

Chapter 18

Fault Detection and Isolation for an Uncertain Takagi– Sugeno Fuzzy System using the Interval Approach

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ABSTRACT

This work deals with the fault detection and localization in the case of uncertain nonlinear systems. The presented method uses the diagnosis based on mathematical models. To model nonlinear systems, the multiple model approach is used. This method uses the Takagi-Sugeno fuzzy systems principle to obtain a nonlinear system named multiple models. This modeling principle has the advantage of obtaining a general model that can describe any class of nonlinear systems. This modeling principle also allows one to obtain the generalization of many results that are already obtained for linear systems to the nonlinear systems. To model the system uncertainties, the interval approach is used because the faults or disturbances are generally unknown, but it is possible to know their upper and lower bounds. The proposed technique is insensitive to measurement uncertainties and highly reliable in case of a fault affecting the outputs system.

1. INTRODUCTION

State estimation plays an important role in a context of system diagnosis. It is an analytical source of redundancy used to generate system failure symptoms by making a comparison between the real behavior signals of the system and the estimated signals. A not desired variation between these signals indicates the possible presence of faults affecting the system operation.

An accurate representation of the system model is the challenge faced by the scientific community. Several methods have been proposed to model the systems behavior in order to ensure proper supervision. Indeed, in many industrial fields, which must give product with good precision or which are dangerous, such as nuclear power plants or aerospace, all faults must be detected to ensure the materials and human security and the product precision (Bedoui et al, 2013). Hardware redundancy is often considered to detect and locate faults solution, or any material is ideal. Each instrument has an uncertainty which is often indicated by the manufacturer. Hardware redundancy consists in using several sensors to measure one output. This technique allows being sure of the output measure. The disadvantage of this technique is the installation blocking and considerable additional cost.

The diagnosis is an important field that allows detecting and locating the origin of faults or failure and permits to locate and track their evolution. It is based on the principle of residuals generation. The principle of residual generation is to compare the evolution of the system state to the state estimated. Computing the state estimation error leads to conclude if the system is faulty or no. If the residual is null, the system has a good behavior and no faults are affecting the system. In the opposite case it is possible to detect a fault affecting the system. These residuals are only functions of the measurement of noise and faults, and are determined, in this work, in the case of sensor faults.

In this work, a method for diagnosis of nonlinear systems with measurement uncertainties (sensors) based on the interval analysis as tools for state estimation is proposed. This method is used to make the fault detection and location.

In general, faults can be detected by developing performing checks to verify the adequacy of the information provided by the model and the sensors. An inconsistency appears when the residual is out of the vicinity of zero (for filter-based methods (Kalman, 1960), observers (Luenberger, 1964) or space parity (Chow & Willsky, 1984)) or when the parameters derived abnormally in the methods of parametric estimations (Isermann, 1984).

The interval analysis is to define an envelope in which the fault is considered non-existent and any measurement deviation inside this envelope is considered normal. Otherwise, the system is declared faulty. This approach has been explored by Adrot (Adrot et al, 2002; 2000) and recently by Bedoui (Bedoui et al, 2014) and applied to a mechatronic system by Letellier (Letellier, 2012).

Recently, Takagi-Sugeno Fuzzy systems are the subject of many researches by virtue of their approximation capabilities (Witczak et al, 2008 ; Khedher & Othman, 2010). They can represent exactly a nonlinear model (Tanaka et al, 1998; Witczak et al., 2008; Khedher & Othman, 2010). They are constructed by a set of linear models blended together with nonlinear functions holding the convex-sum property. In the case of Takagi-Sugeno Fuzzy systems, state estimation is based on the design of nonlinear observers (multiple observers) using the same nonlinear weighting functions as the Takagi-Sugeno models (Akhenak et al, 2009; 2003; Ichalal et al, 2009a; Khedher et al, 2008; 2009).

Approaches using Takagi-Sugeno models, also named multiple models (Murray-Smith & Johansen, 1997), are the object of many works in different contexts including unknown inputs or parameter uncertainties (Akhenak et al, 2007; Ichalal et al, 2009b). Various studies dealing with the presence of unknown

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