ROBUST NONLINEAR CONTROL OF A CLASS OF NONLINEAR PROCESSES: APPLICATION TO WASTEWATER TREATMENT

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Abstract— **In this paper we propose a robust error feedback controller for nonlinear bioprocesses that allows us to track predetermined constant and/or oscillatory profiles while attenuating the disturbances and maintaining the stability conditions of such bioprocesses. Various numerical case studies for an anaerobic digestor model are conducted to test the robustness properties of the proposed controller. It is found that the proposed controller yields excellent responses in the face of parameter uncertainties, load disturbances and set-point changes.**

Keywords— **Robust control, Nonlinear processes, Anaerobic digestion.**

I INTRODUCTION

The severity of the non-linearities in bioprocesses influences the selection of control algorithms for their successful regulation or trajectory tracking control. Control strategies based on a linearized model have shown to yield unsatisfactory performances if the process is subject to large disturbances or significant set-point changes. In addition, the wide range of operating conditions encountered in start-up, shut-down or trajectory tracking of bioprocesses, also pose an important challenge for the application of nonlinear control techniques. In the last two decades, a number of nonlinear control schemes, ranging from nonlinear control based on differential geometric approach (Kravaris and Kantor, 1990), nonlinear model predictive control (Patwardhan *et al.*, 1990) and generic model control (Lee and Sullivan, 1988), have been developed to overcome such problems with limited success since they largely rely on the availability of a good process model, which is not always easy to obtain. In the particular case of bioprocesses, these are complex with poorly understood bioreaction kinetics which usually lead to models with uncertain and/or time varying parameters. These cases are best handled with robust nonlinear control strategies in order to fully meet closed-loop objectives such as tracking, regulation and disturbance attenuation.

In this work, a robust nonlinear model-based control technique is proposed to track predetermined trajectories of nonlinear dynamic bioprocesses under the influence of uncertain parameters and load disturbances. This robust regulator, is an error feedback controller which relies on the existence of an internal model, obtained by finding, if possible, an immersion of the exosystem dynamics into an observable one, which allows to generate all the possible steady state inputs for the admissible values of the system parameters (Isidori, 1995). We illustrate the performance of the proposed control scheme by applying it, via numerical simulations, for the trajectory tracking and disturbance attenuation in an anaerobic digestion (AD) process under the most uncertain conditions. This paper is organized as follows: Section II gives an overview of the theory behind the robust control scheme; a nonlinear dynamical model for a typical AD process is presented in Section III; and the error feedback controllers are developed for three study cases: regulation control, oscillatory disturbance rejection and trajectory tracking. Simulation results and discussion are presented in Section V. Finally, we close the paper with some concluding remarks.

II ROBUST REGULATION PROBLEM FOR NONLINEAR SYSTEMS

Let us consider the following nonlinear system

$$\dot{x} = f(x,u,w,\lambda), \quad (1)$$
$$\dot{w} = s(w), \quad (2)$$
$$e = h(x,w,\lambda), \quad (3)$$

where $x \in \mathcal{R}^n$, $u \in \mathcal{R}^m$ are the state and input variables of the process, respectively; $\lambda \in \mathcal{R}^s$ denotes a parameter vector which may take values in a neighborhood $\wp \subset \mathcal{R}^s$ of the nominal ones; $w \in \mathcal{R}^q$ represents the state of an external signal generator -the