# Chapter 7
# Global Asymptotic Stability of Complex-Valued Delayed Neural Networks for Optimization Problems

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## ABSTRACT

*In engineering sciences, the neural networks (NNs) applications related to solving optimization problems, the existence and uniqueness of stable equilibrium points for dynamical NNs is of crucial importance in the context of both theoretical and application aspects since the concerned NN may keep multiple equilibrium points that may result in some misleading suboptimal outcomes. Therefore, to solve optimization problems effectively, dynamical NNs must be designed with specific structural and dynamical properties. Recently, real-world datasets have become increasingly complex and high-dimensional, illustrating the need for efficient methods to handle processing and optimization tasks. Addressing these challenges, this chapter investigates the asymptotic stability of complex-valued neural networks (CVNNs) with time delays by employing the Lyapunov-Krasovskii functional and the linear matrix inequality (LMI) approach. Finally, numerical examples and graphical illustrations are provided to validate the theoretical findings.*

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## INTRODUCTION

Recently, study on analyzing NNs has gained significant attention, leading to numerous successful applications across various fields, such as signal processing, associative memory, computing, pattern recognition, and more areas of engineering (Haykin, 1994) (J.-D. Cao, 2000) (Zeng et al., 2015) (H. Zhang et al., 2013) (Hopfield, 1982) (T. Wang et al., 2015). Since the establishment of the Hopfield NNs, real-valued neural networks (RVNNs) have been significantly studied (T. Wang et al., 2015) (Z. Wang et al., 2017) (Kwon et al., 2013) (Zeng et al., 2019) (Maharajan et al., 2019). Even though RVNNs has applied in many domains, they exhibit limitations when processing complex data in practical applications such as electromagnetic systems, ultrasound imaging, quantum waves, and optical physical systems. To overcome these limitations, CVNNs have been obtained by incorporating complex algebra into RVNN models (Song et al., 2015b) (Song et al., 2015a) (D. Zhang et al., 2018). CVNNs have also shown significant potential in solving optimization problems in the complex domain. For instance, a complex-valued projection NN has been developed for the constrained optimization of real functions in complex variables, demonstrating strong convergence properties and constraint satisfaction (S. Zhang et al., 2015). More recently, nonlinear complex-variable constrained nonconvex optimization problems have been addressed using novel CVNN-based models (Feng et al., 2021). Additionally, CVNNs have proven highly effective in practical tasks such as specific emitter identification, where complex-valued signals must be processed with high precision and efficiency (Y. Wang et al., 2021). These advancements underscore the growing importance of CVNNs not only for modeling complex signals but also for solving high-impact optimization tasks. To better handle these optimization tasks, the dynamic behaviours of CVNNs is important. In recent years, extensive research on the studying dynamic behaviors of CVNNs has emerged (Tan et al., 2018) (Song et al., 2015b) (X. Chen & Song, 2013) (Samidurai et al., 2019) (Gong et al., 2017) (Z. Zhang et al., 2018) (Tu et al., 2016) (Anbalagan et al., 2019) (D. Liu et al., 2017a) (D. Liu et al., 2017b), focusing on aspects such as global stability (Song et al., 2015b) (X. Chen & Song, 2013) (Samidurai et al., 2019), robust state estimation (Gong et al., 2017), finite-time stability (Z. Zhang et al., 2018), global Lagrange stability (Tu et al., 2016), global robust synchronization (Anbalagan et al., 2019), mean square stability (D. Liu et al., 2017b), and exponential stability (D. Liu et al., 2017a).

On the other hand, time delays are inherent in real-world systems and can often cause instability in system behavior. Thus, it is more practical and reasonable to incorporate multiple time-varying delays into NNs. So far, numerous research studies have been conducted and published on the dynamics of NN models with time delays (Kwon et al., 2013) (Zeng et al., 2019) (Xu et al., 2009) (Y. Chen et al., 2010).

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