CONTROL OF NEW 3D CHAOTIC SYSTEM

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ABSTRACT

In this paper, a new 3D chaotic system is controlled by generalized backstepping method. Generalized backstepping method is similarity to backstepping method but generalized backstepping method is more applications in systems than it. Backstepping method is used only to strictly feedback systems but generalized backsteppingmethod expand this class. New 3D chaotic system is controlled in two participate sections; stabilization and tracking reference input. Numerical simulations are presented to demonstrate the effectiveness of the controlschemes.

KEYWORDS

New 3D chaotic system, Generalizedbackstepping method, Stabilization, Tracking.

1. INTRODUCTION

In recent years, chaos and hyperchaos generation, control and synchronization has become more and more interesting topics to engineering. Therefore, various controllers have been proposed to achieve the stabilization of chaotic systems [3-9]. In [10], the output regulation problem for the Sprott-G chaotic system (1994) has been studied in detail. The tracking of constant reference signals problem for the simplified Lorenz chaotic system has been presented in [11]. [12] has derive state feedback controllers for the output regulation problem of the Sprott-H chaotic system (1994).In [13], active controller has been designed to solve the output regulation problem for the Sprott-P chaotic system (1994) and a complete solution for the tracking of constant reference signals (*set-point signals*). In [14], the tracking of set-point signalsfor the Sprott-F chaotic system has been derived. Active controller has been designed to solve the output regulation problem for the Sprott-K chaotic system [15].sliding controller has been designed for the global chaos control of chaotic systems [16].The adaptive generalized backsteppingmethod was applied to control of uncertain Sprott-H chaotic system in [17].

The rest of the paper is organized as follows: In section 2, a new 3D chaotic system is presented. In section 3, the generalized backstepping method is studied. In section 4, stabilization of new chaotic systems is achieved by generalized backstepping control. In section 5, tracking reference input of new chaotic systems is achieved by generalized backstepping control. In section 6, Represents simulation results. Finally, in section 7, Provides conclusion of this work.

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2. SYSTEM DESCRIPTION

Recently,Congxu Zhuet al constructed the new 3D chaotic system [18]. The system is described by.

$$\begin{aligned}\dot{x} &= -x - ay + yz \\ \dot{y} &= by - xz \\ \dot{z} &= -cz + xy\end{aligned} \tag{1}$$

Where $a = 1.5, b = 2.5, c = 4.9$. Figure 1 and Figure 2 are shown the chaotic system (1).

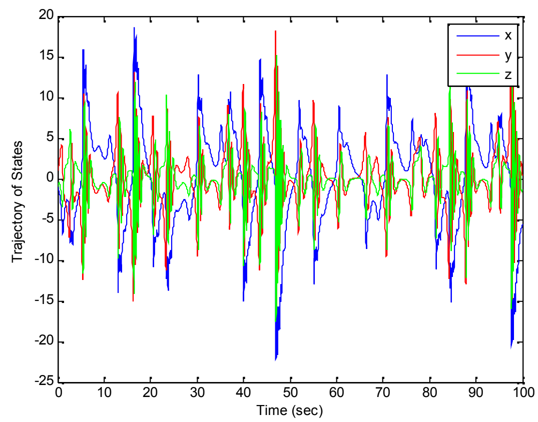

Figure 1.Time response of the system (1).

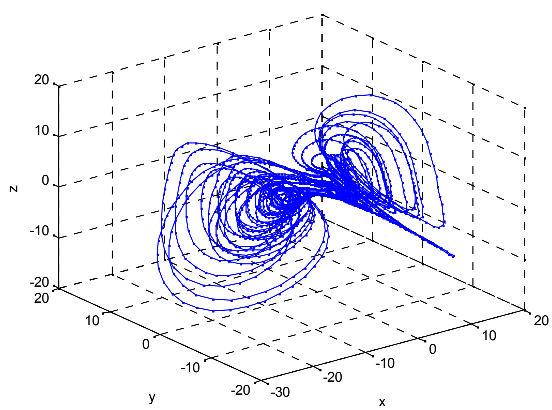

Figure 2. Phase portraits of the hyperchaotic attractors (1).

3. GENERALIZED BACKSTEPPING METHOD

Generalized backstepping method [7-9] is applied to nonlinear systems as follow

$$\begin{cases}\dot{X} = F(X) + G(X)\eta \\ \dot{\eta} = f_0(X,\eta) + g_0(X,\eta)u\end{cases} \tag{2}$$

Where $\eta\epsilon$□and $x = [x_1, x_2, \cdots, x_n]\epsilon$□. Suppose the function $v(x)$is the lyapunov function.

$$V(X) = \frac{1}{2}\sum_{i=1}^{n} x_i^2 \tag{3}$$

The control signal and the extendedlyapunov function of system (2)are obtained by equations (4),(5).

$$u = \frac{1}{g_0(X,\eta)}\left\{\begin{array}{c}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\partial\varphi_i}{\partial x_j}[f_i(X) + g_i(X)\eta] \\ -\sum_{i=1}^{n} x_i g_i(X) - \sum_{i=1}^{n} k_i[\eta - \varphi_i(X)] - f_0(X,\eta)\end{array}\right\}, k_i > 0\,, i = 1,2,\cdots,n \tag{4}$$

$$V_t(X,\eta) = \frac{1}{2}\sum_{i=1}^{n} x_i^2 + \frac{1}{2}\sum_{i=1}^{n}[\eta - \varphi_i(X)]^2 \tag{5}$$

4. STABLIZATIONOF NEW CHAOTIC SYSTEM

The generalized backstepping method is used to design a controller. In order to control new hyperchaotic system we add a control inputs u to the second equation of system (1).

$$\begin{aligned}\dot{x} &= -x - ay + yz \\ \dot{y} &= by - xz + u \\ \dot{z} &= -cz + xy\end{aligned} \tag{6}$$

Stabilization of the state**:**the virtual controllers are as follows.

$$\varphi_1(x,y,z) = \varphi_2(x,y,z) = 0 \tag{7}$$

The control signal$u$ is as follows.

$$u = -(z - a)x - (b + k)y \tag{8}$$

The Lyapunov function as

$$V(x,y,z,w) = \frac{1}{2}x^2 + \frac{3}{2}y^2 + \frac{1}{2}z^2 \tag{9}$$

The gain of controllers (8) was selected.

$$k = 10 \tag{10}$$

5. TRACKING OF NEW CHAOTIC SYSTEM

Let, we add the control law u_1, u_2 and let$\bar{x} = x - r(t)$.Where$x$ is the output of system and $r(t)$ is the desired refrence. The equation (6) would be converted to equation (11), as follows.

$$\begin{aligned} \dot{\bar{x}} &= -\bar{x} - ay + yz - r - \dot{r} \\ \dot{y} &= by - (\bar{x} + r)z + u_1 \\ \dot{z} &= -cz + (\bar{x} + r)y + u_2 \end{aligned} \tag{11}$$

Stabilization of the state**:** In order to use the theorem, it is sufficient to establish equation (12).

$$\varphi_1(\bar{x}, y, z) = -\frac{1}{a}(r + \dot{r})$$

$$\varphi_2(\bar{x}, y, z) = 0 \tag{12}$$

According to the theorem, the control signals will be obtained from the equations (13).

$$u_1 = -(z - a)(x - r) - k_1\left(y + \frac{r + \dot{r}}{a}\right) - by + xz$$

$$u_2 = -(x - r)y - k_2 z - xy \tag{13}$$

And Lyapunov function as

$$V(x, y, z) = \frac{1}{2}x^2 + \frac{1}{2}y^2 + \frac{1}{2}z^2 + \frac{1}{2}(y - \varphi_1)^2 + \frac{1}{2}(z - \varphi_2)^2 \tag{14}$$

we select the gains of controllers (13) in the following form

$$k_1 = 10, k_2 = 10 \tag{15}$$

6. NUMERICAL SIMULATION

This section presents numerical simulations new 3D chaotic system. The generalized backstepping method (GBM) is used as an approach to control chaos in new chaotic system. The initial values are $x(0) = -1, y(0) = 5, z(0) = -6$. Figure 3 shows that (x, y, z) states of new chaotic system can be stabilized with the control laws u(8) to the origin point$(0,0,0)$.Figure 4 shows the control law u (8) to the origin point$(0,0,0)$. Figure 5 shows that$x(t)$when the system tracksthe $r(t) = 1$. Figure 6 shows that $x(t)$when system tracksthe $r(t) = \sin(t)$.

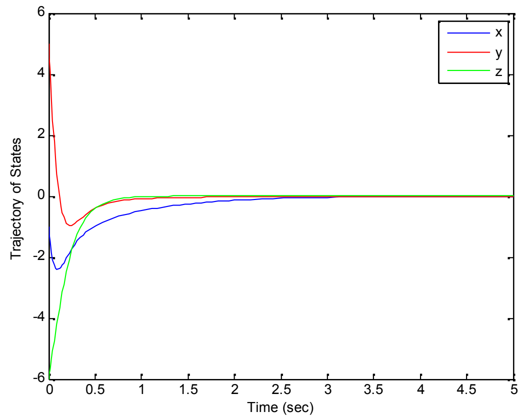

Figure 3.The time response of signals(x, y, z) for the controlled system (6).

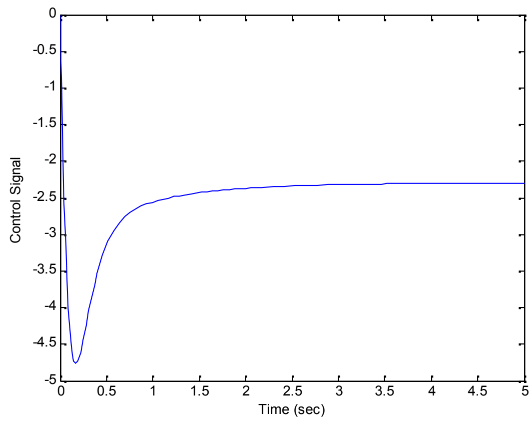

Figure 4. The time response of the control inputs (u) for the controlled system (6).

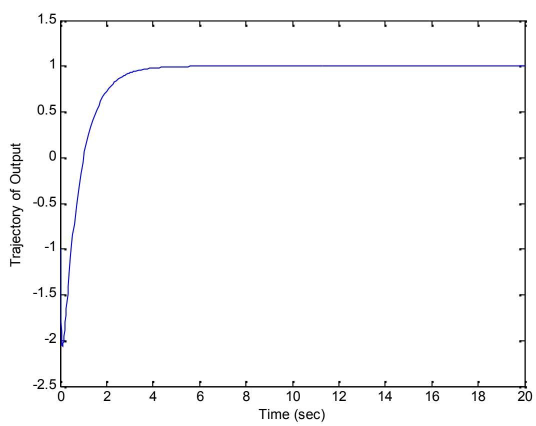

Figure 5. The time response of signal (x) for tracks the trajectory$r(t) = 1$.

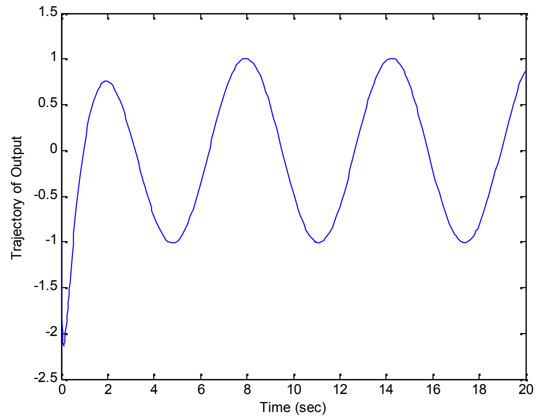

Figure 6. The time response of signal (x) for tracks the trajectory $r(t) = \sin(t)$.

7. CONCLUSIONS

In this paper, a new 3D chaotic system was controlled in two participate sections; stabilization and tracking reference input. This control scheme of new system was achieved by generalized backstepping method. Backstepping method was used only to strictly feedback systems but generalized backsteppingmethod expand this class.

REFERENCES

[1] Chao-Chung Peng, Chieh-Li Chen. Robust chaotic control of Lorenz system by backstepping design. Chaos, Solitons and Fractals 37 (2008) 598–608.

[2 Cheng-Chi Wang, Neng-Sheng Pai, Her-TerngYau. Chaos control in AFM system using sliding mode control by backstepping design.Commun Nonlinear SciNumerSimulat 15 (2010) 741–751.

[3] Faqiang Wang, Chongxin Liu. A new criterion for chaos and hyperchaos synchronization using linear feedback control. Physics Letters A 360 (2006) 274–278.

[4] Yongguang Yu, Suochun Zhang. Adaptive backstepping synchronization of uncertain chaotic system. Chaos, Solitons and Fractals 21 (2004) 643–649.

[5] Sinha SC, Henrichs JT, Ravindra BA. A general approach in the design of active controllers for nonlinear systems exhibiting chaos.Int J Bifurcat Chaos 2000;10(1):165–78.

[6] M.T. Yassen. Chaos control of chaotic dynamical systems using backstepping design. Chaos, Solitons and Fractals 27 (2006) 537–548.

[7] Ali Reza Sahab and Mohammad Haddad Zarif. Improve Backstepping Method to GBM. World Applied Sciences Journal 6 (10): 1399-1403, 2009, ISSN 1818-4952.

[8] Sahab, A.R. and M. Haddad Zarif. Chaos Control in Nonlinear Systems Using the Generalized Backstopping Method. American J. of Engineering and Applied Sciences 1 (4): 378-383, 2008, ISSN 1941-7020.

[9] Ali Reza Sahab, MasoudTalebZiabari, Seyed Amin SadjadiAlamdari. Chaos Control via Optimal Generalized Backstepping Method.International Review of Electrical Engineering (I.R.E.E), Vol.5, n.5.

[10] SundarapandianVaidyanathan, OUTPUT REGULATION OF SPROTT-G CHAOTIC SYSTEM BY STATE FEEDBACK CONTROL, International Journal of Instrumentation and Control Systems (IJICS) Vol.1, No.1, July 2011.

[11] SundarapandianVaidyanathan, OUTPUT REGULATION OF THE SIMPLIFIED LORENZ CHAOTIC SYSTEM, International Journal of Control Theory and Computer Modelling (IJCTCM) Vol.1, No.3, November 2011.

[12] SundarapandianVaidyanathan, STATE FEEDBACK CONTROLLER DESIGN FOR THE OUTPUT REGULATION OF SPROTT-H SYSTEM, International Journal of Information Sciences and Techniques (IJIST) Vol.1, No.3, November 2011.

[13] SundarapandianVaidyanathan, ACTIVE CONTROLLER DESIGN FOR REGULATING THE OUTPUT OF THE SPROTT-P SYSTEM, International Journal of Chaos, Control, Modelling and Simulation (IJCCMS) Vol.2, No.1, March 2013.

[14] SundarapandianVaidyanathan, OUTPUT REGULATION OF SPROTT-F CHAOTIC SYSTEM BY STATE FEEDBACK CONTROL, International Journal of Control Theory and Computer Modelling (IJCTCM) Vol.2, No.2, March 2012.

[15] SundarapandianVaidyanathan, ACTIVE CONTROLLER DESIGN FOR THE OUTPUT REGULATION OF SPROTT-K CHAOTIC SYSTEM, Computer Science & Engineering: An International Journal (CSEIJ), Vol.2, No.3, June 2012.

[16] SundarapandianVaidyanathan, ANALYSIS AND GLOBAL CHAOS CONTROL OF THE HYPERCHAOTIC LI SYSTEM VIA SLIDING CONTROL, International Journal of Information Technology, Control and Automation (IJITCA) Vol.3, No.1, January 2013.

[17] MasoudTalebZiabariand Ali Reza Sahab, ADAPTIVE TRACKING CONTROL OF SPROTT-HSYSTEM, International Journal of Information Technology, Modeling and Computing (IJITMC) Vol.1, No.4, November 2013.

[18] Congxu Zhu, Yuehua Liu, Ying Guo, Theoretic and Numerical Study of a New Chaotic System, Intelligent Information Management, 2010, 2, 104-109.