Analysis tools for the stability and robustness of nonlinear systems

– PhD course - June/July 2007 –

Summary. This postgraduate course aims at giving an overview of some representative tools for the stability and robustness analysis of nonlinear dynamical systems. After reviewing classical Lyapunov stability results, which will constitute a good pretext to introduce the so convenient formalism offered by comparison functions, the notions of *Input-to-State Stability* (ISS) and *Integral Input-to-State Stability* (iISS) will be introduced. While both these notions guarantee interesting robustness properties with respect to external perturbations, we will see that they differ in many aspects, ISS being a much stronger (hence conservative) property than iISS. For both these concepts, simple yet powerful tools will be presented in order to establish them in practice. We will also present control techniques that guarantees ISS or iISS with respect to external disturbances or actuation errors.

We will then focus on properties that arise frequently for controlled system in presence of non-vanishing disturbances, model imprecision, actuator limitations, *etc.* : namely, the *semiglobal* and/or *practical* stability. After having introduced these notions in an intuitive way and presented some typical situations in which these properties may appear as well as the information they provide on the system, we will present Lyapunov sufficient conditions for them to hold.

Finally, based on this framework, we will present tools that simplify the stability and robustness study of complex systems. These tools exploit the fact that many systems may be decomposed, either naturally or by control design, into an interconnection of simpler subsystems. We will present results that guarantee the preservation of ISS, iISS and semiglobal and/or practical stability when the subsystems are interconnected in cascade. The small gain theorem for ISS systems, but also for possibly more general systems, will finally give a powerful answer to the case of a feedback interconnection between the subsystems.

All notions will be presented in a uniform, concise and intuitive manner. Many results will be proven in order to give more insight to the participants of the involved challenges and to present technical tools that may have interest as their own. Many academic examples will be presented along the course in order to fix the ideas, and concrete applications will be evoked.

Organization. This course represents a total of 14 hours for 4 credits CFU. In addition, a 2 hours written exam is planned at the end of the course. The lectures will be given in the **Aula Didattica of the DSEA department** (Facoltà di Ingegneria di Pisa) at the following dates :

- 13/06 : from 10 AM to 12 AM and from 2 PM to 4 PM.
- 20/06 : from 10 AM to 12 AM and from 2 PM to 4 PM.
- 27/06 : from 2 PM to 3.30 PM and from 4 PM to 5.30 PM.
- 04/07 : from 2 PM to 3.30 PM and from 4 PM to 5.30 PM.
- 11/07 : from 10 AM to 12 AM (exam).

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