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Stability and hybrid synchronization of a time-delay financial hyperchaotic system

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Abstract. This paper studies stability and hybrid synchronization of a time-delay financial hyperchaotic system. Based on Lyapunov stability theorem and differential inequalities, stability is obtained by intermittent linear state feedback control. Furthermore, hybrid synchronization method is firstly proposed to synchronize a financial hyperchaotic system and globally synchronization is obtained by proper hybrid controllers and Lyapunov stability theorem. The corresponding numerical simulations are performed to verify and illustrate the effectiveness and correctness of proposing methods.

Keywords: time-delay financial hyperchaotic system, intermittent linear state feedback control, hybrid synchronization, hybrid control.

1. Introduction

In nonlinear science, chaos and hyperchaos study has attracted much attention from scientists and engineers for its applications in diverse areas, such as physical systems, biological networks, secure communications and so on [1,2]. Hyperchaotic systems have more complex behaviors and abundant dynamics than chaotic system because of possessing at least two positive Lyapunov exponents. Therefore, it is extremely important to research on hyperchaotic systems nowadays. Some classical hyperchaotic systems have been proposed, such as the hyperchaotic Chen system, the hyperchaotic Lü system, etc. Due to its applications in many areas, the studies of hyperchaos have not only emphasized on proposing and analyzing new interesting hyperchaotic systems, but also studying hyperchaos control and synchronization. Chaos control is an important subject and it could control system to a predictive target, many methods which include adaptive control, linear feedback control, nonlinear feedback control, fuzzy control, time delay control have been used to achieve it. Up to now, various kinds of synchronization have been proposed to synchronized different systems or identity system with different values, like phase synchronization, lag synchronization, projective synchronization, hybrid synchronization, complete synchronization, anti-synchronization and so on[3-9].

Recently, economy is the hot topic. Basing on the global economic crisis in 2007, we firstly construct a financial hyperchaotic system in [10]. Its dynamical behaviors are more complex and more effective controls are proposed to control it. In fact, hyperchaos system has a strong sensitivity to initial value, so discrete control method is more in line with the actual situation. The intermittent control is active in work time and rest in other time(rest time) [11-13].It reduce control input and save cost. So, we main investigate intermittent control in this paper. Nowadays, most works focus on studying the same kind synchronization between drive system and response system that is the states of response system synchronized to the states of drive system by the same kind synchronization. Whether it has the same phenomenon by two or more kinds of synchronization which defined as hybrid synchronization or not? There is no doubt that it is an interesting problem. Some scholars has investigate hybrid synchronization, [14] study the alternating between complete synchronization and hybrid synchronization of hyperchaotic Lorenz system with time delay, [15] investigate hybrid synchronization of time-delay hyperchaotic 4D systems via partial variables, However, up to now, fewer scholars investigate hybrid synchronization by hybrid control which combine continuous control with discrete control. As a result, in this paper, periodically intermittent linear control is firstly proposed to stabilize the financial hyperchaotic system which we introduce. Basing on Lyapunov stability thermo and differential inequalities, stability of financial hyperchaotic system achieves. We also proposed hybrid synchronization scheme which is firstly applied to financial hyperchaotic system.

This paper is organized as follows. In section 2, describing the time-delay financial hyperchaotic system model. In section 3, presenting stability scheme of a time-delay financial hyperchaotic system. In section 4, hybrid synchronization method of a time-delay financial hyperchaotic system is shown. In section 5, corresponding numerical simulation are given. Finally, making a conclusion in section 6.

2. The time-delay financial hyperchaotic system model

Yu, Cai, etc proposed a financial hyperchaotic system without time-delay in [10], however, time-delay phenomenon often happed in actual situation. Therefore, in this paper, we add time-delay τ to the system that has been proposed in [10], we got a novel time-delay system as follows:

$$\begin{cases} \dot{x} = z + (y - a)x + w(t-\tau) \\ \dot{y} = 1 - by - x^2 \\ \dot{z} = -x - cz \\ \dot{w} = -dxy - kw(t-\tau) \end{cases} \tag{1}$$

where the interest rate x, the investment demand y, the price exponent z, the average profit margin w, they are the state variables, τ is time delay, a, b, c, d, k are the positive parameters of the system(1). When parameters a=0.9, b=0.2, c=1.5, d=0.2 and k=0.17, the four Lyapunov exponents of the system (1) calculated with Wolf algorithm are L_1=0.034432, L_2=0.018041, L_3=0 and L_4=-1.1499. There are three unstable equilibrium points $P_1\left(0, \frac{1}{b}, 0, 0\right), P_{2,3}\left(\pm\theta, \frac{k+ack}{c(k-d)}, \mp\frac{\theta}{c}, \frac{d\theta(1+ac)}{c(d-k)}\right)$, where $\theta = \sqrt{\frac{kb+abck}{c(d-k)}+1}$. According to the hyperchaotic parameter values given above, the equilibrium points are calculated as: P_1 (0, 5, 0, 0), P_2 (1.66, -8.87, -1.11, 17.4) and P_3 (-1.66, -8.87, 1.11, -17.4). Figure1 shows the Lyapunov exponents of system (1). Figure 2(a)-(d) shows the 3-dimensional phase portraits of financial hyperchaotic system (1).

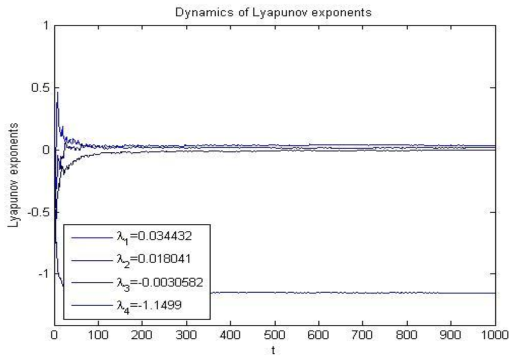
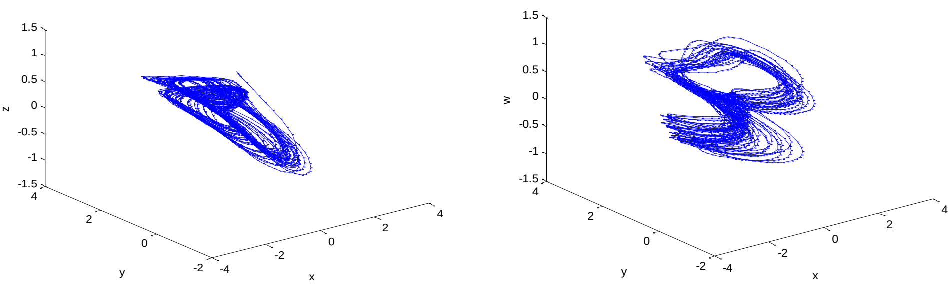


Fig.1: Lyapunov exponents spectrum of system (1) with τ=0.



(a) 3D view in the x-y-z space (b) 3D view in the x-y-w space