Chapter 1

Introduction

Chaos in control system has attracted a lot of attention in the past few decades. A chaotic system has complex dynamical behaviors and is vary sensitive to the tiny variation of initial conditions. Besides the theoretical studies, there is much utilization [1-6], such as cryptographic [7], chemical reactor [8], artificial neural network [9], hydrodynamics, heart beat regulation and so on.

Fractional calculus develops since 17th century [10-13], but the applications of the physics and engineering have been studied till resent year. Now these derivatives/integrals are not only mathematical curiosities but have applications in visco-elasticity [14], feedback amplifiers, electrical circuits, electro-analytical chemistry, fractional multipoles, and neuron modeling [15,16] and related areas in physics, chemistry, and biological sciences. Many systems are displayed with fractional order [17-19]. In [20], chaotic behavior of the fractional order "jerk" model is studied. In [21], chaos control was investigated for fractional chaotic systems by the ''backstepping'' method of nonlinear control design. More recently, many investigations are devoted to the control [22-24] and dynamics [25-29] of fractional order dynamical systems. There are few investigations about delay system with fractional order. In [30], a solution of tracking problem for α-controllable fractional delay system is presented.

In recent years, chaos control and chaos synchronization have been received a great deal of interests among scientists from various fields. The chaotic system performances are often desired to be avoided and to be controlled to achieve some specific behavior. In 1990, Ott et al. [31] utilizeed small time-dependent perturbations of an available system parameter to convert a chaotic attractor to any one of a large number of possible attracting time-periodic motions. In [32] a linear feedback controller is designed to control the Chen system. An algorithm for suppressing the chaotic oscillation in non-linear systems with singular Jacobian matrices has been developed based on the Lyapunov–Krasovskii method by Kuang et al. [33]. Linear feedback control and adaptive control algorithm are used to control chaos effectively in [34]. Many different techniques and methods have been proposed to achieve chaos control, which include sliding method control, impulsive control method, linear feedback control, nonlinear feedback control and H_∞ control method etc.

Since the pioneering work was investigated by Pecorra and Carroll [35], Chaos synchronization has become an important topic in engineering science [36-41]. Many effective control schemes have been developed in a variety of fields, such as parameters adaptive control [42-50], observer based control [51, 52], variable structure control [53, 54], active control [55-59], nonlinear control [60-62], impulsive control [63,64], backstepping design approach [65,66] and so on. The applications of chaos synchronization are implemented extensively including secure communications [67, 68], neural networks [69], physical, chemical [70], and biological systems.

Recently, the concept of synchronization has been extended to the scope, such as lag [71, 72], anticipating [73], phase [74], generalized [75] and anti-synchronization [76]. The basic synchronization called complete synchronization is that the state vectors of the first system $x(t)$ is equal to the state vectors of the second system $y(t)$: $y(t) = x(t)$. The lag synchronization is that the state vector of the second system y delay that of driver system $x: y(t) = x(t-T)$ with positive T. If T is negative, we have anticipated synchronization. If the synchronizations are temporary and intermittent, they are called temporary lag synchronization (TLS) and temporary anticipated synchronization (TAS) [77]. Lag anti-synchronization means

$y(t) = -x(t-T)$. When T is negative, we have anticipated anti-synchronization. If they are temporary and intermittent, they are called temporary lag anti-synchronization (TLAS) and temporary anticipated anti-synchronization (TAAS).

Mackey-Glass delay system is a blood production model [78]. In this thesis, a new double Mackey-Glass delay system, which consists of two coupled Mackey-Glass systems, is studied. Numerical simulations display the chaotic behaviors of the integral and fractional order delay systems by phase portraits and bifurcation diagrams. It is also discovered that TLS, TAS, TALS and TAAS appear for two identical double Mackey-Glass systems, without any control scheme or coupling terms, but with different initial conditions.

Then a control scheme called parameter excited method [79] is applied to control a double Mackey-Glass chaotic system and to synchronize two uncoupled double Mackey-Glass systems. By replacing a parameter of the chaotic system by a noise signal, chaos control can be obtained. By replacing the corresponding parameters of these two chaotic systems by a noise signal, chaos synchronization can be obtained. Moreover, by means of the difference of the timing between two replacements for the first system and the second system, the lag synchronization of two uncoupled double Mackey-Glass systems is achieved. For some chaotic systems, such as physical and electrical systems, which are difficult or even impossible to be coupled, this method is effective and potential in practice [80].

This thesis is organized as follows. In Section 2, the definition and the approximation of the fractional order operator are reviewed. The chaos in integral and fractional order double Mackey-Glass delay system is given by phase portraits and bifurcation diagrams. In Section 3, temporary lag and anticipated synchronizations (TLS, TAS) and temporary lag and anticipated anti-synchronization (TALS, TAAS) are described. Then simulations of TLS, TAS, TLAS and TAAS for two identical double Mackey-Glass systems with different initial values are given. In Section 4, chaos control for a double Mackey-Glass system and chaos synchronization for two uncoupled systems with parameter excited method are presented. Then numerical simulation results of chaos control and of chaos synchronization show the effectiveness of the proposed method. In Section 5, a brief description of lag synchronization scheme based on parameter excitation with two lag noise signals is presented. Numerical simulation results show that lag synchronization, temporary lag synchronization, partial lag synchronization and robustness of lag synchronization are successfully achieved by the proposed method. Finally, some conclusions are drawn in Section 6.