Nonlinear Control for Performance: Frequency domain approach

Dates and time

17-04-2023 from 13.45-16.00
24-04-2023 from 13.45-16.00
08-05-2023 from 13.45-16.00
15-05-2023 from 13.45-16.00

Course location

Cursus- en vergadercentrum Domstad, Utrecht

ECTS

3 ECTS if the homework is completed successfully.
1 ECTS for auditing the course

Lecturers

Marcel Heertjes, ASML and Eindhoven University of Technology
Hassan HosseinNia, Delft University of Technology

Objective

Students who complete this course will be able to analyze and design nonlinear control systems, in particular variable gains, reset control, and hybrid integrator gain systems.

In the industry, linear (motion) control technology has succeeded largely because of its ability to be designed and analyzed using frequency-domain techniques with respect to the sensitivity to disturbances (such as external disturbances or measurement noise) as well as uncertainties for example in higher-order plant dynamics. In this context, one can think of the motion control of wafer scanners, printers, optical storage drives, robots, etc. For nonlinear control, however, most of the attention has been focused on simply ensuring stability. To develop high-performance nonlinear controllers, therefore, it is necessary to develop quantitative performance analysis methods for such nonlinear control systems. In this course, we will present several methods to design and analyze high-performance nonlinear control systems in the presence of disturbances using frequency-domain techniques. These techniques can be used to design nonlinear control systems that outperform linear control systems. Numerous industrial applications, such as the (variable-gain) motion control of stages in wafer scanners, objective lenses in optical storage and hard-disk drives, as well as precision positioning stages, illustrate the feasibility of this approach.

Contents

We will cover the following topics in the indicated weeks:

1. Amplitude-based nonlinear control: variable-gain systems
    a. What are variable-gain systems?
    b. Frequency-domain design & stability analysis
    c. Convergence and nonlinear Bode plots
    d. Examples/Assignment
2. Phase-based nonlinear control: hybrid integrator-gain systems (HIGS)
    a. What are hybrid integrator-gain systems?
    b. Describing function analysis
    c. HIGS-PID control design, loop shaping and tuning
    d. LMI-based stability analysis
    e. Examples/Assignment
3. Complex order Control I
    a. What is complex order control
    b. Constant gain Lead phase control (CgLp)
    c. Approximation of complex order control using Reset
    d. Examples/Assignment
4. Complex order Control II
    a. High order describing function open loop
    b. High order describing function closed loop/ Loopshaping
    c. Tuning higher-order harmonics
    d. Example/Assignment

Prerequisites

Knowledge of basic math, control theory, and frequency-domain motion control tuning.

Homework assignments

Homework will be assigned every week.