FUZZY LOGIC BASED PID CONTROL OF QUADCOPTER ALTITUDE AND ATTITUDE STABILIZATION

MOHAMMED AHMED MOHAMMED MANSOUR

UNIVERSITI TEKNOLOGI MALAYSIA

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MOHAMMED AHMED MOHAMMED MANSOUR

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This project report is dedicated to:

To my beloved mother Sayda EL-Emam and my father Ahmed Othman for their unconditional love and unlimited support,

My brother Ali, my sisters, my cousin El-Emam and My supervisor Dr. Mohd Ariffanan Mohd Basri for fully support from beginning till the end.

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ABSTRACT

This paper presents the development and implementation fuzzy logic based PID control algorithm for a quadcopter system. The quadcopter consists four motors with four propellers placed on the ends. The rotors are directed upwards and they are placed in a square formation with equal distance from the center of mass of the quadcopter. Four different scenarios are presented: altitude movement, pitch, roll and yaw angle. For the all cases 6-DOF model is derived and used. The quadcopter can be perceived as a challenging control problem due to its high nonlinearity, even with four motors it is underactuated and cannot move translative without rotating about one of its axes. The main objective of the controller is to propose a suitable solution for the problem associated with the control of quadcopter. A fuzzy controller was designed according to the process characteristics. The simulation results were carried out in MATLAB/SIMULINK. The corresponding figures and simulation results are presented. The performance of suggested fuzzy controllers is discussed and analysed. Comparing the performance of the proportional and derivative (PD) controller tuned by Zeiger-Nichols method and proportional, integral and derivative (PID) tuned by partial swarm optimization (PSO) results depict that fuzzy logic based PID controller give a better performance in terms of transient responses, steady state responses and overshoot error.

ABSTRAK

Makalah ini membentangkan pembangunan dan pelaksanaan algoritma kawalan PID berasaskan logik kabur untuk sistem quadcopter. Quadcopter ini dilengkapi empat motor dan empat baling-baling. Rotor diarahkan ke atas dan diletakkan dalam bentuk segi empat sama dengan jarak yang sama dari pusat jisim quadcopter tersebut. Empat senario yang berbeza ditunjukan: perubahan altitud, penjunaman, pengulingan dan perewangan. 6-DOF diperoleh dan digunakan untuk semua senario. Kawalan Quadcopter ini boleh dianggap sebagai masalah kawalan yang mencabar kerana ketidaksamaan linear yang tinggi, walaupun dilengkapi empat motor ia masih tidak mencukupi dan ia tidak boleh bergerak secara translatif tanpa berputar pada salah satu paksinya. Tujuan utama pengawal adalah untuk menyelesaikan masalah yang berkaitan dengan pengendalian quadcopter. Pengawal logik kabur direka mengikut ciri-ciri proses. Simulasi dijalankan mengunakan aplikasi MATLAB / SIMULINK. Keputusan simulasi berserta rajah yang berkaitan dibentangkan. Prestasi pengawal logik kabur yang dicadangkan dibincangkan dan dianalisis. Prestasi pengawal berkadar dan terbitan (PD) yang ditala mengunakan kaedah Zeiger-Nichols dan pengawal berkadar, kamilan dan terbitan (PID) yang ditala mengunakan particle swarm optimization (PSO) menunjukan bahawa pengawal PID berdasarkan logik kabur munpunyai prestasi yang lebih baik dari segi sambutan fana, tindak balas keadaan mantap dan ralat lajak.

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LIST OF ABBREVIATION

PID	-	Proportional Integral Derivatives
FLC	-	Fuzzy Logic Controller
UAV	-	Unmanned Air Vehicle
DOF	-	Degree of Freedom
PWM	-	Pulse Width Modulation
IMU	-	Inertial Measurement Unit
PSO	-	Partial swarm optimization

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CHAPTER 1

INTRODUCTION

1.1 Background of the Problem

In these last years, a growing interest has been shown in robotics. In fact, several industries (automotive, medical, manufacturing and space) require robots to replace men in dangerous, boring or onerous situations. Unmanned Aerial Vehicles has attracted a great amount of attention among scientists over the last decades, due to, the widespread area of applications, e.g. near-area surveillance, crop dusting firefighting, exploration both in military and commercial in- and outdoor applications, and so on. Helicopter design has been the center of attention since the beginning of the 20th century. First full-scale four rotor helicopter (quadrotor) was built by Debothezat in 1921 [1].

A quadcopter is a four-rotor helicopter. It has four arms that are attached to the main body and on each arm, there is a motor with a rotor. For the quadcopter in this thesis the motors are actuated by an electronic speed controller (ESC). The ESCs are controlled by the control board, which is the brains and main component of the aerial vehicle, see Fig. 1.1[2]. Quadcopters possess features that make them ideal candidates for autonomous flight because they are much simpler than traditional helicopters due to the elimination of the swashplate and the tail rotor [3]. The quadrotor has the advantages in easy mechanical construction against the traditional helicopter, but there are still issues that prevent it from being widely used in many of the suggested fields and applications. For example, the stabilizing control and guidance of the quadrotor is a difficult task because of the nonlinear dynamic behavior. [1] The studies in quadrotor modeling and control have been increased rapidly recently. A number of examples of these studies can be summarized as following; Altuğ et al. modeled a quadrotor using Euler-Newton method and worked on vision-based stabilization and output tracking control [4]. Suter et al. also studied on image based visual servo control for quadrotors [5]. The model of the system taken referring to [1]. The system consists of six state variables, namely Roll angle, pitch angle, yaw angle, attitude and position. Two tachometers are coupled to the DC motors to measure the other additional velocities of the rotors. Many control techniques have been investigated to study the performance of the Quadcopter system. The aim of designing controllers is to improve the performance indices (settling time, overshoot, rise time, etc.) and to make the Quadcopter track more quickly and accurately to the desired position.

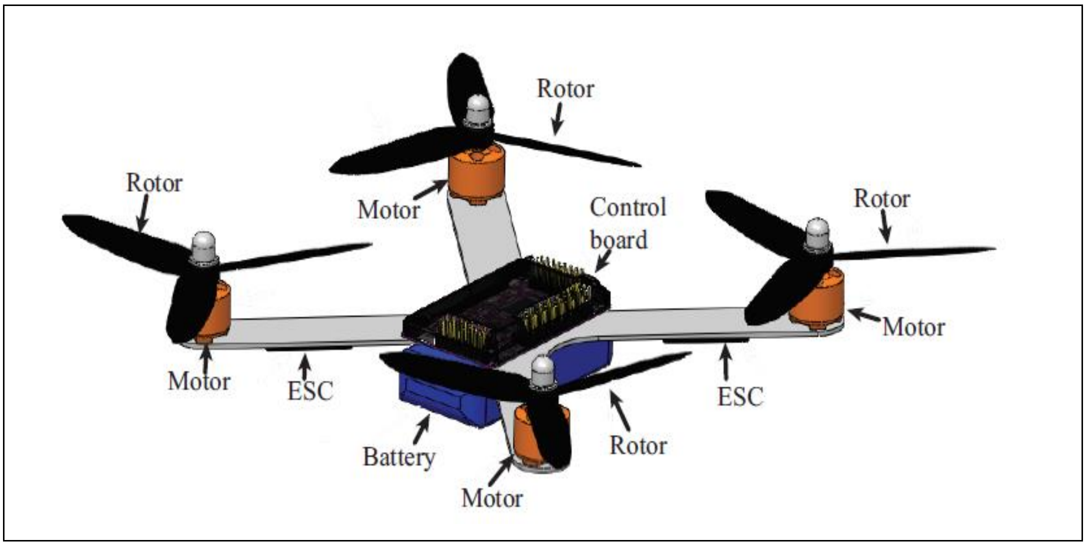

Figure 1.1: The simplest version of a quadcopter with all of the necessary components for flight.

1.2 Statement of the Problem

The control of aerodynamic systems, such as Quadcopter, has become one of the most challenging engineering problems due to nonlinearities and significant cross-coupling between its parameters. The quadcopter is naturally unstable, has a complex dynamic model and six degrees of freedom. Even with four motors it is underactuated and cannot move translative without rotating about one of its axes. This project aims to propose a suitable solution for the problem associated with the control of quadcopter.

1.3 Objectives of the Study

The objectives for this research are stated as follows:

i. To obtain the mathematical model of Quadcopter system.
ii. To design PD & PID controller and a Fuzzy system that adjusts the PID controller.
iii. To compare the performance of PD, PID controller and Fuzzy PID controller.

1.4 Scope of the Study

The scope of the research work is listed as below:

i. The Quadcopter is four-inputs four-outputs system where the inputs are the rotor's speed and the output are the Throttle, Roll, Pitch and Yaw movement.

ii. MATLAB software is used to implement the controllers to test their performance.
iii. PID controller will be a reference for testing the designed controllers.
iv. The specifications of the real Quadcopter in UTM - Control lab is going to be used.

1.5 Report Outline

This report consists of five chapters. Chapter 1 is an introduction of the research project. It covers the background of the research project, problem statement, objectives of the research, and scope of the research. Chapter 2 is a literature review. It contains the PID controller and Fuzzy Logic Controller. It also provides the background theories of previous works concerning on the Quadcopter and the sensors and component for hardware implementation. Chapter 3 is a research methodology that consists of the modeling of the system and flow chart. Chapter 4 shows the preliminary results and also the expected result for this research. The last chapter which is Chapter 5 will show the conclusion and Gantt chart.

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