Stabilization of a Quadcopter

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***Abstract*—Abstract goes here.**

I. Introduction

- Present topic - uses of drones in reality context, chosen because it is a control challenge, rather than revolutionary. In the last years, the interest for quadcopters has increased due to the great possibilities they offer. Among these possibilities, the most well-known ones are surveillance, inspection of big structures and search and rescue missions in difficult environments **SOURCE WEB**.
  The quadcopter constitutes a control challenge due to its naturally unstable and coupled behavior. The system has 6 degrees of freedom, the three position coordinates and the 3 orientations, and there are only four actuation variables which are the motor velocities. The dimension of the problem is explained by McKerrow in **SOURCE**.
- Previous Approaches - examples of what others have done to obtain similar goals of stabilization like we pursue. What have others done differently than we plan to do to obtain the same end result.
  The control of a quadcopter has been addressed many times in the recent years. In Mian et al. **SOURCE** the quadcopter is controlled using a back-stepping technique and non-linear controllers. Other way of solving the issue is presented in Tayebi et al. **SOURCE** in which the quadcopter attitude is modeled using quaternions and controlled with a PD based controller. In **SOURCE**, Mian and Yang model the system using its dynamic equations and use non linear controllers to achieve a steady flight while in Mokhtari et al. **SOURCE** the system is controlled by a mixture of a robust feedback linearization and a linear GH_∞ is utilized.
- Describe our approach shortly.
  The approach presented models the quadcopter by a first principles method. This approach yields a non linear model that describes the attitude and translational behavior of the quadcopter. The model is then linearized around an equilibrium point, which is chosen to be in hovering position. With the linearized equations, controllers for attitude and translational behaviors are designed. The angular controller is obtained by means of a State Space representation while the translational controller is designed using classical control techniques. In the control system, the translational constitutes an outer loop and sets the reference for the attitude controller.
- Describe our approach shortly.
  First, the modeling and controlled approaches are described in more detail. Then, the results are displayed and discussed to finally state the conclusion. **notveryhappywiththissentence**

II. Method

INTRO FOR MODEL

A. Model

- Model - Drawing, equations, linear equations. The quadcopter system is shown in Figure 1. As it can bee seen, the system is modeled by using two coordinate frames. The inertial frame is used to describe the translational movement while the body frame is attached to the quadcopter and applied to characterize its attitude behavior. In the figure, also the positive references for rotational and translational movements are depicted, as well as the main forces and torques acting on the quadcopter.

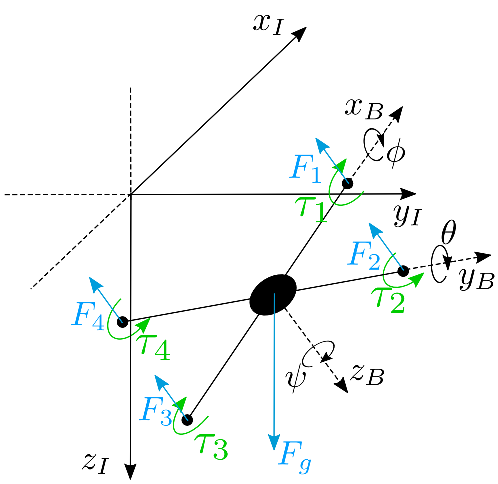

Figure 1: Quadcopter diagram showing the forces acting on the system and the positive references chosen for rotations and translations in both Inertial and Body coordinate frames.

In order to represent the different forces generated in the drone in the Inertial frame a rotation matrix is used. It is built considering a 321 or 123 rotation sequence. **SOURCE ROTATION MATRIX**

1) Motor and Propeller: The four motors in the quadcopter generate the rotation required so the propeller creates the force that lifts the quadcopter. This force is called thrust force and can be modeled as proportional to the square of the motor rotational velocity. MAYBE SOURCE. The coefficient for this equation is called thrust coefficient and has been found by experiments. The rotation of the propellers also generates a torque on each motor due to drag between air and propeller. Drag torque is compensated in the quadcopter by having two of the motors turning in one direction and the two others in the opposite. It can also be described as proportional to the square of the velocity by terms of a drag coefficient that has also been obtained through tests. Equation 1 and 2 show the expression for the thrust force and drag torque caused by the rotation of the propeller.

$$F = k_{th}\omega^2 \tag{1}$$

$$\tau = k_d\omega^2 \tag{2}$$

2) Attitude Model: The attitude model equations are based on Newton Second Law for rotational movement and are represented in Equation 3, 4 and 5.

$$J_x \cdot \ddot{\phi} = k_{th} \cdot (\omega_4^2 - \omega_2^2) \cdot L \tag{3}$$

$$J_y \cdot \ddot{\theta} = k_{th} \cdot (\omega_1^2 - \omega_3^2) \cdot L \tag{4}$$

$$J_z \cdot \ddot{\psi} = k_d \cdot (\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2) \tag{5}$$

The expressions above state how the thrust force difference between motors 1 and 3 affects the roll angular acceleration, how that between motors 4 and 2 affects the pitch angle and how the yaw acceleration depends on the four motors by means of the drag torque generated on the propeller.

3) Translational Model: The equations describing the response of the system along the x, y and z axes is derived from Newton's Second Law. The forces that act on the system are those from the propellers and gravity. These expressions are shown in Equation 6, 7 and 8. FIX EQUATIONS

$$\mathrm{m} \cdot \ddot{\mathrm{x}}_\mathrm{I} = -\mathrm{k_{th}} \cdot ({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \cdot \sin(\theta) \tag{6}$$

$$\mathrm{m} \cdot \ddot{\mathrm{y}}_\mathrm{I} = -\mathrm{k_{th}} \cdot ({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \cdot (-\sin(\phi)) \cdot \cos(\theta) \tag{7}$$

$$\mathrm{m} \cdot \ddot{\mathrm{z}}_\mathrm{I} = \mathrm{F_g} - \mathrm{k_{th}} \cdot ({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \cdot \cos(\phi) \cdot \cos(\theta) \tag{8}$$

B. Control

- Controller - Diagram of controller.
- Angle controller - include observer, linear controller.
- Network effect on the system - Analysis of delay in the system.

III. Results

Simulation vs. reality.
Comment on the results and how that correlates with reality, without discussing possible issues or improvements.

IV. Discussion

Discussing possible issues or improvements of the above results.

V. Conclusion

Summary - what we want the reader to remember.

Acknowledgment

Henrik XXXXX, associated professor at Aalborg University
Christoffer Sloth, associated professor at Aalborg University