Nonlinear Control

Master Degree in Mechanical Engineering

2024/2025

Simulation Project

The project consists in exploring analysis tools and control design techniques learned during the course. Different problems having similar degree of complexity are proposed to each group. The developed analytical solutions should be implement in Matlab/Simulink and simulations must show the evidence of the theoretical conclusions.

PROBLEM 1: consider the output feedback control of a given LTI system:

Group 1:

$$G(s) = \frac{20}{s(s+2)(s+5)}$$

Group 2:

$$G(s) = \frac{10(s+1)}{(s+4)(s+2)(s-1)}$$

Group 3:

$$G(s) = \frac{15}{(s+4)(s+1)(s-2)}$$

Group 4:

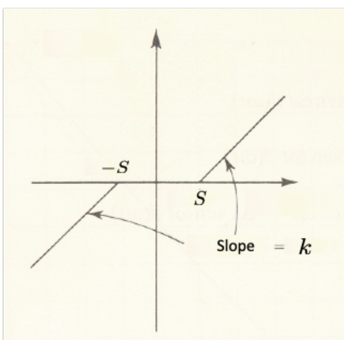
$$G(s) = \frac{100}{s(s+4)(s+10)}$$

Group 5:

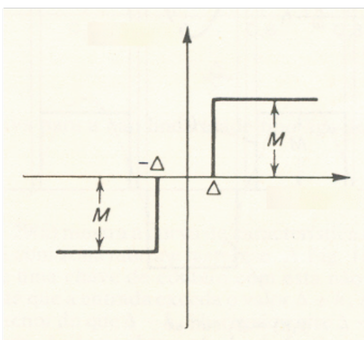
$$G(s) = \frac{20(s+5)}{(s+10)(s+4)(s-2)}$$

Study the effect of having a nonlinear actuator in the feedback loop:

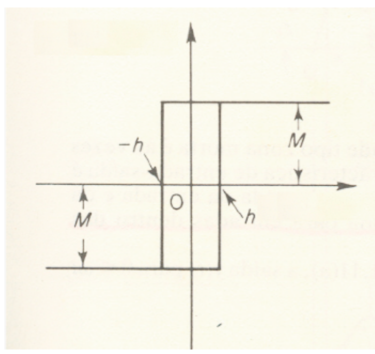
1) Assume one can choose from the following three different nonlinear actuators. Apply the Describing Function method and compare the expected closed-loop results. Select the actuator most suitable for the system, justifying your choice.



Actuator I ($S = 0.5; k = 2$)



Actuator II ($\Delta = 1; M = 1$)



Actuator III ($h = 2; M = 0.5$)

2) Assume that the nonlinearity of the actuator is unknow, except that it lives in sector $K \in [k_1 \;\; k_2]$. Apply the Popov or the Circle Criteria to find the sector region limits that guarantees the sufficient condition for global asymptotical stability of the feedback loop.

PROBLEM 2: consider a given nonlinear dynamic system. Design a suitable controller for the system using the control techniques: 1) feedback linearization (either input-state and input-output); 2) sliding mode control, testing robustness to parametric uncertainties. In both cases choose appropriate closed-loop dynamics.

Group 1:

$$\begin{cases} \dot{x}_1 &= -x_1 + u \\ \dot{x}_2 &= -x_2 - x_1 x_3 + u \\ \dot{x}_3 &= x_1 x_2 \\ y &= x_2 \end{cases}$$

Group 2:

$$\begin{cases} \dot{x}_1 &= x_2 + x_1 x_2 - x_2^2 + u \\ \dot{x}_2 &= x_1 x_2 - x_2^2 + u \\ \dot{x}_3 &= x_1 + x_1 x_2 - x_2^2 - (x_3 - x_1)^3 + u \\ y &= x_1 - x_2 \end{cases}$$

Group 3:

$$\begin{cases} \dot{x}_1 &= x_1 + \frac{2+x_3^2}{1+x_3^2} u \\ \dot{x}_2 &= x_3 \\ \dot{x}_3 &= -x_1^2 x_3 + u \\ y &= x_2 \end{cases}$$

Group 4:

$$\begin{cases} \dot{x}_1 &= -x_3 \\ \dot{x}_2 &= \sin(x_2) + x_3 \\ \dot{x}_3 &= 2x_1^2 - x_3 + u \\ y &= x_1 \end{cases}$$

Group 5:

$$\begin{cases} \dot{x}_1 &= x_1 + 2x_2 \\ \dot{x}_2 &= -3x_1 + x_2^3 + (1 + x_2^2) u \\ \dot{x}_3 &= -2x_1 + x_3 \\ y &= x_3 - x_1 \end{cases}$$

DELIVERABLES:

Each group should submit a written report with a maximum of 20 pages, including figures and references. All Matlab/Simulink scripts used for the simulations should be made available in a separate zip file. A maximum of 10 slides (PPT, Keynote, or PDF) to be used at the oral presentation should also be submitted at the due date.

- **Deadline for the project submission: 15th January.**
- **Oral presentation of the project (15' + 5' Q&A): 15th January, 10h00-12h00** *(room to be announced)*

EVALUATION:

The Simulation Project is evaluated using the scale "*poor, sufficient, good, very good*" on the following items:

1. The scientific content and in-depth analysis
2. The quality of the written report
3. The final conclusions
4. The quality of the slides
5. The oral presentation and Q&A

20th November 2024

Group 1

108470	Pedro Augusto Pereira Magalhães	pedro.p.magalhaes@tecnico.ulisboa.pt
111000	Francisco Rosado de Carvalho	frc26carvalho@gmail.com

Group 2

98555	Afonso Costa Henrique	afonso.henrique@tecnico.ulisboa.pt
100142	Cátia Sofia Mateus Oliveira	catia.oliveira@tecnico.ulisboa.pt
113051	Andreas Urne	urneandreas@gmail.com

Group 3

100216	Lucas Sequeira e Fonseca	lucas.fonseca@tecnico.ulisboa.pt
100272	Tiago Miguel Brito dos Santos Carvalho Neves	tiagoneves540@tecnico.ulisboa.pt

Group 4

87489	Pedro Miguel Aguilar Catela Geitoeira	pedro.geitoeira@tecnico.ulisboa.pt
96485	Samuel Coelho Teixeira	samuel.teixeira@tecnico.ulisboa.pt

Group 5

11434	Bruno Dos Santos Caetano Brazuna Cândido	bruno.candido@tecnico.ulisboa.pt
429479	Abbasali Ghassemzadehahrami	abbasali@centec.tecnico.ulisboa.pt