PhD Course announcement

Title: Introduction to Control Theory

Lecturers: Prof. Mario di Bernardo
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Credits: 6

Bio notes

Mario di Bernardo is a Full Professor of Automatic Control at the University of Naples Federico II, Italy, and also serves as a Visiting Professor at the University of Bristol, U.K. He holds the title of Deputy pro-Vice Chancellor for Internationalization at the University of Naples and oversees the research area and PhD program on Modeling and Engineering Risk and Complexity at the Scuola Superiore Meridionale.

Mario di Bernardo has been recognized for his work in the analysis, control, and applications of nonlinear systems and complex networks. He was honored with the title of Cavaliere of the Order of Merit of the Italian Republic in 2007. He became a Fellow of the IEEE in 2012 for his contributions to the field. He has held various leadership positions in professional societies, including President of the Italian Society for Chaos and Complexity and roles within IEEE societies such as member of the Board of Governors of the Circuits and Systems Society and the Control Systems Society.

His research interests include complex networks, piecewise-smooth dynamical systems, nonlinear dynamical systems, and nonlinear control, with applications in engineering and synthetic biology. He has published extensively in scientific journals, authored a research monograph, and edited two books. Mario di Bernardo's scholarly impact is reflected in his h-index of 51 and citation count, with over 11,000 citations according to SCOPUS. He has received awards such as the IEEE George N. Saridis Best Transactions Paper Award. Additionally, he has been involved in editorial roles in scientific journals and conferences.

He has organized scientific initiatives and events and secured funding from various sources, including the European Union, UK research councils, and the Italian Ministry of Research and University.

Overview

This course will introduce you to the fundamental concept of "feedback" in dynamical systems and to the mathematical foundations of Control Theory. Control theory is the "Science of Feedback" and Mathematical Control Theory a branch of Applied Mathematics whose recent developments have made possible, for example, the implementation of autopilots on airplanes and the landing of automatic interplanetary probes on Mars. Nowadays, novel challenges have arisen which require a proper mathematical understanding. Hybrid Control, Internet congestion control and the control of multiagent systems are just some examples of recent applications of control theory.

Aims:

The course is intended to introduce to the mathematical foundations of Control Theory. The aim of the course is to allow you to develop new skills and analytical tools required to analyse and design methods for the control of both linear and nonlinear dynamical systems.

Intended Learning Outcomes:

By the end of this course, you will be able to use appropriate analytical tools to analyse and control a given dynamical system of interest. Specifically, we will discuss how to:

1. Analyse the controllability, observability and stabilizability of a dynamical system.
2. Develop state feedback controllers to change the evolution of a dynamical system of interest.
3. Synthesize observers to estimate the states of a dynamical system.
4. Optimize the control system design to minimize the control energy spent or achieve control in minimum time.
5. Tame the dynamics of nonlinear dynamical systems and exploit chaos and bifurcations for control system design.

Venue: Scuola Superiore Meridionale, Largo S. Marcellino, 10, 80138 Napoli NA.

Schedule

Lecture	Date	Time	Topics
1	**11/4/2024**	**17:30-19:30**	**Review of fundamental concepts from Dynamical Systems (Part I)**
2	**12/4/2024**	**17:30-19:30**	**Review of fundamental concepts from Dynamical Systems (Part II)**
3	**16/4/2024**	**17:30-19:30**	**Features design**
4	**18/4/2024**	**17:30-19:30**	**Control Systems modelling (Part I)**
5	**19/4/2024**	**17:30-19:30**	**Control Systems modelling (Part II)**
6	**23/4/2024**	**17:30-19:30**	**Stability of feedback systems (Part I)**
7	**26/4/2024**	**17:30-19:30**	**Stability of feedback systems (Part II)**
8	**27/4/2024**	**10:30-12:30**	**Controllability of feedback systems (Part I)**
9	**30/4/2024**	**17:30-19:30**	**Controllability of feedback systems (Part II)**
10	**2/5/2024**	**17:30-19:30**	**Observability and linear observer theory (Part I)**
11	**3/5/2024**	**17:30-19:30**	**Observability and linear observer theory (Part II)**
12	**7/5/2024**	**17:30-19:30**	**Controllability and Observability Canonical Forms**
13	**9/5/2024**	**17:30-19:30**	**State Feedback Control (Part I)**
14	**10/5/2024**	**17:30-19:30**	**State Feedback Control (Part II)**
15	**14/5/2024**	**17:30-19:30**	**Output Feedback Control (Part I)**
16	**16/5/2024**	**17:30-19:30**	**Output Feedback Control (Part II)**
17	**17/5/2024**	**17:30-19:30**	**Control Design (Part I)**
18	**21/5/2024**	**17:30-19:30**	**Control Design (Part II)**
19	**23/5/2024**	**17:30-19:30**	**Optimal Control (Part I)**
20	**24/5/2024**	**17:30-19:30**	**Optimal Control (Part II)**
21	**28/5/2024**	**17:30-19:30**	**Elements of nonlinear control (Part I)**
22	**30/5/2024**	**17:30-19:30**	**Elements of nonlinear control (Part II)**
23	**31/5/2024**	**17:30-19:30**	**Control of multiagent systems**

Content details

Lesson 1-2 – An introduction to feedback control in Science and Engineering: Brief history of automatic controls; Types of control (open loop, closed loop); Examples of applications; A representative example; Characteristics of feedback systems; Components of a control scheme; Dynamical Systems and Modeling Review.
Lesson 3-5 – Control Systems modelling: Representations of a dynamical system; State space representation; Representation in the frequency domain; Simulation of the systems in MATLAB/Simulink.
Lesson 6-9 – Stability and Controllability of feedback systems: Definition of stability and stability criterion; Stability for linear systems; BIBO stability; Stability analysis using Lyapunov direct method; Local vs global stability; Controllability definition and criterion; Interpretation of controllability; Positive controllability.
Lesson 10-11 – Observability and linear observer theory: Observability definition; Observability test and interpretation; Observation problem; Observer design for linear systems; Separation principle.
Lesson 12 – Controllability and Observability Canonical Forms: Controllability canonical form and transformation; Observability canonical form and transformation.
Lesson 13-18 – State and Output Feedback Control: State feedback control scheme; pole placement method for the design of state feedback controllers; Extensions of state feedback control (State feedback + Feed forward action, State feedback + Integral action); Output feedback controllers; Controllers in the frequency domain; PID controllers**.**
Lesson 19-20 – Optimal Control: Definition of optimal control problems; Pontryagin's minimum principle, Linear Quadratic Regulator; Riccati Equations.

Lesson 21-23 – Elements of nonlinear control and the control of multiagent systems: Introduction to nonlinear systems; Phase portrait analysis; Elements of control of nonlinear systems; Introduction to multi-agent and networked systems; elements of control of multi-agent systems.

The exam consists of an oral interview on the topics of the course starting from the discussionof a case study chosen by the student.

Readings/Bibliography

1. Course notes
2. Feedback Systems: an introduction for Scientists and Engineers, K Astrom, R. Murray, Princeton University Press
3. Primer on Optimal Control Theory, Speyer, Jacobson, SIAM Press
4. Mathematical Control Theory, E. Sontag, Springer (more advanced)

The course is in presence.

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