MED'2015 TUTORIAL

QUANTITATIVE FEEDBACK CONTROL AND RESET CONTROL: FUNDAMENTALS AND APPLICATIONS

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Quantitative Feedback Theory (QFT) is a well-established robust control design framework, that have been developed by a number of researchers around the seminal works of Isaac M. Horowitz (1920-2005). After pioneering frequency domain control design for uncertain systems in the 1960s, the first stone of QFT appears in 1972 as the result of a fruitful collaboration with Marcel Sidi. In this work, mainly focused on single input-single output, linear, and time invariant uncertain systems, Nichols chart (NC) first appears to be instrumental in the uncertainty representation (templates), as well as in the modeling of stability and performance specifications (boundaries). As a result, the robust control design problem is stated as a nominal loop gain shaping problem: minimization of the high frequency gain restricted to the frequency response to avoid forbidden regions of NC as defined by boundaries. A large number of works by researchers over the world, and mainly led by Isaac M. Horowitz that kept active for all his life, has extended QFT to cope with a variety of robust control design problems, including multiple-inputs multiple-outputs systems, nonlinear and time-varying systems, systems with hard nonlinearities (amplitude and rate saturation), multi-loop systems, etc. In addition, since its origins QFT has been successfully applied in control practice, solving hard control problems in which the robustness/performance interplay is specially relevant. Experimental applications can be found in many engineering areas including aerospace, naval, chemical, automotive, civil, energy, etc.

Reset control systems trace back to the seminal work of Clegg in 1958, that introduced a nonlinear integrator that sets its output to zero whenever its input is zero. Almost two decades later, two works led by Horowitz propose design methods to incorporate a Clegg integrator (CI), and also a first order reset element (FORE), into a control loop. In the late 90s, the term reset controller is finally coined in the works led by Hollot and Chait to describe a linear and time invariant system with mechanisms and laws to reset their states to zero, being the main motivation its use for overcoming fundamental limitations of linear and time invariant (LTI) control systems. Since reset controller dynamics is a combination of time and event based dynamics, it is not surprising that in the last decade different impulsive/hybrid dynamical system formulations were used for modeling and analysis of reset control systems. There are two main frameworks that has been successfully used for modeling reset control systems: the framework of impulsive dynamical systems (IDS), and the framework of hybrid inclusions (HI).

Tutorial scope

The tutorial will be focused on single-input single-output systems, and will introduce basic concepts as well as control systems analysis and design methods, with emphasis in control practice but showing solid mathematical basis. The tutorial will be developed (tentatively) in two 50 min. sessions, with the following schedule:

QFT for LTI systems.

- Uncertainty representation (templates)
- Design specifications: robust stability and performance (boundaries)
- Two-degrees of freedom feedback control systems
- Loop gain shaping: from manual to automatic procedures
- Precompensator design
- CADCS Tools and Applications

QFT for nonlinear and time-varying systems.

- "Equivalent" LTI systems and disturbances sets
- Design validation through Schauder fixed point theorem
- Stability and Performance analysis
- Case study

Reset control systems: an IDS approach.

- Overcoming LTI fundamental limitations
- Resetting law: zero-crossing, sector-based, reset band, and more.
- Well-posedness, Zeno solutions and time regularization
- Stability Analysis with stable and unstable base system

- A QFT approach to reset control design
- The PI+CI compensator
- Case study

Bibliography

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Speaker

Alfonso Baños is a graduate and doctor in Physics at Universidad Complutense (Madrid) in 1987 and 1991, respectively. His doctoral work was performed at the Instituto de Automatica Industrial (C.S.I.C), in the area of nonlinear control system. In 1992, he joined the Universidad de Murcia where he is currently Full Professor in Systems and Control Engineering. He has been visiting several research groups with pre- and postdoctoral stays, in University of Strathclyde at Glasgow, University of Minnesota at Minneapolis, and University of California at Berkeley. He has led numerous research projects at local, national and european level, and also several technological transfer projects with for example "Centro

Tecnologico de la Conserva", "Centro Tecnologico del Metal", and "MTorres Ingeniera de Procesos". He has published over 110 works in journals and international conferences and holds 3 patents. His research activity has been focused both on control theory, mainly in robust control (QFT) and impulsive/hybrid control (reset control), and control practice with several industrial applications (robotics, process control, thermosolar plants, etc.).

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