Scuola di dottorato SIDRA 2024
"Introduction to the Analysis and Control of Nonlinear Systems"

Teacher: Lorenzo Marconi (Università di Bologna)

School Objectives

Over the last 30-35 years the literature of nonlinear control systems has seen the steady development of systematic methods for stabilization "at large" of non-linear dynamics. The interest towards local analysis and design tools characterizing the specific literature before the 90's have been substituted by "Lyapunov-based" quantitative approaches for the study of nonlinear systems, described by possibly uncertain models, not necessarily near an equilibrium point. The research attempts in this direction brought to a stabilization and regulation theory for nonlinear systems, both by state and output feedback, which has now reached a mature stage.

In this context the goal of the course is to introduce some techniques recently proposed for the analysis and robust stabilization by state and output feedback of nonlinear systems. Both basic methodological aspects and advanced techniques recently proposed in the literature will be addressed. The main objective of the school is to present the topics in a self-contained and systematic way in order to deeply understand the proposed techniques. More in detail, the program of the PhD school articulates in the following way.

The first day is entirely devoted to introduce basic methodological tools that will be then used in the sequel of the school. After a brief introduction to nonlinear dynamics and their distinguishing features with respect to linear dynamics, stability notions and Lyapunov criteria will be presented. Tools for the analysis of nonlinear systems in presence of exogenous inputs will be also addressed, by presenting the notion of Input-to-State Stability and of passivity, their Lyapunov characterizations, and the study of stability of interconnected systems by means of the small-gain theorem. During the second day, the class of system described in normal form will be introduced. In this framework particular emphasis will be given to the concepts of relative degree and of zero dynamics for nonlinear systems, by naturally extending the notion of minimum-phase to the nonlinear context. Global and semiglobal design stabilization techniques by state feedback will be then described with reference to the class of systems described in normal form. In this context, systematic design tools that are nowadays ordinarily used, such as the "backstepping", will be presented.

The final half-day will be then devoted to the problem of output feedback stabilization. In particular, a nonlinear separation principle based on the design of nonlinear observers for systems described in an observability form will be presented.

Teaching aids and instructional materials: Only blackboard will be used during the school. The teaching aids are given by a selected set of books and collection of handouts.

Course Language: English

Program

Monday July 8th 2024		Tuesday July 9th 2024		Wednesday July 10th 2024	
8:30 – 10:00	Introduction to the course and to nonlinear phenomena	8:30 – 10:15	Normal form for nonlinear systems and feedback linearization	8:30 – 10:15	Nonlinear Observers and nonlinear separation principle
10:45 – 12:45	Stability notions for nonlinear systems. Lyapunov criteria	11:00 – 12:45	Zero Dynamics of nonlinear systems	11:00 – 12:45	Nonlinear Observers and nonlinear separation principle
15:00 – 16:30	Nonlinear systems with input – Input-to-State Stability	15:00 – 16:30	Global, semiglobal and practical stabilizability		
17:00 – 18:30	Stability of interconnected systems	17:00 – 18:30	Global, semiglobal and practical stabilizability		