Chapter 12
Convex Polytopic Modeling of Discrete Time Nonlinear Singularly Perturbed System

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ABSTRACT

In this work, the authors propose an analytical and systematic technique to represent the discrete non-linear singularly perturbed system (SPS) by a coupled state multimodel (MM). This approach is realized without loss of information. This strategy can be applicable to any order SPSs. Another significant characteristic of this technique is to choose between several quasi-LPV forms of the nonlinear system that lead to specific properties of the multiple model structure. Also, the obtained MM has the same state trajectory as the initial nonlinear SPS. Therefore, a set of criteria is provided utilizing the formulation of linear matrix inequality (LMI) to select the most appropriate MM for analysis, observation, or control purposes. A simulation example and a tunnel diode circuit are given to validate the effectiveness of the proposed technique.

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INTRODUCTION

In the context of modelling a physical process, different theories have been developed, depending on the type and characteristics of the models. A well-known case is that of processes containing different time scales, which is quite often encountered in the study of real processes.

Among the mathematical relationships linking the different variables of the process considered, some can be dynamic and others static. Furthermore, if a system is described only by dynamic relationships, the latter can reflect slow dynamics or fast dynamics.

If a real system is described by two types of two-time scales, then we have what we call a system with multiple time scales. For example, in the standard form of systems with singular perturbation at two scales of time, these variables are explicitly separated using a parameter ε, called the "parameter of singular perturbation », which affects the derivative with respect to time of the vector of fast states for systems with several time scales, different parameters define the time scales characterizing the system states. The systems who's removing the small parameter is responsible for reducing their order are called singularly perturbed systems. This is a particular representation of the general class of systems at several time scales.

The singular perturbation theory was introduced into the field of automation by towards the end of the 1960s. due to the fact that several physical systems are singularly perturbed, for example, planes, robots, asynchronous machines. Also in (Chang, Tsai, Hwang, & al, 2008), (O'malley & roberte, 2015), (Ailberto & Aaron, 2018), (Ltifi, Bahri & Ltaief, 2023) and (Ltifi m, Bahri & Majda, 2023).

Nonlinear singularly perturbed systems (SPSs) (Assawinchaichote & Nguang, 2002), (Chang, Tsai & Hwang, 2008) and (Luis, Dragan & Chris, 2020) are characterized by a complex structure due to the existence of singularities and non-linearities, so the need for non-linear SPS simplification is an important topic for research. In the past few years, according to the objective of identification, observation, control, diagnosis and stability analysis, decomposition and reduction techniques have been used to decrease the complexity of these systems. In (Castro-Linares, Alvarez-Gallegos & Vasquez-Lopez, 2001) and (Aliyu & Boukas EK, 2011) and (Najmeh, Nader & Khashayar, 2014), the authors neglect the fast dynamic by tender the singular perturbation parameter to zero and approximate the global model by its reduced model (slow dynamic). The reduction technique is realized also in different ways: elimination some phenomena (parameters in the case of a complex mechanism), whose explanatory power is low in the initial system, neglecting model elements (variables and/or parameters) that have no significance for system dynamics, a simplification based on a truncation of a series development or an expansion on the basis of functions.

However, this technique is not always applicable; it can also vary the dynamics of the system and make it unstable. Other works have been considering the decomposition technique which consists to decompose the nonlinear SPS into two decoupled subsystems, then the global model is approximated by these two sub models (Aliyu & Boukas EK, 2011, Aliyu, Perrier & Baron, (2012)). In (Aliyu, MDS & Boukas EK. (2011), (Aliyu & Boukas EK, 2011), (Aliyu, Perrier & Baron,2012) filters have been addressed to examine state estimation problems. The approximation of the filter gains is not considered in these works, but adequate conditions are obtained for the solvability of the filtering problem in nonlinear SPSs. A sliding mode observer was developed in (Castro-Linares, Alvarez-Gallegos & Vasquez-Lopez, 2001) to address a stabilization and regulation control issue in situations where the output of the system depends on the slow state but the slow state is unavailable. This method has the classic local linearization issue, despite the excellent stability performance it offers. However, to address the nonlinear SPS state estimation problem (Najmeh, D., Nader, M & Khashayar, K. 2014) proposed a hybrid Extended Kalman