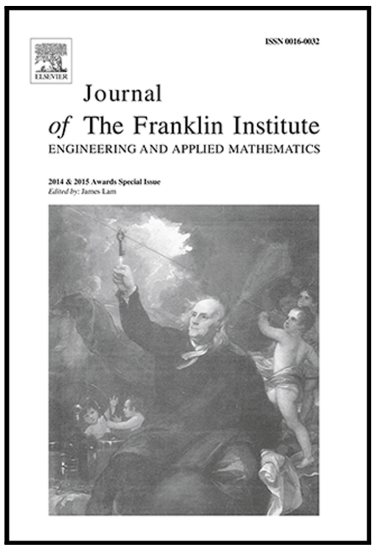

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Xueying Ding, Haitao Li, Shuling Wang

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Set Stability and Synchronization of Logical Networks with Probabilistic Time Delays ⋆

Xueying Ding†, Haitao Li†*, Shuling Wang†

†*School of Mathematics and Statistics, Shandong Normal University, Jinan 250014, P.R. China*

Abstract

Using the algebraic state space representation (ASSR) method, this paper investigates the set stability and synchronization of Boolean networks with probabilistic time delays (PTDs). Firstly, an equivalent stochastic system is established for the Boolean network with PTDs by using the ASSR method. Secondly, based on the probabilistic state transition matrix of equivalent stochastic system, a necessary and sufficient condition is proposed for the set stability of Boolean networks with PTDs. Thirdly, as an application of set stability, the synchronization of coupled Boolean networks with PTDs is studied, and a necessary and sufficient condition is presented. Finally, an illustrative example is given to demonstrate the effectiveness of the obtained new results.

Key words: Boolean network, Probabilistic time delays, Set stability, Synchronization, Algebraic state space representation.

1 Introduction

Nonlinear time-delay system has attracted many scholars' research interest in the last half century due to its wide applications in physiological kinetics, population dynamics, infectious diseases, and so on [23,31,32,37]. Particularly, when modeling gene regulatory networks (GRNs), time delays are non-negligible factors because of the slow processes of transcription, translation and translocation between mRNA and protein [10, 28, 45]. As was pointed out in [32], GRN models which do not consider time delays may even predict wrong behaviors.

As a classic nonlinear model of GRNs, Boolean networks with time delays have been well studied in the last two decades [7, 8, 22, 35]. Chueh et al. [7] reconstructed biological pathways based on time-delay Boolean networks. In [8], temporal Boolean networks were proposed to model GRNs, and model inference problem from noisy data was discussed. Recently, an algebraic state space representation (ASSR) method has been developed for the analysis and control of Boolean networks with time delays [21, 29, 40, 41, 43]. In [41], the Boolean network with time delays was divided into finite subsystems with no time delays, and the controllability and observability of Boolean control networks with time-variant delays were considered. For the recent advances on the ASSR method, please refer to [3, 11, 12, 14, 16–20, 24–27, 30, 36, 44, 46].

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∗ Corresponding author.

Email addresses: 18366137906@163.com (Xueying Ding), haitaoli09@gmail.com (Haitao Li), shulingwang2018@163.com (Shuling Wang).