AALBORG UNIVERSITY
STUDENT REPORT

ED5-3-E16

XXX

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STUDENT REPORT

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Contents

Preface

The project entitled *xxx* was made by two students from the Electronics and Computer Engineering programme at Aalborg University Esbjerg, for the P5 project during the fifth semester.

From hereby on, every mention of 'we' refers to the two co-authors listed below.

Aalborg University, November 2, 2016.

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Chapter 1

Introduction

1.1 Introduction

The theme of this semester's project lies within *Automation*. Automation can be simply described as being the use of diverse control systems for fulfilling a certain task with little to no human interaction. As known from the previous semester, a control system is an instrument which has the role of adapting the behaviour of a system according to a desired state, also knows as steady-steady or reference. Any control system has three components: measurement, control and actuation. Without one of these, automation would not be possible. Essentially, the measure reflects the current state of the system, the controller is the brain that given the measurement decides which action will be performed and the actuator is the one executing the action.

Project ideas around the topic of automation are unlimited, since it is so widely spread. Having discussed a few of them that would meet the semester's requirements, we finally decided to work on the control of a quadcopter. Our decision was for the most part based on the fact that the university had the required equipment available, which enabled us to start working on the project right-away.

Quadcopters are popularly referred to as drones and they have increased their areas of operation from the military sector to more commercial uses such as search and rescue/healthcare, geographic mapping, aerial photography, surveillance etc. Our goal for the project is to design a control system that makes it possible for the quadcopter to be stable - hovering and to also act according to the user's input - manouvering. Basically, our input will be a certain height and the quadcopter has to automatically adjust to that height and mentain its' stability when no further inputs are given. A safety feature - obstacle aviodance will also be implemented.

Chapter 2

Problem Description

This chapter will present how our scopes - hovering and manouvering can be achieved by designing and implementing a control system. A solution will be identified by analyzing which control system component can be represened by which piece of technical equipment. We will also explain the basic working principle of a quadcopter - flight dynamics.

2.1 Physical Setup

motors

speedcontrollers

ardupilot - features: barometer, compass

control approach diagram + explain role of each

infrared sensors

2.2 Flight Dynamics

Before we begin doing any work, it is important to understand how quadcopter works. A quadcopter, as the name suggest, runs on four motors usually placed at equal distances from each other (figure here)

By controlling the speed at which the motors rotate, it is possible to change how quadcopter moves. Movement can be broken down in 3 separate sets of motor speeds:

1) If the two back motors rotate faster than the two frontal motors, the quadcopter will pitch forward. Switching the speeds will result in aft pitch. 2) If the two left motors have higher RPM than the two motors on the right side, the vehicle will roll to the right. Swapping the speeds differences will result in a roll to the left. 3)

Increasing the speed of one of the diagonal pair of the motors will result in yaw to the direction of the torque of the motors. The copter will then spin around its axis.

Now that the effect of speed of the motors is established, it is important to talk about the forces in play. There are 4 main forces affecting quadcopter - thrust, lift, draw and drop (figure again)

The drop - or the gravitational force - affects the vehicle at all times. As any object on Earth, its mass is driven towards the centre of the planet.

The thrust is the force generated by the motors that is allowing the vehicle to move horizontally.

The lift force is also generated by the motors and allows the vehicle to move up.

Draw force - ???

A powered off motors is only affected by the drop force and therefore stays on the ground. In order to lift it up, we need to understand the relationship between quadcopter and the thrust to weight ratio - or TWR for short. This ratio can be determined by equation Ft/Fg and describes the vehicle's ability to move up. With TWR expressed as a number, three cases can be identified: 1) TWR $<$ 1: The gravitational force is higher than the lift force and therefore the quadcopter is drawn towards the ground. 2) TWR = 1: The forces are equal, causing quadcopter's altitude to stay constant. 3) TWR $>$ 1: The thrust is higher than drop force, allowing vehicle to move upwards.

Therefore, in order to get a quadcopter up in the air, it is necessary to generate enough thrust for TWR ration to be higher than one. In order to land it, the TWR must be smaller than 1, allowing the quadcopter to move downwards.

Chapter 3

Physical Setup

xxx

3.1 Motors

3.2 Ardupilot

3.3 Infrared sensors

3.4 Electronic Speed Controllers

ESCs - which stand for Electronic Speed Controllers - are electronic circuits widely used remotely controlled vehicles. Their main purpose is to vary the motor's speed and direction.
In multicopters, they are a vital part for a successful airborne vehicle. Because multirotors rely on fast reaction and performance of motors, a device that is able to supply high frequency, power and resolution

Chapter 4

Mathematical Modelling

In this chapter we will take a look at mathematical models that describe our quadcopter system. To begin with, we can identify an equation that describes torque generated by a motor:

$$Q = K_q I \tag{4.1}$$

Here, Q stands for torque, I - current and Kq - motor constant, relating current to the torque. (ref) Another equation can be identified as:

$$V = R_a I + K_e \omega \tag{4.2}$$

where V is the voltage, R_a is the motors armature resistance, K_e is the back EMF constant and ω is motor's angular rate. (ref)

We can then convert voltage into power in a steady state to get the following equation:

$$P = IV = \frac{Q}{K_q} V \tag{4.3}$$

P - power, which can be related to thrust by equating the power produced by the motors to the ideal power required to generate thrust by increasing the momentum of a column of air. (fix this) This ideal power P_h, when hovering, can be found using the following equation:

$$P_h = T \upsilon_h \tag{4.4}$$

Here, T - thrust force and υ_h is the induced velocity when hovering. This velocity is the change in air speed which is induced by the motor blades with respect to the free stream velocity. However, to simplify the model and to reflect our testing conditions, this free stream velocity is set to zero due to lack of wind force. Using momentum theory, we can identify another equation: (ref)

$$\upsilon_h = \sqrt{\frac{T}{2\rho A}} \tag{4.5}$$

where ρ - air density and A is the area covered by the blade. This area is equal to π multiplied by R^2, which is the radius of the blade.

Since the torque is proportional to the thrust force generated by the motor with a constant ratio K_t, which depends on blade geometry (ref), we can find the relation between the applied voltage and the thrust by combining equations 4.4 and 4.5:

$$\frac{Q}{K_q}V = \frac{K_t T}{K_q}V = \frac{T^{\frac{3}{2}}}{\sqrt{2\rho A}} \tag{4.6}$$

We then get the following equation:

$$T = \frac{2\rho A K_t^2}{K_q^2}V^2 \tag{4.7}$$

Chapter 5

Experiments

Chapter 6

Discussion

Chapter 7

Conclusion

Chapter 8

Appendix

8.1 Appendix code