ISS0031 Modeling and Identification

Exercises for Laboratory Work #3: Linear Systems

These exercises are meant to be completed in the MATLAB environment.

Transfer Functions

1. Consider a heating furnace described by a transfer function

$$G_h(s) = \frac{0.5886}{4801.86s + 1}\mathrm{e}^{-11.2571s},$$

where the input $u(t)$ is power $[W]$ and output $y(t)$ is temperature $[^\circ C]$.

   (a) Analyze the impulse and step responses of this system by creating corresponding functions in the time domain.

   (b) Compare the results to those achieved by built-in MATLAB tools, i.e., by means of defining a transfer function using the `tf()` command, and simulating the response of the system by using `impulse()` and `step()` or `lsim()` commands.

   (c) Study the frequency domain characteristics of this system by using the `bode()` command. What can you say about the system's closed-loop behavior?

   (d) Design a PI controller

$$C(s) = K_p + \frac{K_i}{s}$$

for the system by minimizing a cost

$$J = \sum_{k=1}^{N} |e_k| \,,$$

where $e_k = 1 - y_k$ is the step response error of the closed loop system

$$G_{cl}(s) = \frac{C(s)G_h(s)}{1 + C(s)G_h(s)}$$

by means of the Nelder-Mead simplex algorithm—the `optimize()` function. Can you achieve an improvement in the time domain response? How have the frequency domain characteristics of the open loop control system

$$G_{ol}(s) = C(s)G_h(s)$$

changed? Compare the Bode plots of the initial and optimized open loop control systems.

2. (Individual exercise) Consider a position servo described by a model

$$G_s(s) = \frac{174.8}{s(0.8785s + 1)},$$

where the input $u(t) \in [-1, 1]$ is a dimensionless normalized value and output $y(t)$ is angle $[rad]$. Complete the assignments (a)–(c) from the first exercise. What difference does the absense of the delay term make? For assignment (d), design a PD controller

$$C(s) = K_p + K_d s$$

and carry out all further steps in the corresponding assignment. Why is a PD controller needed here?