Universidade do Porto
FEUP Faculdade de Engenharia

Doctoral Programme in Electrical and Computer Engineering at FEUP

Course Description

Course

Title	Language	Level	Term
Nonlinear Control	English	PhD	1

Course coordinator

Name	Category	Institution
Aníbal Castilho Matos	Prof. Aux.	FEUP

Other lecturers (not TA)	Institution
J. L. Martins de Carvalho Sérgio Reis Cunha	FEUP FEUP

Doctoral Programme in Electrical and Computer Engineering at FEUP

Pre-requisites (max 600 characters)

Undergraduate-level course in Linear Systems.

Objectives (max 600 characters)

To introduce a range of tools to analyze nonlinear systems and to introduce nonlinear feedback control design techniques.

Contents (2500-3000 characters)

1 – Introduction. Examples of common electrical, mechanical and artificial nonlinear systems. (1h)

2 - Second-order systems. Phase plane analysis. Equilibrium points. Limit cycles. Numerical phase portrait construction. Existence of periodic solutions. (5h)

3 – Study of the ordinary differential equation dx/dt = f(t,x). Fundamental properties: existence, uniqueness, continuous dependence on initial conditions, and continuous dependence on parameters. (2h)

4 - Lyapunov stability. Fundamental theorems of Lyapunov method for time invariant system. LaSalle's invariance principle. Stability properties of time invariant linear systems and linearizations. Time-varying nonlinear systems. Stability properties of time-varying linear systems and linearizations. Converse theorems (necessary and sufficient conditions for stability). Boundedness of solutions. Input to state stability. (9h)

5 - Input-output stability. L stability. L stability of state models. L2 gain. L stability of feedback connected systems. Small gain theorem. (3h)

6 – Passivity. Passivity of the memoryless function y=h(t,u). Passivity for nonlinear dynamical systems. Characterization of passive and strictly passive linear systems. L2 and Lyapunov stability. Passivity theorems for feedback systems. (4h)

7 – Frequency domain analysis of feedback systems. Absolute stability. Circle and Popov criteria. The describing function method. (2h)

8 - Feedback control. Control problem formulations. Classical design tools: stabilization via linearization, integral control and gain scheduling. (3h)

9 - Feedback linearization. Input-output linearization. Full state linearization. State feedback control of feedback linearizable systems (stabilization and tracking). (4h)

10 - Nonlinear design tools. Sliding mode control. Lyapunov redesign. Backstepping. Passivity based control. Extensions to output feedback (high gain observers). (8h)

Main Bibliography (max 1000 characters)

Adopted Book:

Khalil, H. K., *Nonlinear Systems*, 3rd edition, Prentice-Hall, 2002.

Other References:

Sontag, E. D., *Mathematical Control Theory*, 2nd edition, Springer, 1998.

Software (max 600 characters)

MATLAB / Simulink

Teaching (max 600 characters)

There will be expository lectures in the end of which a list of problems are proposed. Such lectures are followed by discussion classes to treat problems assigned on the subject.

Assignments (max 1200 characters)

A set of problems will be handed out to the students every week and should returned the week after.

Grading policy (max 400 characters)

The components for student evaluation are:

- Weekly homework assignments.
- Exam: Mid Term exam and a Final exam.

Each component will receive a grading in percentage.

The final score will be calculated according to the following rule:

0,3*HW + 0,2*MTE + 0,5*FE

where HW stands for homework assignment, MTE for Mid term exam and FE for Final exam.

Grading will be either PASS or FAIL.

A PASSing grade corresponds to a minimum of 2/3 of the maximum score.

Evaluation procedure for students under special legal provisions

These students will be subject to all evaluation procedures of regular students, i.e., they must deliver their assignments specified during the course plus any special works also specified plus a final exam, the only difference towards regular students being that they are not required to attend classes and deliver assignments in the same dates as regular students, in the cases the law specifically states it.

Improving grades

Not applicable in a PASS/FAIL policy.