Editorial

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1 Introduction

Over the last two decades, there has been tremendous interest in studying the observability and in designing observers for non-linear systems. This is because filtering and reconstruction of signals play a fundamental role in signal processing, telecommunications and control theory and are used in numerous applications. In spite of the extensive efforts supplied in these research activities, many problems of observation remain opened and really constitute a main challenge. The purpose of this Special Issue is to bring together the main aspects of new theoretical results and practical applications related to observer's synthesis design.

2 Focus on this Special Issue

In the paper by Fliess, Join and Sira-Ramírez, non-linear state estimation and some related topics like parametric estimation, fault diagnosis and perturbation attenuation, are tackled via a new numerical differentiation methodology. The corresponding basic system definitions and properties are presented within the framework of differential algebra. This permits the handling of system variables and their derivatives of any order. The theory is illustrated through several academic examples with numerical simulations.

In the last decade, the LMI techniques have been intensively used to synthesise observers for non-linear observers which can be described by a constant linear part, used to compute the observer gain and a non-linear part which is assumed to be globally Lipschitz. LMI techniques are used in the paper by Zemouche, Boutayeb and Lara to synthesise an observer for a class of non-linear systems with time-delay. This work is a generalisation of the results performed by Rajamani for a class of standard non-linear systems.

The multiple model approach is a tool for modelling real-world complex processes. In this modelling framework, a judicious combination of a set of submodels makes it possible to describe the behaviour of a non-linear system. The

problem of state estimation of non-linear systems represented by this structure is investigated in the paper by Orjuela, Marx, Ragot and Maquin.

In the paper by Panzieri, Pascucci and Setola, the authors focus their research efforts on the Simultaneous Localisation and Mapping (SLAM) of the surroundings problem, which is of non-linear nature and leads to computational challenges. The authors propose a new estimation algorithm called the Interlaced Extended Kalman Filter (IEKF) which enjoys two major features:

1 it results in a nice decomposition of the overall high-dimensional estimation problem into a number of subproblems and through this reduction, it leads to considerable computational gains

2 it copes with the system non-linearities through the use of an EKF, thus providing a non-linear analogue of the previously introduced IKF.

A case study and experimental findings are given to corroborate the merits of the proposed method.

High gain observers are used in the paper by Galeani, L. Menini, A. Tornambè and by Zhang and Besançon. In the first one, the authors consider a simple mechanical system subject to unilateral constraints and impacts and propose an observer to estimate the velocity and the coefficient of restitution. The theory is illustrated by many numerical simulations and an experiment validation. In the second paper, the authors propose an adaptive observer for sensor fault estimation for a class of uniformly observable non-linear systems. More specifically, the global convergence of the adaptive observer is established, thanks to the well known persistent excitation condition.

Unlike the above papers which deal with the observer synthesis for continuous-time systems, the paper by Xiao, Kazantzis and Kravaris focuses on the sampled data systems. Indeed, the authors give a set of conditions, under which a non-linear discrete-time observer inducing linear estimation error dynamics exists for non-linear smooth discrete-time systems. In particular, the existence of a homeomorphism in state space is established that maps the orbits of a linear system with an output injection term onto the observing system, implying the existence of an invariant attracting manifold for the extended system. Within the above framework, it is shown that the discrete-time version of the Hartman-Grobman Theorem can be naturally reproduced as a special case. The performance of the proposed non-linear discrete-time observer is evaluated in two representative case studies, where two different dynamical systems of the Lozi and Hénon-type are considered that exhibit non-linear and chaotic behaviour.

The lack of cheap and reliable instrumentation for the online measurement of the relevant variables in biochemical processes definitely constitutes a serious obstacle for the development of the latter. In order to overcome this problem, intensive researches have focused on the synthesis of software sensors that allow the estimation of the key parameters inside chemical reactors. Two papers dealing with the development of software sensors for chemical reactors are selected in this Special Issue. The paper by Sauvage, Guay, Perrier, Monge and Dochain presents an overview of recent results dealing with the synthesis of state observers for a class of non-linear exothermic fed-batch chemical reactors. The proposed techniques deal with kinetics and heat transfer uncertainties which are frequently encountered in fed-batch processes. The presentation of the different approaches is organised by following the level of knowledge with respect to each kind of uncertainties. Another paper related to parameter estimation in chemical processes by Alamir, Sheibat-Othman and Othman is concerned with the design of a non-linear receding-horizon observer for state reconstruction in batch terpolymerisation reactors. The related investigations show that the state reconstruction problem may be quite ill conditioned in the sense that different states may exist that lead to roughly the same output. It seems however, that when constrained receding-horizon estimation is used together with a dedicated crossing singularity heuristic, state reconstruction is possible even in the presence of measurement noise and up-to 10% error on the r.h.s of the ODE's describing the system's dynamics. The efficiency and the real-time implementability of the overall scheme is shown through illustrative scenarios including both simulation and experimental validation.

We believe that the nine contributions presented in this Special Issue allow to give an overview on some available approaches dealing with the design of non-linear observers and their use in practical applications.