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Global Mittag-Leffler stability and synchronization analysis of fractional-order quaternion-valued neural networks with linear threshold neurons

Xujun Yang^a, Chuandong Li^{a,*}, Qiankun Song^b, Jiyang Chen^a, Junjian Huang^c

^aChongqing Key Laboratory of Nonlinear Circuits and Intelligent Information Processing, College of Electronic and Information Engineering, Southwest University, Chongqing 400715, PR China

^bCollege of Mathematics and Statistics, Chongqing Jiaotong University, Chongqing 400074, PR China

^cDepartment of Computer Science, Chongqing University of Education, Chongqing 400067, PR China

Abstract

This paper talks about the stability and synchronization problems of fractional-order quaternion-valued neural networks (FQVNNs) with linear threshold neurons. On account of the non-commutativity of quaternion multiplication resulting from Hamilton rules, the FQVNN models are separated into four real-valued neural network (RVNN) models. Consequently, the dynamic analysis of FQVNNs can be realized by investigating the real-valued ones. Based on the method of M -matrix, the existence and uniqueness of the equilibrium point of the FQVNNs are obtained without detailed proof. Afterwards, several sufficient criteria ensuring the global Mittag-Leffler stability for the unique equilibrium point of the FQVNNs are derived by applying the Lyapunov direct method, the theory of fractional differential equation, the theory of matrix eigenvalue, and some inequality techniques. In the meanwhile, global Mittag-Leffler synchronization for the drive-response models of the addressed FQVNNs are investigated explicitly. Finally, simulation examples are designed to verify the feasibility and availability of the theoretical results.

Keywords: Fractional order; Quaternion-valued neural networks; Mittag-Leffler stability; Mittag-Leffler synchronization

1. Introduction

Real-valued neural networks (RVNNs) and complex-valued neural networks (CVNNs) have gained considerable popularity in the past decades and have been successfully applied to a wide range of areas, such as signal processing, pattern recognition, combinatorial optimization, and static image treatment (Huang, 2006; Huang, Li, Duan, & Starzyk, 2012; Li & Duan, 2013; Li, Liao, Chen, Hill, Dong, & Huang, 2015; Li, Yu, & Huang, 2014; Li, Yu, Huang, Chen, & He, 2016; Liu, Cao, Yu, & Song, 2016; Song, Yan, Zhao, & Liu, 2016; Zhou & Song, 2013). In such applications, the designed neural networks models always have a unique equilibrium point which is globally stable, so as to avoid the risk of having spurious equilibria and being trapped at local minima (Liao, Chen, & Sanchez, 2002). Therefore, the stability analysis of the unique equilibrium point of neural networks has received extensive attention, and numerous results have been reported in literature, see Chen and Song (2013), Gong, Liang, and Cao (2015), Hu and Wang (2012), and Huang (2007) and references therein. On the other hand, chaos synchronization in neural networks has been an active area of research in nonlinear science for rather a long time, due to its valuable applications to diverse fields such as secure communications, associative memory, biological and chemical reactions, which attract many scholars and researchers to focus their interests on the analysis of synchronization of chaotic neural network, see Huang, Li, Yu, and Chen (2009), Wen, Bao, Zeng, Chen, and Huang (2013), and Wu, Wen, and Zeng (2012) and references therein.

As is well known, RVNNs perform less well in implement of geometrical transformations like two-dimensional (2D) affine transformations. In view of this, CVNNs have been bought in to improve performance on 2D affine transformations, which mainly benefits that CVNNs enable the modeling of a point in 2D space as a single entity instead of a set of two data items (Hirose, 2003). However, when it comes to 3D data case such as body images and color images, CVNNs have to lose its dominant because they are incapable of implementing 3D data directly although such data can be processed by employing many neurons of CVNNs. Fortunately, quaternion-valued neural networks, an extension of CVNNs, have begun to receive a heated research in recent years, due to QVNNs are capable of implementing direct encoding on 3D affine transformations high-efficiently and compactly, especially spatial rotation, which can be extensively applied to various areas such as image impression, attitude control of satellites, computer

*Corresponding author

Email addresses: xujunyangcq@163.com (Xujun Yang), cdli@swu.edu.cn (Chuandong Li), qiankunsong@163.com (Qiankun Song), 18716622493@163.com (Jiyang Chen), hnmou@sina.com (Junjian Huang)

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