Motion Control of Unmanned Aerial Vehicle

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***Abstract*—The abstract goes here.**

***Index Terms*—IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

UNMANNED aerial vehicles, also known as UAVs, are becoming nowadays more and more popular because they are small, cheap to produce, have low operating and maintenance cost, have great maneuverability, can perform steady flight operations and are able to enter high-risk areas without having to compromise human safety. Most applications that involve UAVs have been used in open areas without any obstacles and with a human in control of the UAV. But in recent years people have come up with more modern applications of UAVs that will need UAVs to fly autonomously in densely populated areas, with a lot of other autonomous UAVs around, e.g. Amazon Prime Air delivery system, AltiGator drones services for inspection and data adquisition, or multi-UAVs used to deploy an aerial communications network. This places high demands on UAVs obstacle avoidance capabilities for both moving and static obstacles.

There are many different manufacturers and a vast amount of different UAV models, all with different motors, weights, sensors and lift-to-weight ratio. To make a standard autonomous flight applicable to all these kinds of UAVs, a simple and easy-to-implement multi-UAV mathematical model, that will still be able to avoid obstacles with as few sensors as possible, is needed.

This project aims to study and develop a mathematical model of a quadrotor UAV and the available sensors in it. From the trajectory and pose tracking a state feedback controller will be designed. In order to facilitate the multi-UAV navigation, potential fields or an A* algorithm will be used to make several quads fly to their goals while maintaining collision avoidance with respect to other quads and obstacles. To check the validity of the models, a simulated test environment in MatLab filled with a random reasonable amount of static obstacles and autonomous UAVs will be used.

II. Quadcopter modelling

A. Overview

The UAV is a rigid body quadcopter, with a cross-shaped body and four electrical propellers. Front and rear rotors rotate in a clockwise direction, while right and left rotors do it in a counterclockwise direction, as we can see in Fig.1.

B. Notation

C. Kinematics

To describe the motion of a 6 DOF rigid body, two right-hand reference frames can be defined: the Earth frame and the body frame, as we can see in Fig.1. The Earth frame is static, with the x_E axis pointing towards the North, the y_E axis pointing towards the West, and z_E pointing upwards w.r.t. the Earth. The body frame is attached to the body, with the x_B axis pointing towards the quadrotor's front, the y_B axis pointing towards the left, and the z_B axis pointing upwards. In this case, the axis origin o_B coincides with the quadrotor's structure center.

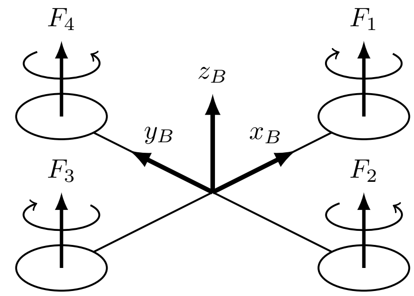

Fig. 1. Quadrotor with propellers and the two reference frames

$$\boldsymbol{R}_x(\phi) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi) & -\sin(\phi) \\ 0 & \sin(\phi) & \cos(\phi) \end{bmatrix} \tag{1}$$

$$\boldsymbol{R}_y(\theta) = \begin{bmatrix} \cos(\theta) & 0 & \sin(\theta) \\ 0 & 1 & 0 \\ -\sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \tag{2}$$

$$\boldsymbol{R}_z(\psi) = \begin{bmatrix} \cos(\psi) & -\sin(\psi) & 0 \\ \sin(\psi) & \cos(\psi) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{3}$$

Rotation matrix

$$\boldsymbol{R}_\Theta(\phi,\theta,\psi) = \boldsymbol{R}_x(\phi)\boldsymbol{R}_y(\theta)\boldsymbol{R}_z(\psi) \tag{4}$$

Transfer matrix

$$\boldsymbol{T}_\Theta(\phi,\theta) = \begin{bmatrix} 1 & \sin(\phi)\cdot\tan(\theta) & \cos(\phi)\cdot\tan(\theta) \\ 0 & \cos(\phi) & -\sin(\phi) \\ 0 & \sin(\phi)/\cos(\theta) & \cos(\phi)/\cos(\theta) \end{bmatrix} \tag{5}$$

Generalized matrix

$$\boldsymbol{J}_\Theta(\phi,\theta,\psi) = \begin{bmatrix} \boldsymbol{R}_\Theta & \boldsymbol{0}_{3\times3} \\ \boldsymbol{0}_{3\times3} & \boldsymbol{T}_\Theta \end{bmatrix} \tag{6}$$

Where the notation $\boldsymbol{0}_{3\times3}$ means a matrix filled with zeros with a 3×3 dimension.

Generalized position: linear and angular position, in the Earth frame

$$\boldsymbol{\xi} = \begin{bmatrix} \boldsymbol{x}^E & \boldsymbol{\eta}^E \end{bmatrix}^T = \begin{bmatrix} x & y & z & \phi & \theta & \psi \end{bmatrix}^T \tag{7}$$

Generalized velocity: linear and angular velocity, in the body frame

$$\boldsymbol{\nu} = \begin{bmatrix} \boldsymbol{v}^B & \boldsymbol{\omega}^B \end{bmatrix}^T = \begin{bmatrix} u & v & w & p & q & r \end{bmatrix}^T \quad (8)$$

In order to relate the derivate of the generalized position in the Earth frame with the generalized velocity on the body frame there is the following equation:

$$\dot{\boldsymbol{\xi}} = \boldsymbol{J}_\Theta \, \boldsymbol{\nu} \quad (9)$$

D. Dynamics

III. Sensors

IV. Quadcopter control

V. Conclusion

It's bloody impossible to do this.

Appendix A
Dynamics or something that's heavy on the maths goes here

Appendix one text goes here.

Appendix B
Something else but similar here, matlab code?

Appendix two text goes here.

Acknowledgment

Praising of Christos goes here! The authors would like to thank...

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.