Introduction

Tasks

- Write a function to amend your QP matrices and vectors in order to implement soft constraints.

Framework provided:

mySoftPadding.m	Template for submission
myMPController.m	Template *not* for submission
SimscapeCrane_MPCsoft.slx	Nonlinear Simscape model for testing controller
SSmodelParams.mat	Physical parameters for the linear ODE
Params_Simscape.mat	Physical parameters for nonlinear simulation
GantryResponsePlot.m	Utility function
MatlabSimulation.m	Simulates the linear gantry crane model
testMyMPC.m	Function to test your RHC law performance
genCraneODE.p	Answer function for a previous assignment
genPrediction.p	Answer function for a previous assignment
genCostMatrices.p	Answer function for a previous assignment
genStageConstraints.p	Answer function for a previous assignment
genTrajectoryConstraints.p	Answer function for a previous assignment
genConstraintMatrices.p	Answer function for a previous assignment

Approach

Suppose you have a horizon length N and a model of a discrete-time system of the form

$$x_{k+1} = Ax_k + Bu_k,\ k = 0, 1, \ldots, N-1 \tag{1}$$

where the state $x_k \in \mathbb{R}^n$ and input $u_k \in \mathbb{R}^m$ at sample instant k. Suppose also that a target state x_e is given and that x_e is an equilibrium point if the input applied to the system is zero, i.e. $x_e = Ax_e$. In the following, symbols are defined as in previous assignments.

- Suppose you are given a positive semi-definite matrix S and a non-negative $\rho \in \mathbb{R}$. Consider the soft-constrained optimal control problem

$$\mathbf{t}^*(x_0, x_e) := \arg\min_{\mathbf{t}} \|x_N - x_e\|_P^2 + \sum_{k=0}^{N-1} \left(\|x_k - x_e\|_Q^2 + \|u_k\|_R^2 + \|s_{k+1}\|_S^2 + \rho \|s_{k+1}\|_1 \right) \tag{2a}$$

$$\text{s.t. (1) and} \tag{2b}$$

$$\check{u} \leq u_k \leq \hat{u},\ k = 0, 1 \ldots, N-1 \tag{2c}$$

$$\check{c} - s_k \leq Dx_k \leq \hat{c} + s_k,\ k = 1, 2, \ldots, N \tag{2d}$$

$$s_k \geq 0,\ k = 1, 2, \ldots, N \tag{2e}$$

  where $\mathbf{s} := \begin{bmatrix} s_1^T & s_2^T & \cdots & s_N^T \end{bmatrix}^T$ is a vector of slack variables to upper bound constraint violations and $\mathbf{t} := \begin{bmatrix} \mathbf{u}^T & \mathbf{s}^T \end{bmatrix}^T$.

Edit **mySoftPadding.m** to augment the matrices of the QP in the previous assignment such that the solution to (2) is given by the solution to the QP

$$\mathbf{t}^*(x_0, x_e) = \arg\min_{\mathbf{t}} \frac{1}{2}\mathbf{t}^T H_s \mathbf{t} + \left[(x_0 - x_e)^T G^T \; g_s^T\right] \mathbf{t} \tag{3a}$$

$$\text{s.t. } F_s\mathbf{t} \leq \mathbf{b}_s + J_s x_0 + L_s x_e. \tag{3b}$$

Please see how the function is called from the test script **testMyMPC.m**. Pay special attention to which matrices are inside and which are outside the function.

- Edit **myMPController.m** so that it provides the value of the RHC law κ for the target state x_e and the current estimate of the state $\hat{x}$, i.e. $\kappa(\hat{x}, x_e) := u_0^*(\hat{x}, x_e)$. Please see how the function is called from the test script **testMyMPC.m**. Pay special attention to which matrices are inside and which are outside the function.
- Open **SimscapeCrane_MPCsoft.slx**, navigate to the block *SimscapeCrane_MPCsoft/MPC* and replace the code inside the MATLAB function block with your own. Note that there are some small differences compared to the previous assignment and **myMPController.m**.
- Once all of the above are in working order you will be able to use **testMyMPC.m** for assessing the performance of your controller. Investigate the effect of using different cost weights, sample period, horizon length, initial conditions, target state, constraints, etc. This will be helpful for the final assignment.

Submission

filename	Description
mySoftPadding.m	Computes the matrices and vectors for the QP (3).

Edit or upload the MATLAB template for the above into Cody Coursework. All your code should be written for the general case and not just for the gantry crane.