Q3 (5 pts)

Please fill out the following project form (one per group). This will primarily be for the TAs to use to understand what you are working on and hopefully be able to better assist you. If you haven't decided on certain aspects of the project, just include what you are currently thinking/what decisions you need to make.

(1) Write down your dynamics (handwritten, code, or latex). This can be continuous-time (include how you are discretizing your system) or discrete-time.

Our project study the dynamics of one drone with a slung attached to the bottom of it.

The drone dynamics is the same as the one we have studied in class, the only difference is that we have additional forces (which is extra control input) generated by the slung.

$$\dot{x} = \begin{bmatrix} \dot{r} \\ \dot{q} \\ \dot{v} \\ \dot{\omega} \end{bmatrix} = \begin{bmatrix} v \\ \frac{1}{2} q \otimes \hat{\omega} \\ g + \frac{1}{m^i}\left(R(q)F(u) + F_c\left(u_5, x, x^\ell\right)\right) \\ J^{-1}(\tau(u) - \omega \times J\omega) \end{bmatrix}$$

The load is modeled as a point mass:

$$\dot{x}^\ell = \begin{bmatrix} \dot{r}^\ell \\ \dot{v}^\ell \end{bmatrix} = \begin{bmatrix} v^\ell \\ g - \frac{1}{m^\ell} F_c(u_1, x, x^\ell)) \end{bmatrix}$$

Here the force is given by the following equation:

$$F_c\left(\gamma, x, x^\ell\right) = \gamma \frac{r^\ell - r}{\left\|r^\ell - r\right\|_2}$$

Also, to make sure the rope is always taut, we have the following constraint:

$$\left\| r - r^{\ell} \right\|_2 = d_{\text{cable}}$$

(2) What is your state (what does each variable represent)?

The state is the joint state of drone and the load. The state is defined as follows:

$$\bar{x} \in \mathbb{R}^{13+6} = \begin{bmatrix} x \\ x^{\ell} \end{bmatrix}$$

(3) What is your control (what does each variable represent)?

The control is the joint control of the drone and the load. The control is defined as follows:

$$\bar{u} \in \mathbb{R}^{5} = \begin{bmatrix} u \\ u^{\ell} \end{bmatrix}$$

(4) Briefly describe your goal for the project. What are you trying to make the system do? Specify whether you are doing control, trajectory optimization, both, or something else.

We are trying to do agile flight with a slung load attached to the drone. Specifically, we are trying to make the drone and the load passing a few gates in a certain order with trajectory optimization.

(5) What are your costs?

The cost is the quadratic cost to reach the desired position.

$$\tilde{x} = \bar{x} - x_{\text{des}}$$
$$J = \int_0^T \left(\tilde{x}^T Q \tilde{x} + \bar{u}^T R \bar{u}\right) dt$$

(6) What are your constraints?

The constrains has two parts: one for dynamics and another for collision avoidance.

For dynamics, we have the following constraints:

$$\begin{aligned} \text{taut cable} \quad & \left\|r - r^\ell\right\|_2 = d_{\text{cable}} \\ \text{cable control} \quad & (u)_5 = \left(u^\ell\right)_1 \\ \text{cable force} \quad & u^\ell \geq 0 \\ \text{control limits} \quad & 0 \leq (u)_j \leq u_{\max}, \quad \forall j \in \{1, \ldots, 4\} \end{aligned}$$

For collision avoidance, we have the following constraints:

$$\begin{aligned} \text{drone collision avoidance} \quad & d_{\text{quad}} + d_{\text{obs}} - \left\|p - p^j_{\text{obs}}\right\|_2 \leq 0 \\ \text{load collision avoidance} \quad & d_{\text{quad}} + d_{\text{obs}} - \left\|p_\ell - p^j_{\text{obs}}\right\|_2 \leq 0 \end{aligned}$$

(7) What solution methods are you going to try?

I am going to use direct collocation to solve the problem. The solver I am using is IPOPT.

(8) What have you tried so far?

I have tried use IPOPT to solve it and it now can navigate the drone to the desired position passing single door.

single door

(9) If applicable, what are you currently running into issues with?

How to scale the problem up to solve a multigate passing problem. For passing single door, the decision variable number is around 1k. For multiple doors, it would take long time to solve the problem.

(10) If your system doesn't fit with some of the questions above or there are additional things you'd like to elaborate on, please explain/do that here.