Robotics Studio 4: Quadrotor three – Proposal

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I. Introduction

The quadrotor is a 4-rotor Unmanned Aerial Vehicle (UAV), which contains of four rigidly attached rotors on the vehicle. Due to its unique rotor's configuration, a control scheme for quadrotor can be synthesized to maneuver with four degrees of freedom. This maneuverability helps users accomplishing desired tasks in dangerous or inaccessible environment. To gain better understanding of control scheme and its application, our team proposes a project on simulating the physics and behavior of the quadrotor.

The scope of this project consists of the following:

1. The entire system will be developed only in computer-simulated environment.
2. The goal of the quadrotor is to vary its altitude and yaw angle, while maintaining minimum change in lateral position.
3. The input from the user interface is the desired attitude of the quadrotor.
4. The control scheme provides 3-dimentional resultant torque and force along the rotational axis of the quadrotor.
5. All physical parameters of the quadrotor are constant and known.
6. At least two sensor types are equipped on the quadrotor: 6-axis IMU (3-axis accelerometer; and 3-axis gyroscope) and range sensor.
7. The simulation result is visualized as the movement in a 3D plane; graphs of position signal and rotation signal are plotted against time.

III. Working of Individual System

2.1 Quadrotor Model

To understand the physics of the quadrotor and its behavior, dynamics and kinematics knowledge are applied. The study of dynamics in FRA131 (Basic Mechanics for Robotics and Automation Engineering) allows us to understand the fundamental dynamics behavior of the quadrotor. However, involving with the various coordinate frames, the modeling process can also be facilitated using 3D kinematics from FRA333 (Kinematics for Robotics System). The insight from both courses helps us constructing a proper mathematics model in a form of differential equations. The derived abstract model is then transformed into a state-space representation, which we learned from FRA231 (Robotics Modeling and Experimentation).

2.2 Control System

The selected quadrotor consists of four propellers in a cross configuration. Each pair rotates in the opposite direction as in figure [1]. This configuration will allow quadrotor to rotate around z-axis. Considering the relationship between propellers' speed and the quadrotor behavior, the quadrotor will hover, when all propellers rotate the same speed. Otherwise, it will have either lateral or rotational movement.

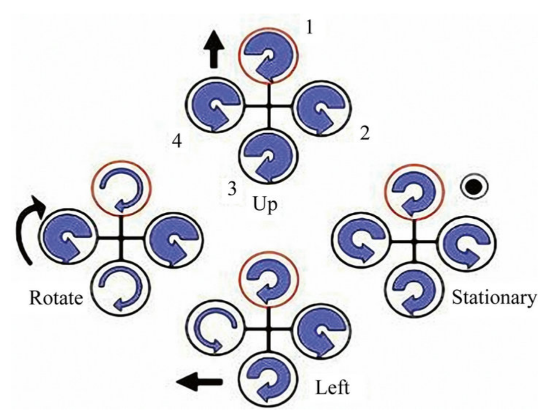

Figure 2.1: results of adjusting each propeller' speed [1]

The controlling system of the quadrotor composes of 3 subsystems: attitude control, altitude control, and lateral flight control[3]. In attitude control, the desired orientation will be described in Euler's angles. However, the desired pitch and roll angles are given by lateral flight control, which tries to maintain the minimum lateral movement. The altitude control will be used to hover a quadrotor to the desired position [3].

There are many control schemes to reach the quadrotor goal. Regarding to [1]Bolandi, Rezaei, Mohsenipour, Nemati, and Smailzadeh' s research, the pose of quadrotor can be controlled by independently varying four rotors' speeds. However, this control scheme can't be applied to attitude and lateral flight control—possible to hovering control only.

According to [2]Bresciani's study, the quadrotor pose can be controlled through thrust (the movement along the z-axis), roll (the rotation about the x-axis), pitch (the rotation about the y-axis), and yaw (the rotation about the z-axis). The result of controlling these four variables indirectly adjust each propeller's speed. Regarding to Bresciani's control scheme, the quadrotor dynamics model is calculated in the quadrotor's body frame, while the desired pose is inputted in global frame. This results in complicated dynamics equation. To simplify Bresciani's control scheme, we decided to construct quadrotor's model in body frame and define state-space representation in global frame.

- *Control Policy*

  Due to the uncertainty that may occur in the flight, a PID controller is applied to the system. For tuning parameters, we will tune PID's parameters based on the lesson in FRA233 (Control Engineering for Robotics).

2.3 Sensor Modeling and state Estimator

To create the closed-loop system, sensor models are added. In the real physical system, many uncertainties occur, such as model error and disturbance of surroundings. Therefore, the state estimation is required [3].

2.3.1 Inertia Measurement Unit (IMU)

In this report, IMU consists of a 3-axis gyroscope and 3-axis accelerometer for controlling orientation and translation of the quadrotor. According to [5]Koksal, Jalamaab, and Fidan's research, the IMU model requires precise estimation to send reliable feedback to the control system. Therefore, the Kalman filter is equipped on the system because of its well performance in noise reduction [5].

2.3.2 Range Sensor

In this report, the range sensor is ultrasonic for measuring flight height. Similarly, with IMU, the range sensor requires estimation [6].

IV. Testing and Visualization

The unwanted signal, noise, is added to both sensors to test the accuracy of the estimator. Meanwhile, air resistance is also added to the system to test the PID controller. The signal graphs are plotted via MATLAB to visualize the result.

V. Further Development

If the works run well as planned, we will develop visualization or/and add optimal sensors into the system. To make a better visualization, we will apply the simulated quadrotor to a virtual world.

References

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Table 1: Action plan

	TASK	Description	RESPONSIBLE	START	FINISH
1	Plannning and Listing all tasks		everyone	24/Aug/21	30/Aug/21
2	Modelling				
	Controller's Model	Altitude Control	Pakapak	31/Aug/21	7/Sep/21
		Attitude Control			
		Lateral Control			
	Dynamic Model	Motion		8/Sep/21	14/Sep/21
	Integrate Modelling			15/Sep/21	21/Sep/21
3	Estimation				
	Range Sensor	State Estimation	Tanach&Nattasit	31/Aug/21	7/Sep/21
	IMU Sensor	State Estimation		8/Sep/21	14/Sep/21
	Integral estimation of IMU and Range sensor			15/Sep/21	21/Sep/21
	Kalman filter	Do kalman filter of state estimation of IMU and Range sensor			25/Sep/21
4	Simulation and Visualization				
	Do Plant		Tanach&Nattasit	22/Sep/21	28/Sep/21
	Controller	PID Tuning			
	3D-plot graph			29/Sep/21	5/Oct/21
5	Futher Develop	Develop Visualization/ Adding sensor	everyone	6/Oct/21	19/Oct/21
6	Presentation				
	Rechecking		everyone	20/Oct/21	26/Oct/21
	Wrting report and Do presentation			27/Oct/21	24/Nov/21
	Proposal Presentation			9/Sep/21	9/Sep/21
	Progress Presentation			11/Oct/21	11/Oct/21
	Final Presentation			25/Nov/21	25/Nov/21