Digital Control Technologies and Architectures - 01PDCYP, 01PDCOV, 01PDCLP

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Laboratory practice 7

Objectives: MPC control design of CT systems using `MPCtools`, review on algebraic design.

Problem 1 (MPC design for zero-regulation of the state using `MPCtools`.)

Consider the mass-damper system introduced in Laboratory practice 4 described by the following state space representation in continuous time.

$$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 0 & -1 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t), \; x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$
$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} x(t)$$

Assume a sampling time $T_s = 0.05$ s and suppose that the system state can be measured. Design an MPC controller using `MPCtools` aimed at regulating to zero the state of the system (within a tolerance of 10^{-4}) considering a regulation time $t_{reg} \approx 2.5$ s with a tolerance of 5% and accounting for the following constraints:

$$\begin{cases} |u(k+i|k)| \leq 5.5, \; i = 0, \dots, H_p - 1 \\ |\Delta u(k+i|k)| \leq 3, \; i = 0, \dots, H_p - 1 \end{cases}.$$

Develop the design procedure through

- MatLab script file named `sxxxxxx_design_MPC.m` following the naming described below for the relevant transfer functions and variables:
  - `Q` $\rightarrow$ weight matrix Q;
  - `R` $\rightarrow$ weight matrix R;
  - `Hp` $\rightarrow$ prediction horizon H_p;
  - `Hc` $\rightarrow$ control horizon H_c;
  - `Ts` $\rightarrow$ sampling time T_s.
- Simulink file named `sxxxxxx_sim_MPC.slx`.

Save all the design results in the `sxxxxxx_MPC.mat` file using the statement `save sxxxxxx_MPC` at the MatLab prompt >>
$\rightarrow$ `>> save sxxxxxx_MPC`

In all of the above files, replace `sxxxxxx` with your own id.

Problem 2 (Review on Algebraic design)

Given the continuous time LTI system described by the transfer function,

$$G_{cont}(s) = \frac{40}{s^2 + 4s - 10}$$

design a digital controller $C(z)$ using a 1dof architecture to meet the following requirements:

1.a $\left|y_{d_2}^{\infty}\right| \leq 5 \cdot 10^{-4}$ in the presence of disturbance $d_2(kT_s) = 0.1\,kT_s$;

1.b $\left|y_{d_1}^{\infty}\right| \leq 5 \cdot 10^{-5}$ in the presence of disturbance $d_1(kT_s) = 0.7\,\varepsilon(kT_s)$;

2. $\hat{s} \leq 25\%$;

3. $t_{s,1\%} \leq 2.5$ s;

4. $t_r \leq 0.9$ s.

Assume a sampling time $T_s = 5$ ms. (Hint: in case of unsatisfaction of the requirement on $\hat{s}$, try to reduce the time constant of the additional poles)

Develop the design procedure through

- MatLab script file named `sxxxxxx_design.m` following the naming described below for the relevant transfer functions and variables:
  - `Gcont` $\rightarrow$ continuous time plant transfer function $G_{cont}(s)$;
  - `G` $\rightarrow$ discrete time plant transfer function $G(z)$;
  - `C` $\rightarrow$ discrete time cascade controller transfer function $C(z)$;
  - `Ts` $\rightarrow$ sampling time T_s;
  - `zeta` $\rightarrow$ damping coefficient ζ, `wn` $\rightarrow$ natural frequency ω_n;
  - `M_S` $\rightarrow$ Sylvester matrix M_S.
- Simulink file named `sxxxxxx_sim.slx`.

Save all the design results in the `sxxxxxx.mat` file using the statement `save sxxxxxx` at the MatLab prompt >>
$\rightarrow$ >> `save sxxxxxx`

In all of the above files, replace `sxxxxxx` with your own id.