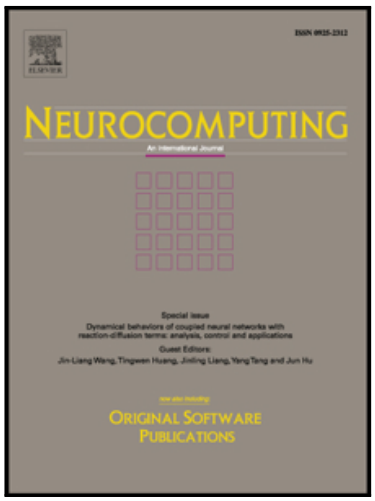

Exponential synchronization and phase locking of a multilayer Kuramoto-oscillator system with a pacemaker

Dongbing Tong, Pengchun Rao, Qiaoyu Chen, Maciej J. Ogorzalek, Xiang Li

PII: S0925-2312(18)30507-1
DOI: 10.1016/j.neucom.2018.04.067
Reference: NEUCOM 19540

To appear in: *Neurocomputing*

Received date: 9 December 2017
Revised date: 23 March 2018
Accepted date: 2 April 2018

Please cite this article as: Dongbing Tong, Pengchun Rao, Qiaoyu Chen, Maciej J. Ogorzalek, Xiang Li, Exponential synchronization and phase locking of a multilayer Kuramoto-oscillator system with a pacemaker, *Neurocomputing* (2018), doi: 10.1016/j.neucom.2018.04.067

Exponential synchronization and phase locking of a multilayer Kuramoto-oscillator system with a pacemaker

Dongbing Tong[a,b,*], Pengchun Rao[a], Qiaoyu Chen[c], Maciej J. Ogorzalek[d], Xiang Li[a,e,*]

[a] *Adaptive Networks and Control Lab, Department of Electronic Engineering, School of Information Science and Technology, Fudan University, Shanghai 200433, China*
[b] *College of Electronic and Electrical Engineering, Shanghai University of Engineering Science, Shanghai 201620, China*
[c] *School of statistics and mathematics, Shanghai Lixin University of Accounting and Finance, Shanghai 201620, China*
[d] *Department of Information Technologies, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Krakow 30-348, Poland*
[e] *Research Center of Smart Networks and Systems, School of Information Science and Technology, Fudan University, Shanghai 200433, China*

Abstract

This paper explores exponential synchronization and phase locking of a Kuramoto-oscillator network with multi-harmonic coupling functions. In the presence of pacemaker and distributed controllers, such a Kuramoto-oscillator network is a multilayer system, and we present several conditions to achieve exponential synchronization and phase locking. We estimate the lower bounds for the synchronization and phase locking rate of such a multilayer Kuramoto-oscillator network. Finally an example of the multilayer system illustrates the effectiveness of the theoretical results.

Keywords: Exponential synchronization, phase locking, multilayer system, Kuramoto-oscillator, multi-harmonic coupling function, pacemaker.

1. Introduction

Synchronization is one of the fundamental characteristics to understand the self-organization phenomena [1–3] in coupled oscillator networks, which can be observed in many biological, physical and social systems with various applications [4–10]. People may witness such phenomena including chorus of crickets [1], flash of fireflies [2], unification of brain signals [3], synchronous firing of a cardiac pacemaker [4, 5], synchronous behaviors in the Josephson junction array [6, 7], consensus behaviors in multi-agent systems [8, 9], and the rhythmic applause in the theater [10].

Among these examples, the phase locking of oscillators is significant due to the oscillators behavior within a certain span of frequencies. In simple organisms, for example, the phase locking of circadian oscillations has been reported for the cyanobacterial cells [11, 12]. Similarly, the phase locking of the cell cycle progression has been confirmed for the circadian mutation of organisms [13]. Moreover, the phase locking has been shown to exist for the auditory hair cell ribbon synapse by Multi-quantal release [14, 15].

The Kuramoto model of coupled phase oscillators is among the topics of general interest in the literature, and has been regarded as a paradigmatic model describing and explaining the transitions from incoherent to synchronous states in the ensembles of coupled oscillators. The Ku-

☆This work was partly supported by the National Science Fund for Distinguished Young Scholar of China (Grant No. 614250192), the National Natural Science Foundation of China (Grants No. 71731004, 61673257, 11501367), the China Postdoctoral Science Foundation (Grant No. 2015M581528), and the Natural Science Foundation of Shanghai (Grant No. 15ZR1419000).

*Corresponding author.
Email addresses: tongdongbing@163.com (Dongbing Tong), lix@fudan.edu.cn (Xiang Li)