Chapter 2
Stability of Large-Scale Fuzzy Interconnected System

ABSTRACT

This chapter studies the asymptotic stability of large-scale fuzzy interconnected systems. It firstly focused on the general stability analysis. Then, by using some bounding techniques, the fuzzy rules in interconnections to other subsystems are eliminated. Such condition leads to a reduced number of LMIs. Also, we will present the stability result for the discrete-time case. Finally, we give several examples to illustrate the use of corresponding results.

2.1 INTRODUCTION

It is well known that one of the most important and difficult part of analysis and synthesize for large-scale nonlinear interconnected systems is to handle their interconnections. Due to the fact that each subsystem has several interconnections to the other subsystems, an overall large-scale nonlinear system contains a lot of interconnections. In general, if a nonlinear subsystem in large-scale system is represented by a T–S fuzzy system, its interconnections maybe include the nonlinear dynamics of the other nonlinear subsystems. In that case, such condition leads to the well-known “rule-explosion” problem in (Liu & Li, 2004), when increasing the number of subsystems. The work in (Wang & Luoh, 2004) derived the stability results on the large-scale fuzzy interconnected systems, where it required the matrix-equality constraints that were not easy to solve by using LMI toolbox. A special class of large-scale
nonlinear systems with linear interconnection matrix $\tilde{A}_{ij}$ was investigated in (Hsiao & Hwang, 2002; Zhang, Li, & Liao, 2005; Zhang & Feng, 2008; Lin, Wang, & Lee, 2006). The restrictive condition with linear interconnection is not always suitable for practical implementations.

The chapter firstly derives the stability results for continuous-time systems and for discrete-time systems, respectively. Then, by using some bounding techniques, the fuzzy rules generated by the interconnections to other subsystems are eliminated. In that case, the corresponding stability results with reduction number of LMIs are obtained.

### 2.2 GENERAL STABILITY ANALYSIS

This section will derive the general stability conditions for large-scale T-S fuzzy interconnected systems.

#### 2.2.1 Problem Formulation

Consider a continuous-time large-scale nonlinear system containing $N$ subsystems with interconnections, where the $i$-th nonlinear subsystem is represented by the following T-S fuzzy model:

**Plant Rule** $R_i^l$: IF $\varsigma_{i1}(t)$ is $F_{i1}^l$ and $\varsigma_{i2}(t)$ is $F_{i2}^l$ and ... and $\varsigma_{ig}(t)$ is $F_{ig}^l$, THEN

$$
\dot{x}_i(t) = A_{il}^l x_i(t) + \sum_{j=1, j \neq i}^{N} A_{ij}^l x_j(t), \quad l \in L_i := \{1, 2, \ldots, r_i\}
$$

(1)

where $i \in \mathcal{N} := \{1, 2, \ldots, N\}$, $N$ is the number of the subsystems. For the $i$-th subsystem, $R_i^l$ is the $l$-th fuzzy inference rule; $r_i$ is the number of inference rules; $F_{i0}^l (\emptyset = 1, 2, \ldots, g)$ are fuzzy sets; $x_i(t) \in \mathbb{R}^{n_i}$ denotes the system state; $\varsigma_i(t) := [\varsigma_{i1}(t), \varsigma_{i2}(t), \ldots, \varsigma_{ig}(t)]$ are the measurable variables; $A_i^l$ is the $l$-th local model; $A_{ij}^l$ denotes the nonlinear interconnection of the $i$-th and $j$-th subsystems for the $l$-th local model.

Define the inferred fuzzy set $F_i^l := \Pi_{\emptyset=1}^g F_{i\emptyset}^l$ and normalized membership function $\mu_i^l[\varsigma_i(t)]$, it yields
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