Development of Automatic Take Off and Smooth Landing Control System for Quadrotor UAV

Syed. F. Ahmed
Universiti Kuala Lumpur, British Malaysian Institute, Malaysia
Center of Excellence for Unmanned Aerial Systems (CoEUAS)
Universiti Malaysia Perlis, Malaysia

D. Hazry
Center of Excellence for Unmanned Aerial Systems (CoEUAS), Universiti Malaysia Perlis, Malaysia

Kushsairy Kadir
University Kuala Lumpur, British Malaysian Institute, Malaysia

Abadal Salam T. Hussain, Zuradzman M. Razlan, Shahriman AB
Center of Excellence for Unmanned Aerial Systems (CoEUAS), Universiti Malaysia Perlis, Malaysia
E-mail: hazry@unimap.edu.my
www.unimap.edu.my

Abstract

This paper covers the development of automatic takeoff and smooth landing control system for UAV Quadrotor. This paper includes development, simulation, mathematical modeling and experimental results of flight test. Developed UAV model has a system to stabilize the quadrotor. Altitude stabilization in quadrotor make the quadrotor can perform take off and smooth landing perfectly and can avoid crash during landing which was proved during experiment. Yaw, pitch, and roll in quadrotor body is detected by gyro sensor when flying is balanced by gyro sensor. Gyro sensor act as input that detect stabilization problem and input data will be sent to microcontroller to make new output for quadrotor.

Keywords: UAV, Quadrotor

1. Introduction

The Quadrotor is one of the Unmanned Aerial Vehicle (UAV) that use four propeller for flying. They are four unit of brushless DC motor that mount at each of end quadrotor structure (M. Kamran Joyo, 2013). Flying object needs to take off and landing safely. Therefore the development of automatic takeoff and smooth landing system is very crucial for safety system in Quadrotor. The advantages of this system are totally eliminate the use of the pilot to airborne the UAV and it is more secure and reliable for autonomous flight. Quadrotor is very useful in many applications for example in monitoring, surveillance, search & rescue, agriculture and military. Quadrotor also suitable to use at the place that human cannot enter for example danger zone. Uses of quadrotor at this case can save the people life from danger. We can deploy quadrotor for monitoring hazardous zone such as power plant and radioactive leakage area. Installment of automatic takeoff and smooth landing system can make new user easily to handle quadrotor and can avoid air crash (Tanveer, 2013). The knowledge in kinematics and dynamics is very important and useful for understanding the physics and characteristic of quadrotor. Quadrotor attitude and height from bodies to ground can be measured by using two type of sensor. Inertial measurement unit (IMU) is a main part that be used while to predict distance ultrasonic sensor and infrared sensor are used. Micro control unit is a part that handled data processing and control algorithms and generate signal to four brushless DC motor that was mounted at the structure.

2. Objective, Scope and Problem Statement

The flying quadrotor is not easy to take off and landing for new user because quadrotor tends to easily crash when the user controlled it recklessly and strong wind when flying outdoor. The development of automatic takeoff and landing will solve this problem when the system detect emergency or receive the automatic landing command and this will save the quadrotor from crash. When to deploy the quadrotor without automatic command, the user will be difficult to predict the lift force of quadrotor and this will consume more power of battery. The development of automatic takeoff will help new user to solve this problem. Another problem in this project is to make quadrotor maintain its stability in air. The uses of gyroscope in quadrotor will help the quadrotor microcontroller accept four output roll, pitch, yaw and throttle. This input will be process by microcontroller and generate new output for quadrotor to change the speed of quadrotor to make it stable.

3. Literature Review

In 1920 - 1930 quadrotor is already has been design and build at that time but the quadrotor is handle by a man. The quadrotor build at that time is bad performance, lack of stability and very large shape and heavy. People cannot make it unmanned at that time because there a no microcontroller, sensor and electronic control system. Nowadays many of the microcontrollers developed by manufacturer for example: Arduino, PIC18 microchip and basic stamp. All of this microcontroller can be used for making the electronic control system of quadrotor to make it unmanned.

4. Methodology

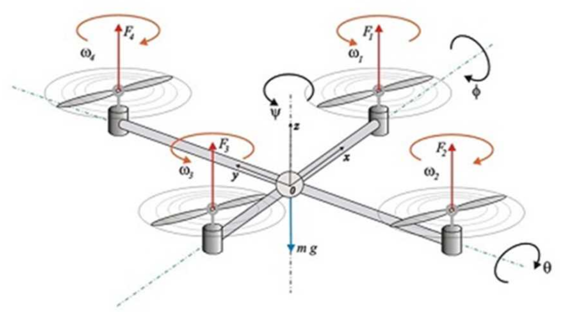

Fig. 1. Direction of propeller and free body diagram

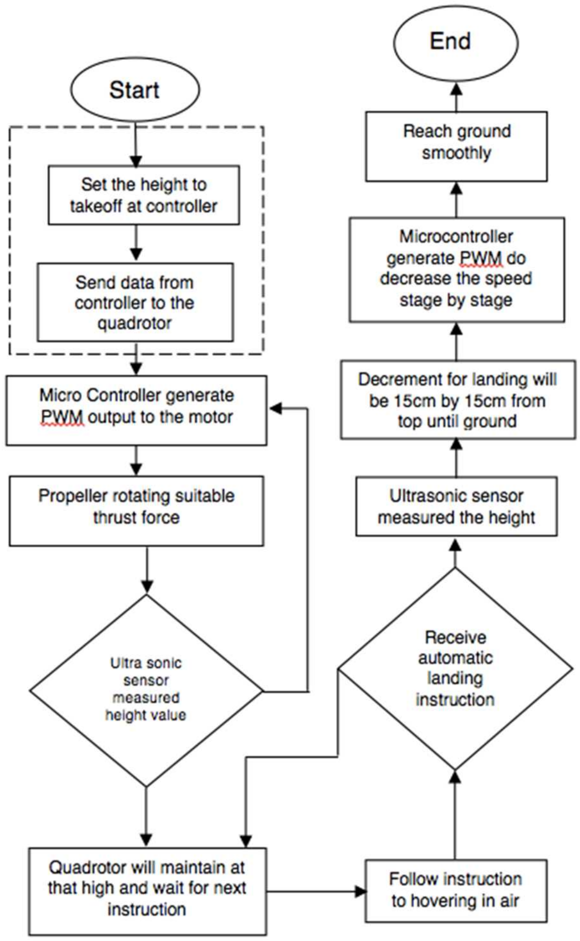

Fig. 2. Flow Chart of the works

In quadrotor front and back propeller must rotate anti-clockwise and right and left propeller must rotate clockwise as shown in Fig. 1. to eliminate torque produced by the motor (Tanveer, 2014). By have a correct orientation of propeller we can hover the quadrotor.

X, Y and Z represent the fixed body frame of quadrotor. The blue arrow is a weight of quadrotor W = mg. The red arrow in Fig. 1. show the angular speed of quadrotor. Ψ is for yaw angle, ϕ is for pitch angle and Θ is for roll angle (Warsi, 2014)(Joyo, 2014).

5. Quadrotor Control System

Closed loop control system is important during takeoff and landing of a quadrotor. Control system is important in the systems that need accuracy. Accurate value of PWM will make quadrotor fly at actual output that already set by the user. This closed loop control system is also can be used to perform smooth landing. When automatic landing button is pressed, the quadrotor will decrease the motor speed due to height level that read by ultrasonic sensor.

6. Results & Analysis

Table 1. Total mass of quadrotor

Part	Quantity	Mass(g)
Propeller	4	40
Receiver	1	12
Brushless DC motor	4	140
Electronic speed controllers	4	80
Quadrotor structure	1	500
Screw, nuts	20	80
Wiring	1.5 meter	38
Arduino board	1	30
	TOTAL	**920**

6.1 *Analysis of Quadrotor Thrust Force*

The average mass of quadrotor is 920 grams. Therefore, we need thrust force equal to quadrotor mass to lift up quadrotor. By using static thrust equation, we can estimate analytical data to make the quadrotor mass equal to thrust force. Firstly we need to find at what rpm the mass of quadrotor is equal to the thrust. Thrust must be multiply by four because quadrotor has four propellers.

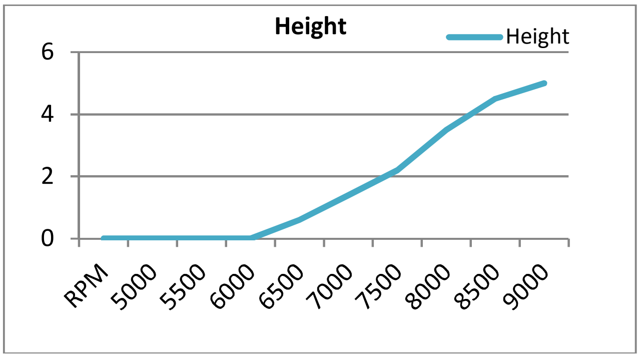

Fig. 3. Automatic takeoff graph

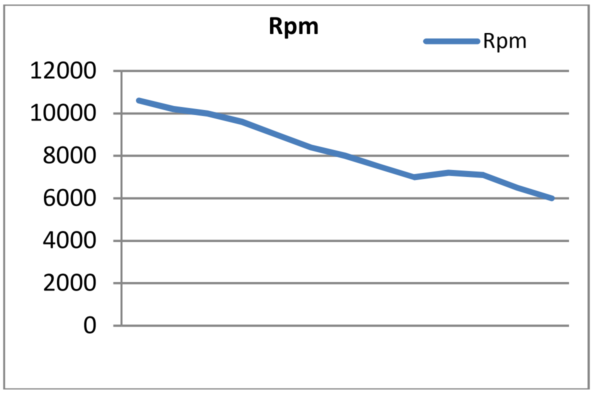

Fig. 4. Automatic smooth landing graph

6.4 *Roll, Pitch and Yaw Error*

Analysis of roll error

Performance of roll stabilization error of roll angle when quadrotor is in static condition is less than one degree. The data taken in this experiment is in 10 second. The red line is in figure below show the good stability without error that we need. The blue wave is the gyro detection in change of roll during static fly and the black wave is error of roll during static fly (M. Kamran Joyo, 2013)

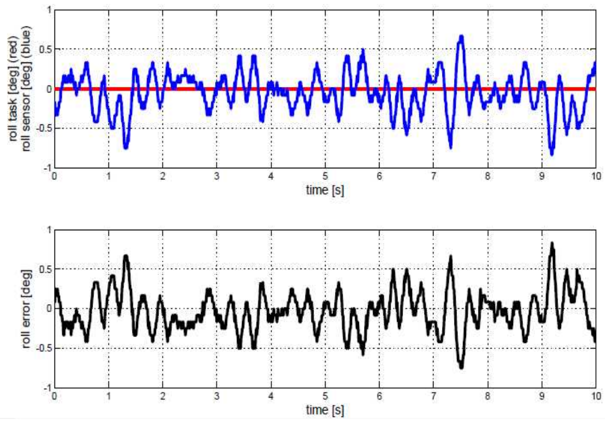

Fig. 5. Error of Roll

Analysis of pitch error

Figure below shows the performance of pitch stabilization pitch angle also less than 1 degree. The data taken in this experiment is in 10 second. The red line is in figure below show the good stability without error that we need. The blue wave is the gyro detection in change of pitch during static fly and the black wave is error of pitch during static fly.

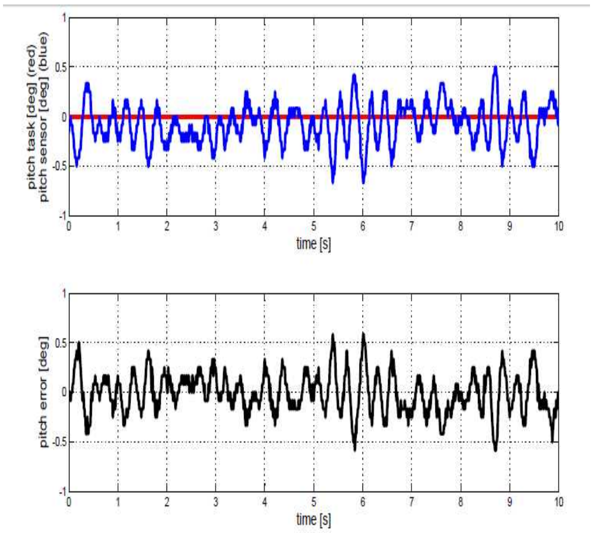

Fig. 7. Error of pitch

Error of pitch and roll must be low to make a good stabilization and the longitudinal acceleration condition. The movement of pitch and roll almost same but the different is in a different axis. Will occur if one of these two angles was different than zero degree during static.

Analysis of yaw error

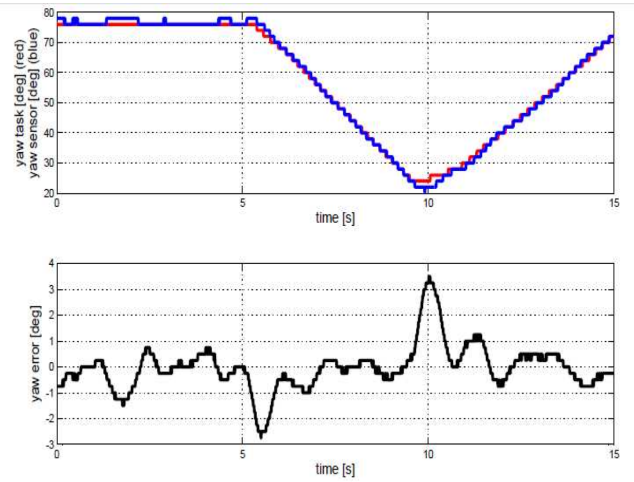

Figure below show the performance of yaw stabilization. Longitudinal acceleration does not effected by error of yaw during static condition. The change of yaw angle of quadrotor can be -90˚, 90˚, -180˚, 180˚and high than that.

Fig. 8. Error of yaw

Error of yaw in figure above during static is less than 2 degree while when turning to another direction the yaw error become high that 2 degree and less than 4 degree.

7. Conclusion

Development of automatic takeoff and landing that move along Z-axis is look like a simple task but its require many concept such as thrust study, control system, sensor interface, stability study, PWM, and Newton second law of motion. In this paper shows the first step of development quadrotor starting from the body structure.

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