

CHAPTER 1

Introduction

During the last few years, the network synchronization has been challenged in various applications and research fields such as signal processing, associative memory, communication, engineering applications, and so on [14, 27, 30, 46, 59]. The network synchronization have drawn much researcher's attention by which the synchronization in an array of linearly coupled neural networks (NNs) was mostly studied. Many researches on global and local synchronization in coupled NNs have also been obtained [36, 37, 42, 60]. In [11], the cluster synchronization in an array of hybrid coupled NNs with delay was studied. The findings showed that the common behavior was induced by coupling in NNs. In [34, 52], the synchronization of coupled NNs with only constant coupling was studied. In [27, 46], by considering the existence of delays in spreading caused the finite speeds of transmission, the authors extended the model given in [8, 62] to a uniform model with both constant and delay couplings. Moreover, note that coupled network usually has special nature because of the presence of an array of networks of a variety of a sizes and lengths, and it was desirable to model coupled system by introducing continuously distributed coupling over a certain duration of time such that the distant past has less influence compared to the recent behavior of the state. So, there still exists coupling terms between the state and delay variables. The decentralized nature of real-word coupled networks is explained by the delay variables. The synchronization of networks, the constant, delay, and distributed delay couplings should be taken into discussion altogether, which led to the introduction of hybrid coupling [10, 11, 17, 62, 64]. The synchronization of chaotic NNs has become an significant area of study. Many researches in the synchronization problems for NNs have been proposed [2, 3, 12, 13, 19, 20]. In [52], the authors presented the synchronization in an array of linearly coupled NNs with time-varying delay. It is well known that time-varying delay is frequently encountered in electronic implementations of NNs due to the finite switching speed of the amplifiers and communication time. Therefore, it is necessary to consider the variable of time-varying delay effect for the synchronization problem of NNs.

The research of dynamical properties for delayed NNs has been increasingly interesting among the researchers in various fields, such as online optimization, associative

memories, signal and image processing, and so on [1, 6, 14, 15, 18, 23, 53]. There are two types of time delays. Basically, the first one is called discrete time delays for which the delays could be either constant or time varying [9, 24, 25, 51, 67, 68], and the other one is distributed time delays for which the delays are distributed over certain duration of time [30, 42]. Usually, discrete and distributed delays can simultaneously occur in signal transmission. Newly, stability analysis for NNs with both distributed and discrete delays have been received research interests [35, 40, 41, 43, 48, 50] and the references therein. For distributed delays including unbounded and bounded distributed delays in NNs [34, 57, 58, 71], have just been investigated extensively. Furthermore, there are many results relating with stability and periodic oscillation of NNs with unbounded distributed delays [49, 57, 58, 71]. In [34], the authors took into account of chaos synchronization phenomena in NNs with unbounded distributed delays. They raised that the synchronization problem of coupled NNs with distributed (“bounded or unbounded”) and discrete has not obtained enough research attention. There has been still a room for more studied [36, 37, 54]. Additionally, the delays may typically exist in an interval in many practical cases ($0 < h_1 \leq \tau(t) \leq h_2$), [47, 55, 62, 63, 65]. The range of delay varies in an interval time-varying for which the lower bound is not only restricted to 0. In some cases, synchronization or stability analysis of NNs with time delay in leakage (“forgetting”) term has been studied. The leakage term plays an important role in the dynamical behavior of NNs [16, 44, 45]. In [44], NNs with leakage delay could be viewed as a class of important neural networks. Time delay in the leakage term has the great impact on the dynamics of NNs since the delay in the stabilizing negative feedback term has a tendency to destabilize a system. So, it is necessary to further investigate the synchronization problem for two chaotic NNs with leakage delay. NNs may not be synchronized when a controller is not added into the infrastructure of individual nodes. Hence, the controlled synchronization of NNs is one of important topics in both theoretical researches and practical applications, such as feedback control [5], sample-data control [16, 26], adaptive control [4, 31], backstepping control [29], intermittent control [72, 73], etc.

Various control approaches have been applied for synchronizing and controlling the coupled NNs. Most findings are based on state-feedback control and adaptive control because of simply theoretical proof and well control performance. Nevertheless, in order to take advantage of the communication networks, and modern high-speed computers, it is more preferable to use digital controllers instead for analog circuits [16, 26, 69]. Base on this concept, in [69], the exponential synchronization sampled-data control problem was investigated for NNs with mixed time-varying delays. Moreover, the sampled-data tech-

nology has been applied in many practical engineering i.e. the synchronization of a class of general complex networks with time-varying coupling delays via sampled-data control [28]. Control linear econometric models in [60, 73], were used in a variety of purposes such as manufacturing, transportation and communication in practice. An intermittent control is the control systems by discontinuous control inputs at a control period [7, 33, 56, 72, 73]. In some cases, it is impossible to use only synchronization of NNs at all times. In fact, using synchronization of NNs in some intervals could prove only more cost effective than using synchronization of NNs at all times. On the other hand, the intermittent control scheme could be useful in communications, where the synchronization of NNs between transmitter and receiver can be used by means of transmitting information [73]. To the best of the author's knowledge [7, 16, 26, 33, 56, 72, 69, 73], the synchronization control problem has not been considered of the hybrid coupled NNs. It has been still an open and challenging problem. Hence, it is very important to create less conservative and easy-to-check criteria for ensuring the synchronization for hybrid coupled delayed NNs with sampled-data and intermittent feedback controls.

Goal

In this thesis, the synchronization problems for coupled NNs with time-varying delays and hybrid couplings are investigated. The goal of this work is to study and introduce a general array model of coupled delayed NNs with hybrid couplings for handling synchronization problem. Global and exponential synchronization for coupled NNs are studied and analysed. For global synchronization, the coupled NNs, with simultaneous show the discrete and unbounded distributed delays, are studied in the case of constant and interval time-varying delay couplings. For exponential synchronization, the coupled NNs with presence leakage delay is studied in the case of constant, interval time-varying delay and distributed delay couplings. Furthermore, the problem of synchronization for coupled delayed NNs with hybrid coupling designed by controller is studied as well. In this work, the global synchronization for hybrid coupled NNs are proposed by feedback and sampled-data feedback controls. The exponential synchronization for hybrid coupled NNs with feedback and intermittent feedback control are further studied. The design of inner-coupling, outer-coupling, and some free matrices representing the relationships between the system matrices, some sufficient conditions are systematically established to meet the synchronization by constructing the improved Lyapunov-Krasovskii functionals and Kronecker product properties. The criteria are derived in terms of Linear matrix

inequalities (LMIs) solved efficiently by standard convex optimization algorithms. Numerical examples with their simulations and the obtained results are given to show the effectiveness of the proposed method.

The guideline of what to expect in the individual chapter of this thesis is provided and the remainder of this thesis is organized in five chapters as follows.

Chapter 1

In chapter 1, the general introduction and statement of the problem of synchronization for coupled NNs with time-varying delays and hybrid coupling via sampled data feedback control and intermittent feedback control are provided. The goal and structure of the thesis are presented in this chapter as well.

Chapter 2

In chapter 2, the overview basic concepts, notations and mathematical definitions of linear systems and NNs with time delays are given. Also, the underlying concepts of stability and synchronization, important definitions, lemma, propositions and results, which will be used in later chapters, are provided, and clearly explained.

Chapter 3

This chapter investigates the global synchronization of coupled delayed NNs with hybrid coupling in the case of constant and time-varying delay couplings. The designed controller ensures the global synchronization of hybrid of couple delayed NNs are proposed by feedback and sampled-data feedback controls. Based on the design of the inner-coupling matrix, the outer-coupling matrix and some free matrices representing, the relationships between the system matrices, some sufficient conditions are established to achieve global synchronization by the construction of improved Lyapunov-Krasovskii functional and Kronecker product properties. The criterias are mathematically expressed in terms of LMIs which can be solved efficiently by standard convex optimization algorithms. Numerical examples and their simulations with the obtained results are presented to show the effectiveness of the proposed method.

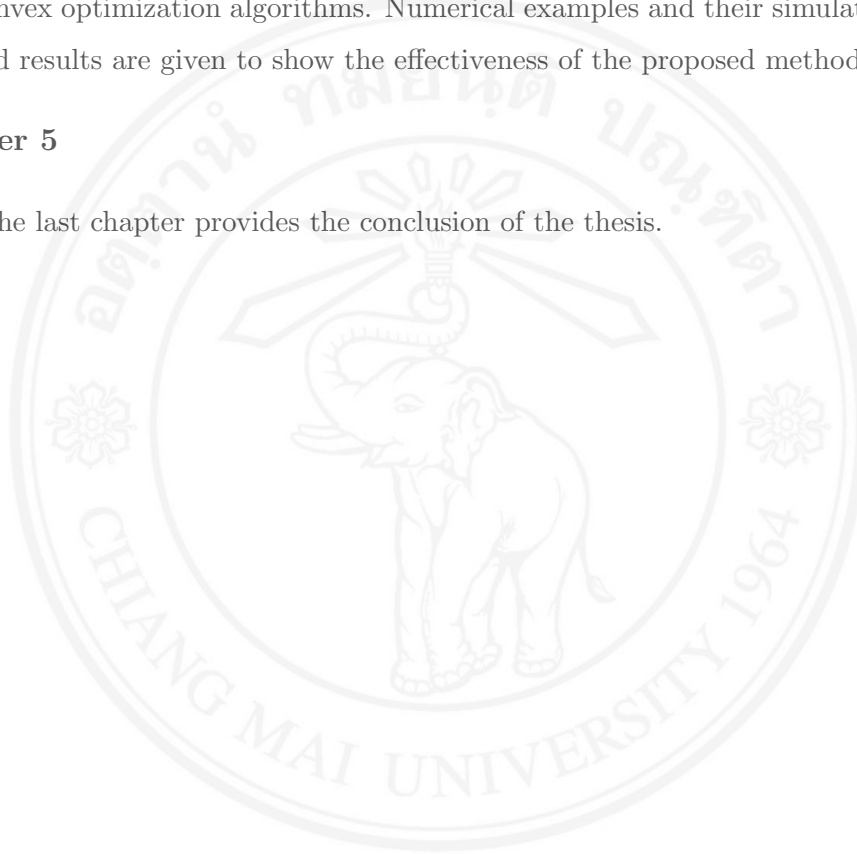
Chapter 4

This chapter investigates the exponential synchronization of coupled delayed NNs with hybrid coupling in the case of constant, time-varying delay and distributed delay

couplings. The designed controller ensures the exponential synchronization of hybrid of couple delayed NNs are proposed by feedback and intermittent feedback controls. Based on the design of the outer-coupling matrix, the inner-coupling matrix and some free matrices representing the relationships between the system matrices, some sufficient conditions are established to achieve exponential synchronization by the construction of improved Lyapunov-Krasovskii functional and Kronecker product properties. The criterias are mathematically expressed in terms of LMIs which can be solved efficiently by standard convex optimization algorithms. Numerical examples and their simulations with the obtained results are given to show the effectiveness of the proposed method.

Chapter 5

The last chapter provides the conclusion of the thesis.

The seal of Chiang Mai University is a circular emblem. It features a central figure of an elephant standing and facing left. Above the elephant is a traditional Thai umbrella (parasol). The entire emblem is encircled by a border containing the university's name in Thai script at the top and 'CHIANG MAI UNIVERSITY 1964' in English at the bottom.

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