OLCAR - Exercise 1 – ILQC

Answers to question related to programming exercise

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# Problem 1

Design LQR controller with one goal state (2.)

Question 1: How does the controller behave with varying positions of the Task.goal\_x?

Question 2: What is the cause of the varying performance (model, cost function,...)?

Question 3: How do changes in Task.cost.Q\_lqr and Task.cost.R\_lqr affect the behavior?

Task.cost.Q\_lqr (further on named Q) penalize the distance the object is away from the goal position, while Task.cost.R\_lqr (further on named R) penalizes the control effort it takes to come there. As a result of this, the cost matrix Task.cost.Q\_lqr influences the speed the quadrocopter reaches the goal position, while the cost matrix Task.cost.R\_lqr has influence on the control effort.

Choosing Q and R is a trade-off between these two issues.

Design LQR controller with a via-point (3.)

Question 4: How does a via-point change behavior of the LQR controller?

Until a certain time Task.vp\_time the controller only aims to reach the intermediate via point Task.vp1. After this time, the cost function differs.

Question 5: Why is the system capable of reaching further away Task.goal\_x states?

Because of the dynamic cost function.

Question 6: Defining via points Task.vp and time Task.vp\_time seem to have a positive influence on the system behavior and increase stability. What are the disadvantages?

Time

# Problem 2

Design the ILQC controller (1.)

Question 7: How do the trajectories of the LQR and ILQC controller differ? How do the costs

compare?

|  |  |  |
| --- | --- | --- |
| Goal (x,y,z) | LQR | ILQC |
| (5,0,10) |  |  |
| (5,0,-10) |  |  |
| (5,0,-30) |  | Unstable |
| (15,3,-1) | Unstable | Unstable |
| (10,3,-1) |  |  |
| (12,0,0) |  |  |

The trajectories of the ILQC seem to be less smooth than the LQR ones.

The ILQC cost function consists of pure quadratic terms of the control and the state trajectories and also some additional linear terms of the control and state trajectories, while the LQR cost function is purely quadratic. Overall, the ILQC cost function includes the same terms as the LQR cost function but additionally has some extra terms.

Still, the cost of the ILQC controller is smaller compared to the cost of the LQR controller. In such a way it can be stated, that ILQC produces a better solution than LQR.

Question 8: Why does the ILQC perform better for distant and similarly well for close goal states?

The ILQC controller includes both, a feedback and a feed-forward control term, while the LQR only consists of the feedback control part. Including the feed-forward control allows the ILQC to consider a more “global” picture of the problem formulation.

Include via-points for the ILQC controller to pass through (2.)

Question 9: How must the via-point weighting matrix Q\_vp be chosen for the algorithm to determine the optimal via-point velocity on its own?

The weighting matrix has to be chosen as a 12x12 (according to the size of the state vector) diagonal matrix. All the off-diagonal elements are zero, since the differences of the different states are penalized uncorrelated to each other (meaning, that there are no mixture terms of multiple states in the weighing matrix Q\_vp).

In order to allow the algorithm to determine the optimal via-point velocity on its own, the corresponding elements of the diagonal weighting matrix can be set to zero. In our case, the last six elements on the diagonal should be set to zero, in order to not penalize deviations in linear and angular velocities.

Question 10: How can exact passing through the via-point be enforced and how can it be included only as a soft suggestions on top of the other performance criteria?

The importance the passing through the via-point gets assigned depends on the values of Q\_vp compared to the values of the other weighting matrices (Qm\_f, Qm, Rm, …). If the values of Q\_vp are considerably larger than the ones of the other weigthing matrices, the passing through the via-point is enforced while smaller values soften this constraint.