CHAPTER 1
Introduction

It is well known that the existence of time delay in a system may cause instability and oscillations. Examples of time delay systems are chemical engineering systems, biological modeling, electrical networks, physical networks and many others, [5, 12, 19, 27, 53]. The stability criteria for system with time delays can be classified into two categories: delay independent and delay dependent. Delay-independent criteria do not employ any information at different levels. Delay-dependent stability conditions are generally less conservative than delay-independent ones especially when the delay is small. In several situations, time delays are time-varying continuous functions which vary from 0 to a given upper bound. In addition, the range of time delays may vary in a range for which the lower bound is not restricted to be 0; in which case time delays are called interval time-varying delay. A typical example with interval time delay is the networked control system, which has been widely studied in the recent literature, see [6,32,64]). Recently, there is important type of time delay, namely distributed delay, where stability analysis with distributed delayed has been studied extensively, see [1, 6, 49, 60, 64].

In many practical systems, models of systems are described by neutral differential equations, in which the models depend on the delays of state and state derivatives. Heat exchanges, distributed networks containing lossless transmission lines and population ecology are examples of neutral systems. Because of its wide application, several researchers have studied neutral systems and provided sufficient conditions to guarantee asymptotic stability of neutral time delay systems, see [12, 27, 42, 53] and references cited therein.

In recent years, there have been great attentions on the stability analysis of neural networks since it has been widely applied to various systems such as signal processing, pattern recognition, association, content-addressable memory, and optimization, see [3,6,7,54,60]. In performing a periodicity or stability analysis of a neural network, the conditions to be imposed on the neural network are determined by the characteristics of various activation functions and network parameters. When neural networks are created for problem solving, it is desirable that the activation functions are not too restrictive. As a result, the considerable research work on the stability of neural networks with various activation functions and more general conditions, see [7, 29, 40]. It is noted that these stability conditions are either with testing difficulty or with conservatism to some extent.

It is known that exponential stability is more favorable property than asymptotic stability since it gives a faster convergence rate to the equilibrium point and any information about the decay rates of the delayed neural networks. Therefore, it is particularly important, when the exponential convergence rate is used to determine the speed of neural computations. The exponential stability property guarantees that, whatever transformation occurs, the networks ability to store rapidly the activity pattern is left invariant by self-organization. Thus, it is important to determine the exponential stability and to estimate the exponential convergence rate for delayed neural networks. In the past few decades several researchers have studied the exponential stability analysis problem for delayed neural networks. A number of results on this topic has been reported in the literatures and references cited therein, see [7, 32, 49].

It is well known that nonlinearities may cause instability and poor performance of practical systems. These nonlinearities have driven many researchers to study in the literatures, see [10,22,25,42,52]. Many nonlinear control systems can be modeled as a feedback connection of a linear neutral system and a nonlinear element. One of the important classes of nonlinear systems is the Lur'e system whose nonlinear element satisfies certain sector constraints. Recently, there are several researches on the asymptotic stability of a class of neutral and Lur' e dynamical systems with time delays, see examples [10, 13, 55, 65] and references cited therein. The problems have been dealt with stability analysis for neutral systems with mixed delays and sector-bounded nonlinearity [10], robust absolute stability criteria for uncertain Lur'e systems of neutral type [13], robust stability criteria for a class of Lur'e systems with interval time-varying delay [55].

In practical control designs, due to systems nonlinearities, failure modes or systems with various modes of operation, the simultaneous stabilization problem has often to be taken into account. The problem is concerned with designing a single controller which can simultaneously stabilize a set of systems. Recently, the exponential stability and stabilization problems for time-delay systems have been studied by several researchers, see for examples [1, 4, 21, 39]. The problems have been dealt with for various control areas such as exponential stabilization for linear time-delay systems [1], exponential stabilization for uncertain time-delay

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systems [21], exponential stabilization for linear uncertain polytopic time-delay systems [39].

Among the usual approaches, there are several research studies on the stabilization problem of neural networks which have been reported in the literature, see [6, 10, 33, 34, 49, 61]. In [61], a robust stabilization criterion is provided via designing a memoryless state feedback controller for the time-delay dynamical neural networks with nonlinear perturbation. In most studies, time-varying delays are required to be differentiable see for examples [6, 33, 34, 49]. Therefore, their methods contain some conservatism which can be improved upon. Motivated by these researches, we propose criteria that remove the restriction on state delay in our work.

In this thesis, neutral type for neural network and Lur'e systems with time-varying delays are studied. We shall investigate the problem of stability analysis and controller design for neutral systems with time-varying delays. In Chapter 3, we study the problem of delay-dependent criterion for asymptotic stability for uncertain neutral system with time-varying delays and time-varying nonlinear perturbations. The restriction to the derivative of state delay is removed, which means that a fast interval time-varying delay is allowed. Based on the Lyapunov-Krasovskii theory, we derive new delay-dependent stability conditions in terms of LMIs which can be solved by various available algorithms. The new stability condition is much less conservative and is more general than some existing results.

In Chapter 4, we consider the problem of exponential stabilization of neutral-type neural networks with interval and distributed time-varying delays. There are various activation functions which are considered in the system and the restriction on differentiability of state delay is removed, which means that a fast interval time-varying delay is allowed. Based on the construction of improved Lyapunov-Krasovskii functionals combined with the Liebniz-Newton's formula and the integral terms. New delay-dependent sufficient conditions for the exponential stabilization of the system are established in the form of LMIs without introducing any free-weighting matrices. The new stability condition is much less conservative and more general than some existing results.

In Chapter 5, we consider the problem of robust stability for a class of uncertain neutral and Lur'e dynamical systems with sector-bounded nonlinear functions. The time delay is a continuous function belonging to a given interval, which means that the lower and upper bounds for the time varying delay are available. Moreover, the state delay function is not necessary to be differentiable. To the best of the authors knowledge, there were no global stability results for uncertain neutral and Lur'e dynamical systems with some sector conditions, see [10, 13, 55, 65]. Based on the construction of improved Lyapunov-Krasovskii functionals combined with the Liebniz-Newton's formula and the integral inequalities, new delay-dependent sufficient conditions for the uncertain neutral and Lur'e dynamical of system are established in the form of LMIs.

In Chapter 6, we deal with the problem of absolute stability of neutral type Lur'e systems with time-varying delays. To the best our knowledge, our results are among the first on investigation of absolute stability of neutral type Lur'e systems with time-varying delays. By introducing new augmented Lyapunov-Krasovskii functional which have not been considered yet in stability analysis of Lur'e systems. Using new Lyapunov-Krasovskii functional, matrix-based quadratic convex approach combined with some improved bounding techniques for integral terms such as Wirtinger-based integral inequality, so some new cross terms are introduced. This enhances the feasible stability criterion. The new stability condition is much less conservative and more general than some existing results. Numerical examples are given to illustrate the effectiveness of our theoretical results.

In Chapter 7, we study the exponential stability problem for uncertain neutral-type neural networks with both interval time-varying delays and generalized activation functions. The constraint on the discrete delay is not necessarily differentiable and the information on derivative of neutral delay is not required. To the best of our knowledge, this is the first study under these conditions on discrete and neutral delays. Furthermore, a new activation function which has not been considered yet in other literature is proposed and utilized to reduce the conservatism of stability criterion.

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