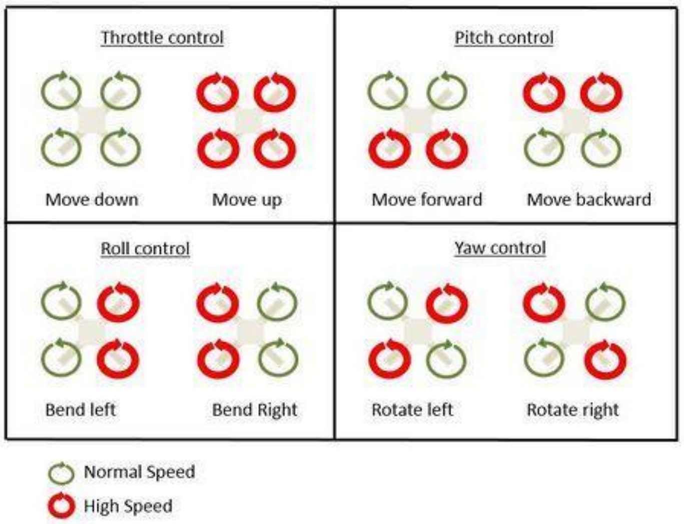

Figure 2: Motion in 3D space
Image Source

Flight Controller:
A flight controller is responsible for issuing commands to the motors as per the required motion. The flight controller relies on sensor data to generate accurate motion commands so that the drone maintains its pose as it moves from Point A to Point B. Commonly used flight controllers in quadcopters are PixHawk, KK and MultiWii.

PID

The PID or Proportional Integral Derivative algorithm is a widely used control loop feedback mechanism in control theory. At the crux of the algorithm an **error value** is calculated **'e(t)'** based on the difference between a **set point** or a **desired point** and the measured current point. A **correction value** is calculated based on **Proportional, Derivative and Integral** terms and is then applied to the system to reduce the error value. PID can be applied to any system oscillating like a pendulum and desires to maintain a center reference.

Common examples in robotics that use the PID algorithm are: line following robot, object tracking using image processing and maintaining drone pose during flight.

We have prepared a very thorough guide to help you understand PID. Please refer Understanding PID.pdf. Additionally you can refer to the resources given in References.pdf for detail information of implementation and usage of the PID algorithm.