LMI-BASED FAULT DETECTION FUZZY OBSERVER DESIGN WITH MULTIPLE PERFORMANCE CONSTRAINTS FOR A CLASS OF NON-LINEAR SYSTEMS: COMPARATIVE STUDY

DENGFENG ZHANG1, HONG WANG2, BAOCHEUN LU1 AND ZHIQUAN WANG3

1School of Mechanical Engineering
Nanjing University of Science and Technology
No. 200, Xiaolingwei, Nanjing 210094, P. R. China
mydfzhang@gmail.com; lubaochun@mail.njust.edu.cn; wangzqwhz@yahoo.com.cn

2Control Systems Centre
University of Manchester
Manchester, M60 1QD, United Kingdom
hong.wang@manchester.ac.uk

Received September 2010; revised July 2011

ABSTRACT. In view of the conservatism of the conventional linear matrix inequality (LMI) based fault detection observer design for Takagi-Sugeno fuzzy nonlinear systems with more If-Then rules, an improved fuzzy observer design is presented. The identical transformation of matrix inequalities is employed to reduce the conservatism and the number of LMI constraints, which can accommodate to the models with more rules. The multiobjective optimization strategy is also applied to dealing with the multiobjective constraints on the disc poles index, the quasi $L_2$-norm indices of the residual’s robustness to disturbances and sensitivity to faults. The resulting observer not only is less conservative, but also meets the multiple performance requirements of fault detection. Meanwhile, two other methods are introduced for comparative study. Moreover, to enhance the effect of fault detection in residual evaluation, a weighted BIC criterion-based algorithm is introduced to determine the finite-time window for online evaluation. Simulative examples demonstrate the effectiveness of the proposed method.

Keywords: Takagi-Sugeno fuzzy model, Fault detection, Fuzzy observer, Multiobjective optimization, Matrix identical transformation

1. Introduction. Over the last decades, many researchers have paid attention to the problem of observer-based fault detection and diagnosis (FDD) for dynamic systems subjected to various possible faults [1-3]. Most of the early studies are focused on linear systems; see [4] and the references therein. In more recent years, observer-based fault detection (FD) for nonlinear systems has received a great deal of attention [5]. Whereas, due to the complexity in modeling nonlinearities, observer-based FDD for nonlinear system is still an open challenge. Recently, Takagi-Sugeno (T-S) fuzzy model as a typical description of nonlinear systems, its FDD problem has been widely studied; see for example [6-15] and the references therein. Through observing those results, it is obvious that many existing results are mainly focused on the LMI-based observer design to ensure only the stability of the residual systems, according to the conventional common quadratic Lyapunov function. Consequently, one problem is that only a few results touched upon the FD performance requirements [9, 13, 15]. Although many intelligent algorithms on the multiobjective programming and optimization have been developed [16, 17], it is negative to solve the FDD problem by such intelligent algorithms [17]. Another problem is