RBE502 - Project- Group F

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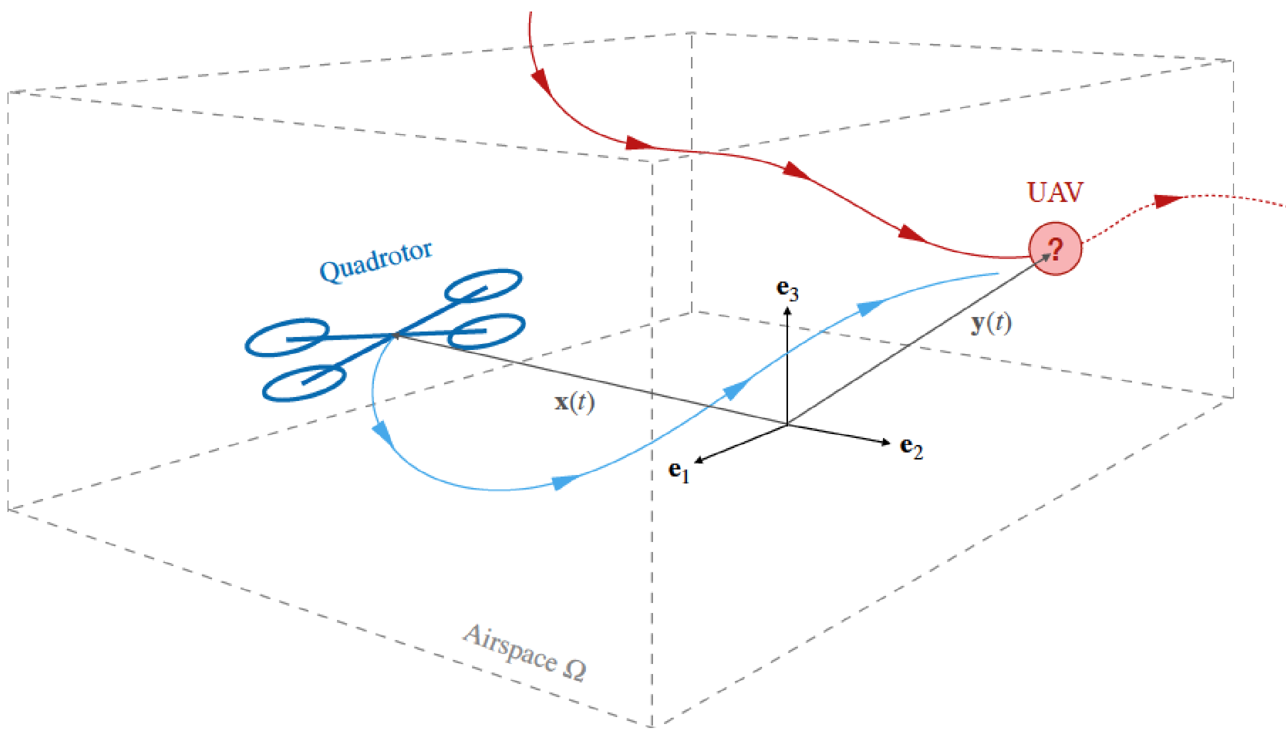
Situation/Problem

The mission is defense of a designated airspace. Our quadrotor is assigned to monitor a limited airspace, launch if an unidentified UAV enters that airspace, capture the bogey and return to base without leaving the airspace. If the bogey leaves the airspace before being captured, our quadrotor should return to base. When captured the bogey should be assumed to generate external forces on our UAV. The figure below depicts the scenario.



Materials and Methods

Coordinate frames are identified for the reference/inertial frame $E = e_1, e_2, e_3$ at the center bottom of the airspace and the body frame $C = c_1, c_2, c_3$. All rotors are equidistant from the center of mas and in the same $c_1 - c_2$ plane as the body center of mass.

The external forces and moments on the system are represented by $\boldsymbol{r}$ and $\boldsymbol{n}$, where $\boldsymbol{r} = r_1c_1 + r_2c_2 + r_3c_3$ and $\boldsymbol{n} = n_1c_1 + n_2c_2 + n_3c_3$ directly applied to the center of mass. We are assuming that the torque of the rotor is proportionaly related to the input thrust via the constant $\sigma > 0$, for $\tau_i = \sigma u_i$. We will be utilizing $\boldsymbol{I}$ as our inertial matrix, where:

$$\boldsymbol{I} = \begin{bmatrix} I_x & 0 & 0 \\ 0 & I_y & 0 \\ 0 & 0 & I_z \end{bmatrix} \tag{1}$$

Parameter	Value	Units	Description
l	.02	m	Distance from center of mass to center of each rotor
m	.5	kg	Total mass of quadrotor
I_x	1.24 kgm^2	s	Mass moment of inertia about c_1 axis
I_y	1.24 kgm^2	s	Mass moment of inertia about c_2 axis
I_z	1.24 kgm^2	s	Mass moment of inertia about c_3 axis
g	9.81	$\mathrm{m/s}^2$	Gravitational acceleration
σ	.01	m	Proportionality constant relating u_i to τ_i

Table 1: Quadrotor Parameters

where I_x, I_y and I_z represent the mass moments of inertia about c_1, c_2 and c_3 respectively.

We have also had established for us that there exists a rotation matrix - $R_{C/E}$ - which rotates from frame C to frame E. This rotaton matrix is the result of a Euler angle $z-y-x$ rotation along ϕ, θ, and ψ, respectively. This rotation matrix is such that:

$$R_{C/E} = \begin{bmatrix} \cos(\psi)\cos(\theta) & \cos(\psi)\sin(\phi)\sin(\theta) - \cos(\phi)\sin(\psi) & \sin(\phi)\sin(\psi) + \cos(\phi)\cos(\psi)\sin(\theta) \\ \cos(\theta)\sin(\psi) & \cos(\phi)\cos(\psi) + \sin(\phi)\sin(\psi)\sin(\theta) & \cos(\phi)\sin(\psi)\sin(\theta) - \cos(\psi)\sin(\phi) \\ -\sin(\theta) & \cos(\theta)\sin(\phi) & \cos(\phi)\cos(\theta) \end{bmatrix} \tag{2}$$

And

$$T^{-1} = \begin{bmatrix} 1 & \sin\phi\tan\theta & \cos\phi\tan theta \\ 0 & \cos\phi & -\sin\phi \\ 0 & \frac{\sin\phi}{\cos\theta} & \frac{\cos\phi}{\theta} \end{bmatrix} \tag{3}$$

Results

Discussion

References

[1] Jinho Kim, S. Andrew Gadsden, Stephen A . Wilkerson. "A Comprehensive Survey of Control Strategies for Autonomus Quadrotors". arXiv:2005.09858v1. 20 May 2020.

[2] Madani, T, and A Benallegue. “Backstepping Control for a Quadrotor Helicopter.” 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems. IEEE, 2006. 3255–3260. Web.

[3] Jing Qiao, Zhixiang Liu, Youmin Zhang. "Payload Dropping Control of an Unmanned Quadrotor Helicopter Based on Backstepping Controller". MATEC Web Conf., 277 (2019) 01004. DOI: https://doi.org/10.1051/matecconf/201927701004.

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