Project 1 - Current and speed control of a permanent-magnet DC motor

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Abstract

The aim of this practice is to design a stabilizing controller for a low-frequency permanent-magnet DC motor. The model taken from [1] has, as initial condition, a current of 0.2 A and a speed of 70.3 rad/sec:

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) + B_w w(t) \\ y(t) = Cx(t) + Du(t) \end{cases}$$

$$A = \begin{bmatrix} -R_a/L & -K_e/L \\ K_t/J_1 & -f_r/J_1 \end{bmatrix} \quad B = \begin{bmatrix} 1/L \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

The input u is the armature voltage, the states are the current i and the motor speed n, and the parameters $R_a = 1.203$ Ohm, $L = 0.005584$ H, $K_e = 0.08574$, $K_t = 1.2006K_e$, $J_1 = 0.000169992$ N m s^2/rad, $f_r = 0.000294$ N m s/rad are the resistance, inductance, motor velocity constant, torque constant, motor inertia and friction coefficient, respectively. The vector signal w represents the parameter uncertainties and it is equal to [1, 1], while, after the discretization with a sampling time $T_s = 1$ ms, the matrix B_w is

$$\bar{B}_w = \begin{bmatrix} -0.0085 & -0.0006 \\ -0.0603 & 0.0002 \end{bmatrix}$$

The current and the motor speed are bounded in, respectively, $[-2, 2]$ A and $[-150, 150]$ rad/s, while the control limit saturation is $[0, 12]$ V.
Warning: to avoid a recently found bug in **quadprog**, you have to use the following option **optimset ('LargeScale','off')**. Check the help in **quadprog** to see how you pass options.
Once you have the MPC code running, you can set the option '**display**' to '**off**'. This will make the simulation a bit faster.

Exercises

1. Design a stabilizing LQ controller for the given initial conditions (Hint: **dlqr** and **c2d** may be helpful MATLAB commands).

2. Create an MPC controller without any active constraints. Make sure that it is consistent with the control law from LQR (they should coincide if the prediction horizon **N** is sufficiently long).

3. Add control constraints. Is it still working? Does it better than the LQR? How does it behave when you try to make it more aggressive?

4. Add the constraint on the current and on the motor speed.

5. Suppose that the state is not measurable, then study the effect of the introduction of a Kalman filter in the schema with the MPC on the overall performances.

References

[1] X. Q. Liu, H.Y. Zhang, J. Liu and J. Yang. *Fault detection and diagnosis of permanent-magnet DC motor based on parameter estimation and neural network*, IEEE Trans. Ind. Elec., 47(5):1021–1030, 2000