Hand-In Exercise 3: State Space Control of Flying Drone

This exercise addresses the control of a multiple-input multiple-output (MIMO) system - a flying drone. In particular, we consider a very simplified model of a flying drone that only has one translational and a rotational degree of freedom, i.e., it can fly up/down and rotate about one axis as indicated in Figure 4. Forces can be applied to the drone using two propellers that are placed a distance r away from the center of the drone (gravity is omitted for simplicity).

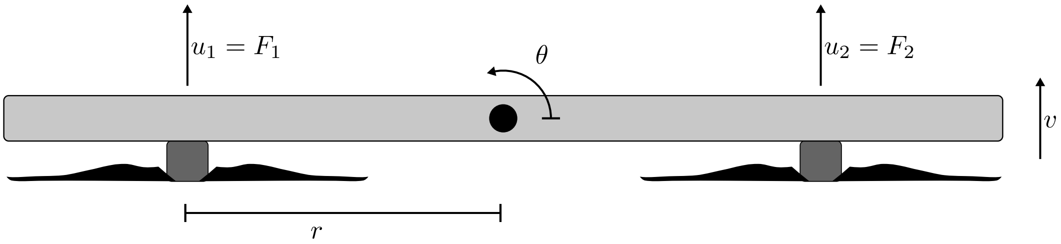

Figure 4: Diagram of flying drone that is controlled via two propellers, which apply forces F_1 and F_2 to the drone.

For this exercise, a linearized model of the system is considered which is given by

$$\begin{aligned} J\ddot{\theta} &= r(u_2 - u_1) - b_1\dot{\theta} - b_2 v \\ m\dot{v} &= u_1 + u_2 - b_3 v \end{aligned} \tag{1}$$

where θ is the angle of the drone [rad], v is the vertical velocity [m/s], J is the inertia [kgm], m is the mass [kg], r is half the spacing between the propellers [m], and b_1, b_2, b_3 are coefficients related to the drag of the robot. The parameter values of the drone are: The inertia of the drone J is 1 kgm^2, the radius of drone r is 1 m, the mass of drone m is 5 kg, the drag coefficients are $b_1 = 1$ Nm/(rad/s), $b_2 = 0.5$ Nm/(m/s), $b_3 = 1$ N/(m/s).

Design a controller for the system using modern control methods (state space control) according to the following steps.

1. **System Analysis**
   - Put the model (1) on state space form, while assuming that the angle θ and the position p (height) is measured.
   - Determine if the system is observable and controllable.
2. **Controller Design**
   - Design an integral control for the system using pole placement. The control should ensure that the system has a 5 % settling time of 1 s.
   - Evaluate the performance of the system by changing the reference to the system from $(p, \theta) = (0, 0)$ to $(p, \theta) = (1, \pi/8)$. You should plot both u, y, and the state x.
3. **Observer Design**
   - Determine appropriate locations for observer poles.
   - Design a full-order observer for the system using pole placement.
4. **Simulation**
   - Simulate the observer-based controller by changing the reference to the system from $(p, \theta) = (0, 0)$ to $(p, \theta) = (1, \pi/8)$. You should plot both u, y, and the state x.

A report compiled according to the provided template should document the above steps with block diagrams and graphs related to the simulations. Each result should be explained and interpreted in the report.