Robotics Studio 4: Quadrotor three – Proposal

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**I. Introduction**

The quadrotor is a 4-rotor Unmanned Aerial Vehicle (UAV), which contains the maneuvering ability of traditional helicopters with lower mechanical complexity [1]. Because of the maneuvering ability, the quadrotor becomes a tool helping users completing desired tasks in a dangerous or inaccessible environment. Furthermore, the quadrotor is usually used [1] in research of developing control laws. To have a better understanding of control laws and its application, our group decided to research this topic.

Regarding the COVID-19 situation and limited time, we limit the scope of the study as follows:

1. The action of a quadrotor is limited to hovering, which means translation in the x-y plane and orientation do not occur.
2. The input of the closed system is height.
3. The quadrotor’s behavior is controlled by torque in the x, y, and z-axis; and force in the z-axis.
4. The study is limited to the simulation process.
5. All physical parameters of the quadrotor are constant.
6. At least two sensor types are used: 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) supports the understanding of the behavior of the quadrotor and creates its state space (in the global frame). The kinematics study in FRA333 (Kinematics for Robotics System) helps us deal with variables in different frames (between global and   
body frame). In this report, the rotation matrix of the quadrotor will be described in Euler’s angles. For modeling and find the state space of the system, we use the knowledge from FRA231 (Robotics Modeling and Experimentation).

*2.2 Control System*

The quadrotor is a vehicle having four propellers in a cross configuration. The two pairs of its propellers rotate in the opposite direction for the control purpose in figure 1[1]. The hovering action occurs when the propellers have the same speed. Otherwise, it will create rotation.

Diagram, shape, circle

Description automatically generated

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 [3]. In attitude control, the desired orientation will be described in Euler’s angles. After the quadrotor’s orientation is controllable. The hovering control, altitude control, will be used to hover a quadrotor to the desired position [3].

In hovering control, [1]Bolandi, Rezaei, Mohsenipour, Nemati, and Smailzadeh suggested that x, y, z, roll, pitch, and yaw can be controlled by independently varying four rotors’ speeds. This solution is possible because all variables are linearized (in a hovering situation, the derivative of variables is zero). However, this solution can’t be used in any further development—possible to hovering control only.

According to [2]Bresciani, controlling the quadrotor, a 6-degree-of-freedom vehicle, with four rotors can reach a maximum of 4 DOF. He stated that in the body frame, the four best controllable variables are 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). Due to the complexity of frame reference, Bresciani’s solution is not suitable for this study. To simplify the difficulties in changing frame reference, we decided to control the torque and thrust in its body frame and modeled the system in a global reference frame.

* *Control Policy*

Due to the uncertainty that may occur in the flight, a PID controller is used. 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. 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 used because of 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 noise is added to both sensors to test the accuracy of the estimator. Moreover, air resistance is 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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| [3]  [4]  [5]  [6] | T. Choopojcharoen, "IMPLEMENTATION OF CONTROL & ESTIMATION OF QUADROTOR IN MATLAB", 2016.  A. Mukarram, U. Amin Fiaz, U. Ijaz Khan, "Altitude Control of a Quadcopter", BS. thesis, Electrical Engineering, Pakistan Institute of Engineering & Applied Sciences, Islamabad,  Jun. 2015. Access on: Sep 1, 2021. [Online]. Available: https://www.researchgate.net/publication/309486306\_Altitude\_Control\_of\_a\_Quadcopter  N.Koksal,M.Jalalmaab and B. Fidan,"Adaptive Linear Quadratic Attitude Tracking Control of a Quadrotor UAV Based on IMU Sensor Data Fusion",2019 (pg.6,7) Access on: Sep 1, 2021. [Online]. Available: https://www.mdpi.com/1424-8220/19/1/46 /html  K. Malandrakis, Roland Dixon, A.Savvaris and A. Tsourdos,"Design and Development of a Novel Spherical UAV",2016 (pg.6) Access on: Sep 1, 2021. [Online]. Available: https://reader.elsevier.com/reader/sd/pii/S2405896316315270?token=5F8B565DE4C51ECE9606AA93B572B0F47B5502A6C2BDAD5AB0D6EF0D50CC2123587F200071E4A55F4AC1A659CD5E6463&originRegion=eu-west-1&originCreation=202 10903195908 |

**Table 1:** Action plan

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| --- | --- | --- | --- | --- | --- |
|  | **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 |