

## PREFACE

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An artificial neural network mimics the functionality of biological neural networks, where neurons serve as fundamental units for information processing. Widely applied in fields such as information processing, weather forecasting, and medicine, artificial neural networks play a crucial role in diverse applications. Before engaging with any neural network model, assessing the system's stability, synchronization, and dissipativity is imperative. The stability, synchronization, and dissipativity of neural network models encompass various facets that merit careful consideration. This thesis examines and analyzes specific aspects of stability and synchronization within the context of neural networks, laying a foundational understanding for subsequent model exploration and application.

The thesis delves into issues about the stability, synchronization, and dissipativity of neural networks across its five chapters. Commencing with Chapter 1, the introduction provides a comprehensive overview of artificial neural networks, elucidating their historical development. This foundational chapter offers insights into various types of neural networks and explores the significance of delay differential equations within this context. Furthermore, key definitions and methodologies integral to the thesis are introduced, enriching the reader's understanding and establishing a solid framework for the subsequent chapters.

Chapter 2 focuses on an in-depth exploration of fixed-time synchronization within quaternion-valued neural networks (QVNNs) with mixed time-varying delays. The motivation is to provide an understanding of fixed-time synchronization, a distinctive feature where system synchronization is achieved within a finite time, independent of initial conditions. This chapter introduces a Lyapunov functional and devises a novel controller to facilitate the desired synchronization. Additionally, the

chapter includes a comparative analysis of settling times utilizing different lemmas, contributing further insights into the dynamics of the synchronization process.

Chapter 3 focuses on investigating quasi-projective synchronization within non-identical complex-valued recurrent neural networks (CVRNNs), incorporating proportional delays and mismatched parameters. Using nonlinear Lipschitz activation functions is coupled with Lyapunov stability criteria and the matrix measure approach. By designing a well-suited controller, the chapter establishes a sufficient condition for the projective quasi-synchronization criteria of the non-identical CVRNNs model, employing a detailed description of the matrix measure approach. Furthermore, the chapter delves into examining error bounds across various values of the projective coefficient, revealing an increasing trend in error bounds as the coefficient rises.

Chapter 4 establishes the global exponential stability of delayed Cohen-Grossberg inertial neural networks (CGINNs) by introducing a novel Lyapunov functional different from the conventional reduced-order method. The newly developed Lyapunov functional, combined with two distinct control schemes and applying the inequality technique, is employed to establish the global exponential stability of the considered second-order inertial neural networks (INNs). The dynamical behavior of CGINNs, as explored in this study, deviates from the conventional reduced-order method by incorporating variable substitution. The method proposed in this chapter leverages simpler inequalities, facilitating a more straightforward achievement of stability criteria for CGINNs compared to previous studies.

Chapter 5 investigation is centered on the anti-synchronization problem within quaternion-valued inertial neural networks (QVINNs) with unbounded time delays. Employing two distinct control strategies—feedback and adaptive controllers and Lyapunov theory, the chapter establishes various conditions ensuring the anti-synchronization of QVINNs. Unlike existing results for QVINNs, which often rely on

the variable substitution approach, reducing the order of the original second-order system to a first-order system, this study adopts a non-reduction order method and non-separation approach for QVINNs. The focus here on a non-reduction order method is more concise, providing a more realistic and manageable approach for dealing with QVINNs featuring unbounded time delays. Finally, the chapter demonstrates the application of QVNNs in associative memory, showcasing their ability to restore true color image patterns accurately.

Chapter 6 tackles the challenges of exploring the global and exponential dissipativity of QVINNs characterized by unbounded time-varying delays. Notably, this investigation is conducted without resorting to order reduction of INNs and quaternion separation methods. The chapter establishes several robust and multi-parameter criteria for ensuring global dissipativity in QVINNs by introducing innovative Lyapunov functional and applying inequality techniques. These criteria not only generalize but also refine existing results. The analysis extends to estimating globally attractive sets and exponentially attractive sets. Diverging from traditional methods that involve separating QVNNs into real-valued neural networks (RVNNs) and reducing INNs to first-order systems, this article presents a foundation grounded in alternative approaches. Unlike previous results focused on the global dissipativity of traditional neural networks (NNs) with bounded discrete time delays, this chapter addresses the more realistic scenario of INNs with unbounded time-varying delays. In a departure from common practice, where the rate of convergence  $\lambda$  is typically bounded in studies on exponential stability, synchronization, and dissipativity, this article explores dissipativity criteria without an upper bound on the convergence rate  $\lambda$  specifically in the context of global exponential dissipativity. Furthermore, the efficacy of QVNNs in storing true color image patterns is demonstrated, reinforcing the practical relevance of the research.