Multirotor Drone Control

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Introduction

Unmanned Aerial Vehicles, or quadcopters, have been used mainly for military purposes due to their guarantee of stealth, safety, and efficiency. A common misconception is that all drones are akin to small planes. In fact, drones vary in design, and while some are plane-like, others can be multirotor structures with simpler interfaces. It is this class of drones that has become easily accessible not only for military use, but for commercial, scientific, and recreational use as well.

Applications

Primarily due to their multirotor design, the maneuverability of drones allows for applications beyond reconnaissance and attack. These specific aircraft—drones with three or more rotors—are ideal for use in racing, product delivery, filming, photography, and monitoring, among other things. Because of widespread use, drone owners must be aware of FAA laws and regulations in place for the area that they would like to fly in. If flying in the desired area is not a problem, then the owner should consider the equipment needed depending on the application. Different equipment can be mounted onto or taken off the drone to lighten payload, decrease power consumption, and increase battery life.

Battery Life

Battery life is something all drone owners must be aware of due to current technology limitations, which allow drones to achieve a maximum flight time of about 26 minutes (James, 2017). Under normal conditions like relatively warm temperatures with no wind, a drone averages a flight time of 15 minutes (LaFay, 2015). Larger UAVs require bigger batteries to compensate for their more powerful motors and bigger propellers to maintain flight time.

Positioning

Most drones come with a gyroscope and/or GPS for localization and stabilization. Sensors and receivers like these are all controlled by the main controller chip on the center of the drone. Aside from these electrical components, a drone has rotors with propellers at the end of each leg. Usually one or two of these rotors or legs are marked with LEDs, designating the front of the drone and aiding with orientation during flight (Flight, 2016).

Flight Modes

Before setting out and attempting to fly a quadcopter, it is important to learn about how drones and their controls function. Practicing with smaller aircraft is indispensable to successfully piloting bigger aircraft.

A drone can be configured to one of several flight modes, which correspond to different drone behaviors as well as different uses of the controls on the associated remote. The remote itself can switch the drone between modes, as will be mentioned later.

The most common flight mode is Standard, or Normal. In this flight mode, the front of the drone always corresponds to the LED-indicated rotors (LaFay, 2015). Other modes include Heads Free, First Person View (FPV), Loiter, and Stabilize.

All modern drones have a Return-To-Home mode that utilizes GPS or a similar receiver/sensor. This mode returns the drones to their takeoff location if connection to the remote control is lost or the battery power is near depleted (DJI, 2015).

Heads Free Mode

Heads Free mode creates an absolute orientation for the drone, no matter its actual front orientation. This is the simplest mode to use, but not ideal when learning how to maneuver a drone with precision.

First Person View (FPV) Mode

FPV mode requires the drone to have a live-feed camera that the pilot can use to ensure that they are flying where they want. This is useful when becoming familiar with the four motions, discussed later in the report.

Loiter and Stabilize Modes

Loiter mode maintains your location, direction, and altitude even when you are not touching the controls. Stabilize mode is like Loiter mode in that it aids the pilot by leveling out when no controls are being touched. Loiter and Stabilize mode are useful when transitioning from FPV mode where mistakes are anticipated. They are also useful on windy days where controlling the drone is more difficult. Other more manual modes may be configured to the drone when the pilot becomes comfortable with the basic drone controls (Flight, 2016).

Multirotor Control

Drone Controls

There are four main controls for maneuvering drones: throttle, pitch, yaw, and roll. These four controls are pictured in figure 1.

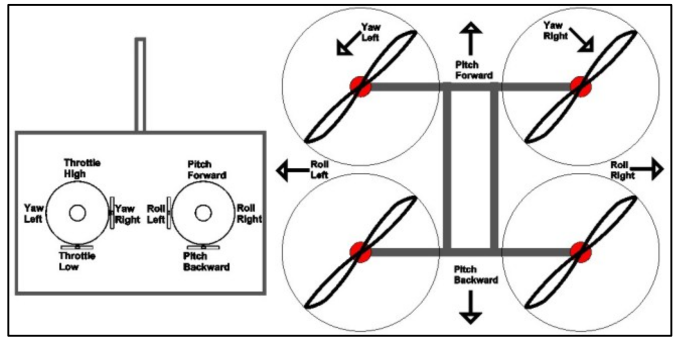

Figure 1. Controls and drone diagram for roll, pitch, yaw, and throttle (Quadcopters Are Fun, 2017)

It is assumed that the drone in this figure is on a certain mode in which the left stick of the controller affects the throttle and yaw of the drone, and the right stick controls the pitch and roll. In this mode, the throttle adjusts the altitude of the drone. Pushing the corresponding stick forwards increases elevation and pulling it backwards decreases it. Pitch, or elevator, tilts the drone forward or backward, causing it to displace in the corresponding directions. As an example, when in Stabilize mode, pushing the right stick in figure 1 forward for one second and letting go of the stick afterwards causes the UAV to tilt forward for one second, then level out and remain in place. To depict differences in modes, in this same example if the drone were in Loiter mode, the drone would continue to drift in the direction it was made to go even after letting go of the sticks. Yaw rotates the drone along the z-axis, like a swivel chair. Finally, roll, or aileron, tilts the drone in a similar fashion to pitch, but allows it to displace sideways as opposed to forward and backward.

Controller

The pilot must learn the drone remote to get started with practice. A typical and perhaps basic controller is demonstrated in figure 2, below. While the left and right sticks were discussed prior, it is important to note that different modes may require the sticks to be in different neutral positions. For example, in Loiter mode, the throttle stick must be in the center so that the drone does not change elevation. In Stabilize mode, on the other hand, the speed of the rotors is determined by where the throttle stick is. This means that if the throttle stick is all the way down, the rotors shut off. In other more manual modes, the sticks must be constantly adjusted for the drone to move or remain stationary, notably to account for wind or sudden changes in movement.

Figure 2. Drone transmitter with universal parts (UAVCoach, n.d.)

The trims (see Fig 2) aid in calibrating the drone in the event that it tilts off balance. Trims on a drone are identical to a boat trim, which is helpful if the pilot has experience with nautical vehicles. The flaperon switch denoted in Fig 2 is not used with multirotor UAVs, as they do not have flaperons. Finally, the landing gear switch may be product-specific or may serve to switch between modes on some remote controls. Flying a drone may seem daunting at this point, but just knowing the basics may be enough to have a successful flight.

Control Software

The alternative to flying a drone completely manually or semi-autonomously is to upload software to the drone's motherboard (i.e the controller onboard mentioned earlier) via USB or Wi-Fi. Computer software or smartphone apps make it easy to plan and execute trips for the drone from one location to the next with incredible precision in altitude, location, direction, and orientation, without much remote controller use. A recommended application to use is Mission Planner, which provides the drone with a Return-To-Home mode in case the trip fails in any way. This application also allows for control over how many GPS satellites the flight planner wants to keep track of the drone. The more satellites to track the drone, the more accurate its location becomes. Nonetheless, it is always important to have one person supervising the application mid-flight and another person piloting the drone in case something goes wrong.

Conclusion

Again, as with many products that offer diverse applications, it is important to be informed about what is and is not needed on the drone. This is extremely important when considering battery life, as any additional mass increases power consumption and slows the flight. The pilot must also be competent with drone control to maximize flight time, otherwise it is recommended to have pre-planned, automated routes uploaded to the drone to not waste power on incorrect yaws or over-extended pitches/rolls. Finally, it is important to take note of weather conditions to achieve the best performance. A windy day causes the drone to exert itself and have its battery drain before the flight mission is completed. Having an automated flight on a windy day may also cause the drone to end up in an incorrect location.

As an example of specific applications, the Tufts Senior Design Blue Team plans to use a drone to survey an area of land and gather enough data to create a three-dimensional voxel of the area. For this purpose, it is useful to have pre-planned flight missions for the drone to partake, so that onboard calibration may take place. Using a drone for this purpose is essential, but not the most vital aspect of the project. Each flight must be executed as expected, since the focus of the project is data acquisition. Despite the short flight time that drones provide today, UAVs offer a wide range of services that seem promising for the future.

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