WORK DOCUMENTATION

This document is meant to cover the work we have done so far. It is meant to be as specific as it need to be to help us review the work and give it a solid logical structure.

The main chapter are going to be:

* Equation of motion and derivation.
* Design of control system (for now showing and commenting Simulink block system).
* PID tuning.
* Adaptive and robust control.

EQUATION OF MOTION AND DERIVATION:

To model the drone, we are going to use mechanical and dynamics theory to find meaningful equations that represent the physical drone.

We start by defining an inertial frame of reference and a body frame of reference , fixed to the drone. We can define the attitude of the body frame of reference relative to the inertial frame of reference using Direction Cosine Matrix (dcm).

The Direction Cosine Matrix is a matrix ;

are the direction of the body frame of reference axis expressed in the inertial frame of reference. If we define es the angle around the roll, pitch and yaw axis, we can express each rotation as an elementary rotation:

A picture containing text, font, diagram

Description automatically generated

Combining these 3 elementary rotations together we get the Direct Cosine Matrix:

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We can express a generic vector x from the body frame of reference to the inertial frame of reference x’:

We can define the rotational velocity of the drone:

This vector is expressed in the body frame of reference.

Define the position vector in the inertial frame of reference. We can also define the linear velocity vector of the drone in the inertial frame reference and the linear acceleration .

We must consider the force output that the drone can produce. The quadrotor can produce trust forces from its propellers with the following geometry:

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We can arrange the Second Law of Motion of Dynamics expressed in the inertial frame of reference:

Where is the force active on the drone written in the body frame reference:

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Therefore, rewriting separating each component:

In the last equation, we are also considering the gravity force. Note that we are completing neglect aerodynamic drag and other external forces.

We still need 3 other equations to match the 6 DoF our drone. We can make use of the Euler equations:

are the 3 principal moment of inertia of the Inertia Matrix . Due to symmetry in the geometry, .

is the distance between the drone center of mass and the position of the rotors.

Here is some useful material to go into detail about what have just been written:

Lecture\_notes\_prof\_Bernelli\_part1.pdf

4 - Posizione e orientamento del corpo rigido.pdf

MECHNICS AND SYNAMICS NOTES (folder)

CONTROL DESIGN

This part is meant to show step by step the buildup of the control system architecture.

The first thing to notice when working with a quadcopter is that it is underactuated. It means that we have more DoF than actuators (6 DoF against 4 propellers).

Therefore, we cannot move freely the quadcopter in the 3D space without changing other degree of freedom, in this case the attitude.

It is straightforward to notice that, to obtain longitudinal and lateral translational maneuvers, the drone must incline towards the direction of movement.

This dynamic can be implemented on the control system dynamic by developing the attitude controller such that it is subjected to translation dynamics controller.

Another crucial point of the control system technique is the use of PIDs controller. This will be an effectively and easy to build control system design that will require a careful tuning of the PID gains to achieve stability.

We will first show the plant model that we have built explaining and commenting the use of quaternion to handle the attitude configuration. This way we can reduce the number of parameters from 9 to 4. The drawbacks of this kind of parametrization are the loss of physical meaning of the quaternion equations.

First, we thought of modelling our quadcopter model using the typical euler angles configuration. However, since by adopting this method, we risk having some singularities, our focus shifted to modelling using quaternions.