Differential Flatness-based Control

November 4, 2019

1 Differential Flatness Based Control

This homework is based on the differential flatness paper [1] discussed in the class. Add a path following (using differential flatness and LQR) block that takes in four trajectory inputs and outputs four control commands $F, \phi_c,\ \theta_c,\ r^d$.

- Do not discuss or share your code and Q and R matrices with fellow students.
- Matlab can be used all the time.

1. Design a LQR controller for a quadrotor to track y_{traj}. The objective is minimize the tracking error $x - x^r$ meaning find the best Q and R weighting matrices and then showing that the gain matrix K computed based on Q and R matrices gives you the minimum tracking error.

$$y_{traj}(t) = \begin{bmatrix} p_n^r(t) \\ p_e^r(t) \\ p_d^r(t) \\ \psi^r(t) \end{bmatrix} = \begin{bmatrix} a\cos(\omega_2 t) \\ b\sin(\omega_1 t) \\ n + c\sin(\omega_3 t) \\ \psi^r(t) \end{bmatrix}$$

where $\omega_1 = \frac{2\pi}{T}$ for the following four scenarios

(a) $a = 1.5, b = 0.75, c = 0, n = -0.75, \omega_2 = \frac{\omega_1}{2}, \omega_3 = \omega_1$ and $T = 5s$.

(b) $a = 1.5,\ b = 0.75,\ c = 0.5,\ n = -0.75,\ \omega_2 = \frac{\omega_1}{2},\ \omega_3 = \omega_1$ and $T = 10s$.

(c) $a = 0.75$, $b = 0.75$, $c = 0$, $n = -0.75$, $\omega_2 = \omega_1$, $\omega_3 = \omega_1$ and $T = 10s$.

(d) Generate an unique trajectory (what ever you can cook up) and track it using the LQR controller.

For all the 4 cases Submit (a) 3-D trajectory plots that include the reference trajectory and actual trajectory (b) Commanded and actutal attitude angles (ϕ, θ, ψ) (c) Error plots $x_r - x$ (d) Simulation videos.

References

[1] J. Ferrin, R. Leishman, R. Beard, and T. McLain, "Differential flatness based control of a rotorcraft for aggressive maneuvers," in *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on.* IEEE, 2011, pp. 2688–2693.