Preface

The purpose of this volume in the newly established series Advances in Delays and Dynamics (ADD@S) is to provide a collection of recent results on the design and analysis of *Low Complexity Controllers for Time Delay Systems*.

It is widely recognized that mathematical models of many man-made or natural dynamical systems contain time delays. Common sources of delays in engineering applications and in physical sciences are transport lag, queuing, processing and propagation time delays, as well as non-negligible computational time. For example, in data communication networks, while packets travel from source to destination they experience propagation delay due to physical distance between the two ends; processing and queuing at the routers may also contribute significantly to the end-to-end delay. Therefore, a challenging aspect of control over networks (for example tele-operations) is to compensate the effect of such time delays, which may very well be time varying. Typically, complex interconnected (networked) systems contain multiple time delays between various sub-systems and agents; these delays have be taken into account in the solution of related networked control problems such as synchronization, coordination, consensus, etc. Besides lumped time delays, where the delay value is a single parameter, distributed delay models are also used in various applications, ranging from chemical and biological processes to economics.

In the literature many different techniques have been proposed for the analysis and control of time delay systems. Widely used techniques include Lyapunov-based analysis and design in the time domain, and spectral methods in the frequency domain. The reader will find examples of these techniques in this volume. However, there is one common theme in all the chapters included here, that is, contributions towards *low complexity* controller design. Since time delay systems are special cases of infinite dimensional systems, general analysis and design methods developed for infinite dimensional systems work for systems with time delays as well. One way to obtain *low order* controllers for such systems is to design a controller for the "reduced order model of the plant." Another way is to design an infinite dimensional controller for the original plant model, then to do model order reduction for the controller, keeping track of the degradation in performance and stability robustness measures. These classical indirect methods for low order controller design have been widely discussed in the literature. Some of the papers in the present volume propose *new direct design methods* for fixed structure and low order controllers.

An important point to emphasize here is that what is meant by *low complexity* controller is not necessarily low order controller. For example, Smith predictor or similar type of controllers include a copy of the plant internally in the controller, so they are technically infinite dimensional. However, the impulse response of $(1 - e^{-Ts})/s$, appearing in a Smith predictor-based control structure, is of finite duration, i.e., it is nonzero on the time interval from 0 to T. So, its sampled-data implementation is an FIR filter whose dimension is $\lceil T/T_s \rceil$, where T_s is the sampling time. Moreover, FIR filters, being cascade banks of unit delays, have very nice numerical properties from the point of reliable implementation. Therefore, such predictor-based controllers are considered as low complexity. Similarly, although they are infinite dimensional, repetitive controllers can also be considered as low complexity.

The chapters in this volume deal with several aspects of low complexity controller design for systems with time delays. The main ideas of the individual chapters included here have been presented and discussed at the First Workshop organized by the International Scientific Research Network on Delay Systems (GDRI "*DelSys*), coordinated by the CNRS (French National Center for Scientific Research). The workshop was held in November 2012 at the *Laboratory of Signals and Systems* (a common research organization between CNRS, Supelec and University Paris-Sud), Gif-sur-Yvette, France.

The book is divided into three Parts: (I) Design Techniques, (II) Numerical Methods, and (III) Applications. Descriptions of the chapters contained in these three parts are given below.

Part I: Design Techniques

Part I of the book focusses on design techniques for time delay systems. In the following chapters, careful attention has been paid to the development of control algorithms which have a low complexity.

The first chapter by *C. Fiter, L. Hetel, W. Perruquetti* and *J.-P. Richard* deals with the development of online controller using a state-dependent sampling policy. The second chapter proposed by *H. Özbay* and *A.N. Gündes* is concerned with the design of first order controllers for unstable infinite dimensional plants. The third chapter provided by *P. Zitek, J. Bušek* and *T. Vyhlídal* proposes a new antiwindup conditioning scheme against actuator saturation in internal model control with delays. The next contribution in Part I is by *L. H. V. Nguyen* and *C. Bonnet*; this chapter considers a class of fractional neutral delay systems with an infinite number of poles asymptotic to the imaginary axis, a parameterization of all stabilizing controllers is obtained from fractional PI controllers designed earlier. The chapter by *C. Moussaoui, R. Abbou* and *J.-J. Loiseau* cope with the design of controllers for a class of delayed and constrained systems. Part I of the book ends with contributions from *A. Quadrat* and *A. Quadrat*, on the controller structure for automatic visual tracking on a mobile platform; in particular, delay effects are studied and low order controllers are compared.

Part II: Numerical Methods

Part II is dedicated to useful numerical methods for the analysis and design of controllers with reduced complexity for time-delay systems. The first paper by *S. Gumussoy* and *W. Michiels* proposes a tuning method for a fixed order and structure H_∞ controller for interconnected systems with delays. In the second contribution by *A. Baños, F. Pérez Rubio, S. Tarbouriech*, and *L. Zaccarian*, reset controllers are proposed for systems with delay in the state, that achieve delay-independent stability of the closed loop. The paper by *S. Olaru, N. Stanković, G. Bitsoris* and *S.-I. Niculescu* presents reduced complexity invariant sets for linear time-delay systems. The contribution by *D. Danciu* and *V. Răsvan* introduces new results in low order controller design using the method of lines for systems of conservation laws. In the last paper, by *A. Seuret* and *F. Gouaisbaut*, an alternative inequality to the Jensen's one is proposed to obtain tractable LMI conditions with reduced conservatism on the stability conditions, allowing then a more efficient analysis of control of delay systems by output feedback.

Part III: Applications

The last part of the book exposes several low complexity controller designs for time-delays systems with specific industrial applications such as oil-well drilling systems, haptic manipulators interfaces, and temperature control in SI engine exhaust catalyst.

The first chapter by *D. Bresh-Pietri, T. Leroy* and *N. Petit* deals with the control oriented input-delay model of the distributed temperature of a SI engine exhaust catalyst. The next two chapters focus on control of drilling systems. The one by *B. Saldivar, S.Mondié* and *A. Seuret* addresses modeling and control of the stick-slip phenomenon in oil-well drill-strings. The chapter by *T. Knüppel, F. Woittennek, I. Boussaada, H. Mounier* and *S.-I. Niculescu* propose a flatness-based control approach for suppressing vibrations occurring along a rotary oil-well drilling system. Finally, the last chapter of the book by *B. Liacu, I-C. Moraărescu, S.-I. Niculescu, C. Andriot, D. Dumur, F. Colledani* and *P. Boucher* presents low complexity control architectures for haptic interfaces subject to communication delays; the chapter includes an extensive experimental comparative study.

We would like to thank the managing editors of the Springer book series *Advances in Delays and Dynamics* (ADD@S), Dr. Thomas Ditzinger and Dr. Silviu-Iulian Niculescu, for their close collaboration and careful reading of the manuscript.

Their suggestions have significantly improved the overall quality of the present volume.

November 2013

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http://www.springer.com/978-3-319-05575-6

Low-Complexity Controllers for Time-Delay Systems
Seuret, A.; Özbay, H.; Bonnet, C.; Mounier, H. (Eds.)
2014, XVI, 238 p. 61 illus., 11 illus. in color., Hardcover
ISBN: 978-3-319-05575-6