1. INTRODUCTION

Chaotic systems are dynamical systems that are highly sensitive to initial conditions. This sensitivity is popularly known as the butterfly effect (Alligood, Sauer, & Yorke, 1997).

Chaos synchronization problem has received great attention in the literature since Pecora and Carroll (1990, 1991) published their results on chaos synchronization in early 1990s. Since the chaos synchronization has been extensively studied in the last three decades (Pecora & Carrol, 1990, 1991; Pan, Xu, & Zhou, 2010; Sundarapandian, 2011a, 2011b, 2011c). In most of the chaos synchronization approaches, the master-slave or drive-response formalism is used. If a particular chaotic system is called the master or drive system and another chaotic system is called the slave or response system, then the idea of anti-synchronization is to use the output of the master system to control the slave system so that the sum of the outputs of master and slave systems tends to zero asymptotically with time.

Since the seminal work by Pecora and Carroll (1990, 1991), a variety of impressive approaches have been proposed for the synchronization of the chaotic systems such as...
the sampled-data feedback method (Murali & Lakshmanan, 2003), OGY method (Ott, Grebogi, & Yorke, 1990), back stepping method (Wu & Lu, 2003), active control method (Ho & Hung, 2002; Hagn, 1967; Li, Chlouverakis, & Xu, 2009; Liu et al., 2004; Lu et al., 2004; Lorenz & Atmos, 1963; Murali & Lakshmanan, 2003; Ott, Grebogi, & Yorke, 1990; Pecora & Carroll, 1990; 1991; Pan, Xu, & Zhou, 2010; Sundarapandian, 2011a, 2011b, 2011c; Sundarapandian & Sivaperumal, 2011; Wu & Lu, 2003; Yau, 2004), etc.

In this manuscript, we study the anti-synchronization of non identical Pan, Lorenz, Lu, Liu and Cai chaotic systems using active nonlinear control. Explicitly, using active nonlinear control and Lyapunov stability theory, we achieve the global chaos anti-synchronization of non identical chaotic system addressed above. Numerical simulations are carried out to illustrate and validate the proposed synchronization results.

2. METHODOLOGY

Consider the chaotic system described by the dynamics

\[ \dot{x} = Ax + f(x) \]  

(2.1)

where \( x \in \mathbb{R}^n \) is the state of system, \( A \) is the \( n \times n \) matrix of the system parameters and \( f : \mathbb{R}^n \rightarrow \mathbb{R}^n \) is the nonlinear part of the system. We consider the system (2.1) as the master or drive system.

As the slave or response system, we consider the following system described by the dynamics

\[ \dot{y} = By + g(y) + u \]  

(2.2)

where \( y \in \mathbb{R}^n \) is the state of the system, \( B \) is the \( n \times n \) matrix of the system parameters, \( g : \mathbb{R}^n \rightarrow \mathbb{R}^n \) is the nonlinear part of the system and \( u \in \mathbb{R}^n \) is the controller of the slave system.

If \( A = B \) and \( f = g \), then \( x \) and \( y \) are the states of two identical chaotic systems. If \( A \neq B \) or \( f \neq g \), then \( x \) and \( y \) are the states of two different chaotic systems.

In the nonlinear feedback control approach we design a feedback controller \( u \), which anti-synchronizes the states of the master system (2.1) and the slave system (2.2) for all initial conditions.

If we define the anti-synchronization error as \( e(0), y(0) \in \mathbb{R}^n \)

\[ e = y + x \]  

(2.3)

then the synchronization error dynamics is obtained as

\[ \dot{e} = By + Ax + g(y) + f(x) + u \]  

(2.4)

Thus, the anti-synchronization problem is essentially to find a feedback controller \( u \) so as to stabilize the error dynamics (2.4) for all initial conditions \( e(0) \in \mathbb{R}^n \).

Hence, we find a feedback controller \( u \) so that

\[ \lim_{t \to \infty} \| e(t) \| = 0 \quad \text{For all, } e(0) \in \mathbb{R}^n \]  

(2.5)

We consider a Lyapunov function \( V(e) = e^T Pe \), where \( P \) is a positive definite matrix, then \( V : \mathbb{R}^n \rightarrow \mathbb{R} \) is a positive definite function.

We assume that the parameters of the master and slave system are known and that the states of both systems (2.1) and (2.2) are measurable.

If we find a feedback controller \( u \) so that

\[ \dot{V} = -e^T Q e \]  

where \( Q \) is a positive definite matrix, then \( \dot{V} : \mathbb{R}^n \rightarrow \mathbb{R} \) is a negative definite function.

Thus, by Lyapunov stability theory, the error dynamics (2.4) is globally exponentially stable and hence the states of the master system (2.1) and slave system (2.2) will be globally and exponentially anti-synchronized.
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