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Observers design for uncertain Takagi–Sugeno systems with unmeasurable premise variables and unknown inputs. Application to a wastewater treatment plant

A.M. Nagy Kiss[a,*], B. Marx[a], G. Mourot[a], G. Schutz[b], J. Ragot[a]

[a] Centre de Recherche en Automatique de Nancy, UMR 7039 – Nancy-Université, 2, Avenue de la Forêt de Haye, 54516 Vandœuvre, France
[b] Centre de Recherche Public "Henri Tudor", LTI Unit Business and Systems Analytics, 29, Avenue John F. Kennedy, L-1855 Luxembourg-Kirchberg, France

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ABSTRACT

This article aims the observer synthesis for uncertain nonlinear systems and affected by unknown inputs, represented under the multiple model (MM) formulation with unmeasurable premise variables. A proportional integral observer (PIO) is considered. In order to design such an observer, the nonlinear system is transformed into an equivalent MM form. The Lyapunov method, expressed through linear matrix inequality (LMI) formulation, is used to describe the stability analysis and for the observer synthesis. An application to a model of wastewater treatment plant (WWTP) is considered and the performances of the proposed approach are illustrated through numerical results.

1. Introduction

In the field of the observer/controller synthesis, the extension of linear methods to nonlinear systems is generally a difficult problem since there is no general and systematic approach for the nonlinear case. The existing results are obtained for particular cases of nonlinear systems: bilinear systems, Lipschitz nonlinearities, LPV systems, etc. Several approaches are reported in the literature along the last decades in order to design observers for nonlinear systems: the extended Kalman filtering [1,2], the methods based on Lyapunov functions [3,4], the methods based on coordinate transformation using canonical observer forms [5,6], the high gain observers [7,8] or sliding mode observers [9,10] are only a few of them.

The multiple model (MM) [11] – also called in the literature Takagi–Sugeno fuzzy model [12] – has received a special attention in the last two decades, due to its ability to generalize some linear tools to the nonlinear case [13]. The MM is mainly based on the idea of a complexity reduction of nonlinear systems, by aggregating linear submodels using weighting functions [12]. Several techniques [14–16,13] were developed in order to obtain such a structure from a general representation of a nonlinear system. Then the MM approach is a mean to deal with nonlinear systems and to design observer for such systems [17–22]. In observer/controller designs, the MM approach allows to avoid the need of Lipschitz hypothesis like [3,4] does. In [5,6] some structural constraints for the nonlinear system are requested whereas it is not the case in the MM framework. For the sliding mode observers [9,10], the chattering effect is an important inconvenience, since a high frequency oscillation is produced. Also, some Lipschitz structural constraints are needed in order to overcome the mentioned inconvenience.

In this paper, the MM formulation is obtained by applying a method proposed in [23] to represent nonlinear systems into an equivalent MM. Only the general steps of this technique are reminded in this paper. The major inconveniences of the previous works are avoided: the transformation is realized without loss of information, the obtained system has exactly the same state trajectory as the initial system, the choice of different linearization points is no longer necessary.

The MM under study in this paper involves unmeasurable premise variables depending on the state variables. Most of the

* Corresponding author. Tel.: +33 6 42 57 98 18.
E-mail addresses: anca-maria.nagy@ensem.inpl-nancy.fr (A.M. Nagy Kiss), benoit.marx@ensem.inpl-nancy.fr (B. Marx), gilles.mourot@ensem.inpl-nancy.fr (G. Mourot), georges.schutz@tudor.lu (G. Schutz), jose.ragot@ensem.inpl-nancy.fr (J. Ragot).

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