MATLAB test: Assignment Examples

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Rules: Only one exercise will be assigned to each student.
The total time for implementing a solution and discussing it is about 45 minutes.
It is encouraged to write a brief list of the steps needed to complete this assignment before starting to work on the code.

[Ex.1] Consider the system associated to state-space model:

$$\begin{cases} \dot{\boldsymbol{x}} = \boldsymbol{A}\,\boldsymbol{x} + \boldsymbol{B}\,u & (1) \\ y = \boldsymbol{C}\,\boldsymbol{x} & (2) \end{cases}$$

$$\boldsymbol{A} = \begin{bmatrix} 0 & 1 \\ 0 & -10 \end{bmatrix} \qquad \boldsymbol{B} = \begin{bmatrix} 0 \\ 120 \end{bmatrix}$$
$$\boldsymbol{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \qquad D = 0 \tag{3}$$

1. Design a physically-implementable PID-type controller to asymptotically track step references and linear ramps, with performance specification for the step response $t_r = 0.15$ and $M_p = 0.2$. If using the Bode method, consider varying the α parameter to improve performance.

2. Implement the system and the controller in simulink. All the preinstalled toolboxes, functions and blocks can be used.

3. Evaluate how the introduction of a symmetric saturation at $|u|_{max} = 10$ affects the performance and propose a solution.

[Ex. 2] Consider an LTI system associated to a SISO transfer function:

$$P(s) = \frac{90}{s^2 + 60s + 3} \tag{4}$$

1. Choose an appropriate sample time and design a discrete-time state-space feedback controller and full-state observer to asymptotically track step references, with performance specification for the step response $t_r = 0.25$ and $M_p = 0.2$.

2. Implement the system and the controller in simulink. All the preinstalled toolboxes, functions and blocks can be used.

[Ex. 3] Consider the system associated to state-space model:

$$\begin{cases} \dot{\boldsymbol{x}} = \boldsymbol{A}\,\boldsymbol{x} + \boldsymbol{B}\,u & (5) \\ y = \boldsymbol{C}\,\boldsymbol{x} & (6) \end{cases}$$

$$
\boldsymbol{A} = \begin{bmatrix} 0 & 1 \\ -2 & -40 \end{bmatrix} \qquad \boldsymbol{B} = \begin{bmatrix} 0 \\ 40 \end{bmatrix}
$$

$$
\boldsymbol{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \qquad D = 0 \tag{7}
$$

1. Exactly discretize the system for $T_S = 0.01ms$ and design a stabilizing, optimal state-space controller with integral action via the LQ method aiming to guarantee each (extended) state-component square-norms lesser than 10, and control square-norm lesser than 20. To reconstruct the state implement a full-state observer.

2. Implement the system and the controller in simulink. All the pre-installed toolboxes, functions and blocks can be used.

[Ex. 4] Consider the system associated to state-space model:

$$
\begin{cases} \dot{\boldsymbol{x}} = \boldsymbol{A}\,\boldsymbol{x} + \boldsymbol{B}\,u & (8) \\ y = \boldsymbol{C}\,\boldsymbol{x} & (9) \end{cases}
$$

$$
\boldsymbol{A} = \begin{bmatrix} 0 & 1 \\ 0 & -20 \end{bmatrix} \qquad \boldsymbol{B} = \begin{bmatrix} 0 \\ 60 \end{bmatrix}
$$

$$
\boldsymbol{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \qquad D = 0 \tag{10}
$$

1. Employ the error-space approach to design a controller to asymptotically track step references and sinusoidal signals with frequency $\omega = 6$rad/s, with performance specification for the step response $t_s = 0.2$. To reconstruct the state second component, employ a filtered derivative of the output.

2. Implement the system and the controller in simulink. All the pre-installed toolboxes, functions and blocks can be used.