

Control systems for multirotor aircraft

Introduction

To control a system, sensors are needed as well as actuators and a control software. This paper reviews the mathematical theory behind the software to control a multirotor aircraft. The public demand of UAVs is increasing, and the aircrafts are becoming more specialize on specific tasks as photography, transportation or entertainment. Each task requires specialized mechanical and electrical design however the same control system structure can be found in almost all the UAVs commercially available no matter their task. This paper focuses on this specific algorithm, the PID controller. [1]

Commercial application

There are countless commercial applications for multirotor aircraft, this paper focuses on three examples and the characteristics and requirements for their respective control systems.

Amazon Prime Air [2]

Amazon has a patent on autonomous mass air delivery. [3] The key factor on this business is the reliability, the company needs a robust system more than a fast or high-performance system.

Verity Studios [4]

Verity is a start-up born from researchers on ETH Zurich. This company creates live shows using a swarm of quadrotors with choreographed acrobatics and formations. The control system on these aircrafts is completely performance oriented.

DJI Phantom 4 [5]

DJI is one of the most successful drone company with the Phantom 4 as their current most sold quadrotor. These aircrafts focus on outdoor photography and sports tracking which translate on a balanced control system, robust to be capable of sustaining gusts of wind and fast to follow sports like mountain bike.

Underlying technology

There are two parts to the control system of a multirotor Aircraft, building a mathematical model of your aircraft and building a controller. The mathematical model is a set of equations that determine the response of the system to given inputs and disturbances. The model relies heavily on the geometry of the craft and therefore is unique to it. However, the same set of equations, namely Euler-Newton equation, apply to them no matter the number of rotors or their distribution, so a general model can be derived with parameters

specific to each aircraft. [6] The second part is the controller; the system is given a reference input such a position or orientation and the controller acts on its coordinates to match the reference values. The controller receives an error signal which is the difference between the references and the variables, with this information it delivers an input signal to the system which affect the variables and the error is recalculated. Specifically for a multirotor aircraft, a position is sent, the controller delivers a signal to the motors to move the craft which is calculated from the distance to the target. The proportional, integrative and derivative controller or PID calculates the thrust signal with three coefficients multiplied to the error, its integral and its derivative over time. [7] These coefficients are unique to the system and to the response that the system requires.

Implementation

The implementation of the control software starts with creating the mathematical model as described before. However, the model is never completely accurate and external factors which are not included on the model can affect the system. These differences are accounted as disturbances. The tuning of the three parameters on the PID is a compromise between fast and robust control. [8]

References

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