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CHAOS CONTROL IN A MULTI-TROPHIC ECOLOGICAL SYSTEM MODEL WITH FEEDBACK CONTROL

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Abstract: In this paper, based on the mathematical model of a nonlinear ecological model, complicated dynamical behavior of multi-trophic ecological system model is investigated. Also, this paper discusses chaos control of the three dimensional multi-trophic ecological systems based on linear feedback control technique. Using linear feedback control theory, chaos control of three dimensional chaotic multi-trophic ecological system is realized with linear controllers. Designed controllers are applied to the chaotic multi-trophic ecological model for stabilization of system. After controller is added to the system, the change in behavior of multi-trophic ecological model from chaotic behavior to stable behavior is shown with feedback control. The linear controllers provide that the multi-trophic ecological system converges to zero equilibrium. Numerical simulations show that the proposed method is effective for chaotic multi-trophic ecological system.
Keywords: multi-trophic ecological system, mathematical model, chaos control, linear feedback control technique

1. INTRODUCTION

Many scientists has extensively studied the chaos, after the first attractor is found by Lorenz in 1963 [1]. Many chaotic systems were introduced such as Liu system [2], Chen system [3], Chua system [4], Rössler system [5] etc. after Lorenz found the first chaotic system. However, the chaotic behavior of system should be controlled when chaotic behavior is sometimes undesirable. So, chaos control has received increasingly attentions from researchers, since OGY [6] method has been proposed. Many control methods have been proposed for the control of chaotic systems such as adaptive control [7], sliding mode control [8], linear feedback control [9], etc. In this paper, the control of the chaotic multi-trophic ecological model is investigated based on feedback control. Feedback controller is designed to control chaotic system.

Simulation results show that the controller designed based on feedback control can regulate the chaotic system effectively. The rest section of this paper is organized as follows. In section 2, the chaotic multi-trophic ecological model is described. In section 3, based on feedback control, the controller is designed and feedback control of chaotic multi-trophic ecological model is achieved. Also, numerical results are given and discussed graphically. Finally, conclusions are given in section 4.

2. CHAOTIC MULTI-TROPHIC ECOLOGICAL SYSTEM

The chaotic Multi-Trophic Ecological system model which shows the chaotic behaviour is studied and analysed by Hastings a Powell [10]. We study the complicated dynamic behaviour and control of chaos in a nonlinear ecological system model whose chaotic behaviour of it was shown by reference [10].

The state equations of chaotic Multi-Trophic Ecological system model are written below in Eq. (1) [10, 11].

$$\begin{aligned} \dot{x} &= rx(1-Kx) - f_1(x)y \\ \dot{y} &= -d_1 y + f_1(x)y - f_2(y)z \\ \dot{z} &= -d_2 z + f_2(y)z \end{aligned} \qquad (1)$$

where $f_i(u) = a_i u / (1 + b_i u)$.

The Matlab Simulink model of the multi ecological system is given in Figure 1. Also, chaotic phase portraits and 3d graph of the Multi-Trophic Ecological system model system obtained by ode solver in Matlab are shown in Figure 2.

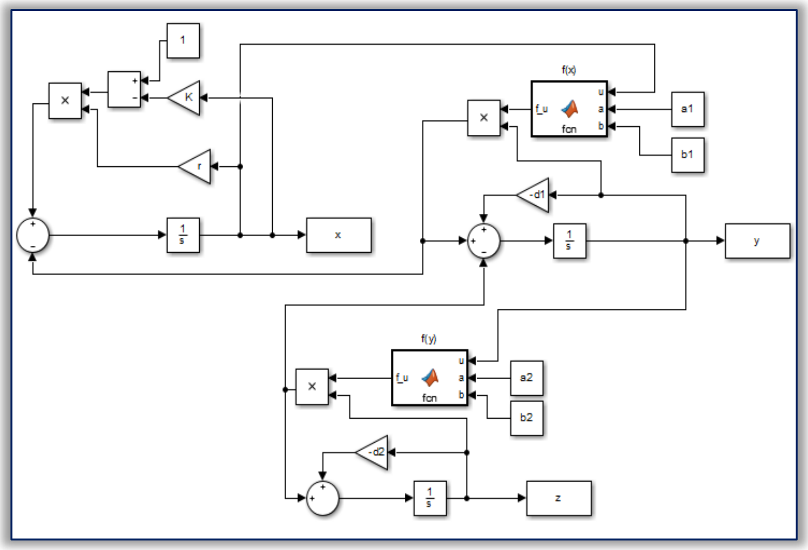

Figure 1. The Matlab-Simulink model of multi-ecological system

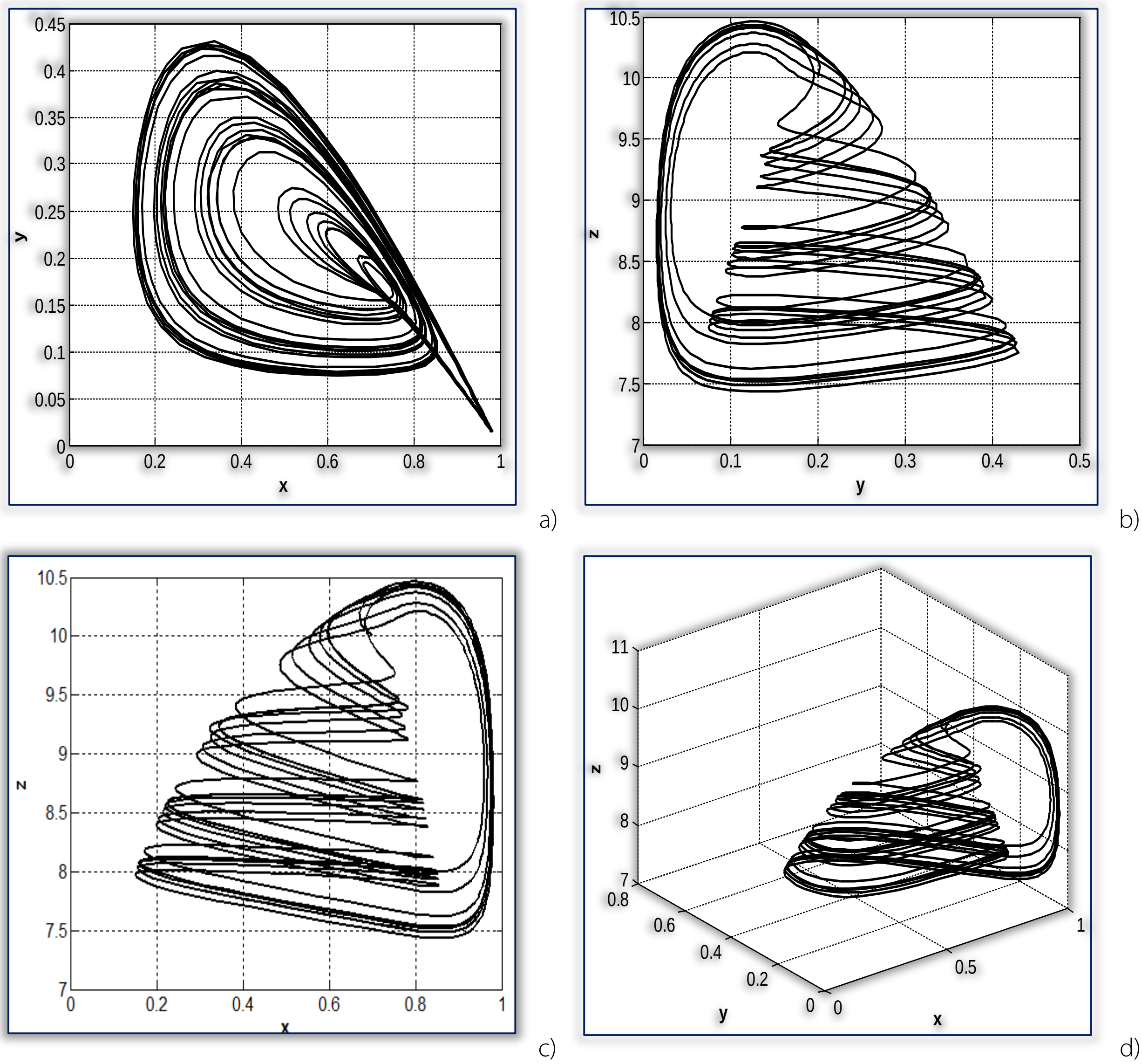

Figure 2. (a) Projection of attractor into the (x,y) (b) (y,z), (c) (x,z) and plane (c) the attractor of system with parameters: K =r =1; a1=5; a2 =0.1; b1 =3; b2 =2; d1=0:4; d2 =0.01 [2].

Using model of system in Matlab, when parameters and initial conditions are given in table 1 and 2 respectively [2]. Chaotic phase portraits and time series of system are obtained as shown in Figure 2 and Figure 3(a) respectively.

Table 1. The parameters of the chaotic system

Parameter	Values
K	1
r	1
a_1	5
a_2	0.1
b_1	3
b_2	2
d_1	0.4
d_2	0.01

Table 2. The initial conditions of the chaotic system

State variable	Value
x(0)	0.7
y(0)	0.2
z(0)	10

3. FEEDBACK CONTROL OF CHAOTIC MULTI-TROPHIC ECOLOGICAL MODEL

The control of chaotic system (2) is achieved using feedback control theory. The controlled model given by:

$$\begin{aligned} \dot{x} &= rx(1-Kx) - f_1(x)y - u_1 \\ \dot{y} &= -d_1 y + f_1(x)y - f_2(y)z - u_2 \\ \dot{z} &= -d_2 z + f_2(y)z - u_3 \end{aligned} \quad (2)$$

where $f_i(u) = a_i u / (1 + b_i u)$.

where u_1, u_2 and u_3 are external control inputs and are proposed as follows $u_1 = k_1 x_1$, $u_2 = k_2 x_2$, and $u_3 = k_3 x_3$ where k_1, k_2 and k_3 are all positive feedback gains [12, 13, 14, 15].

The designed control signal based on feedback control technique is added to the Multi-Trophic Ecological system at t=700s. Figure 3(b) shows the time history of the controlled system with feedback controller activated at t=700s.

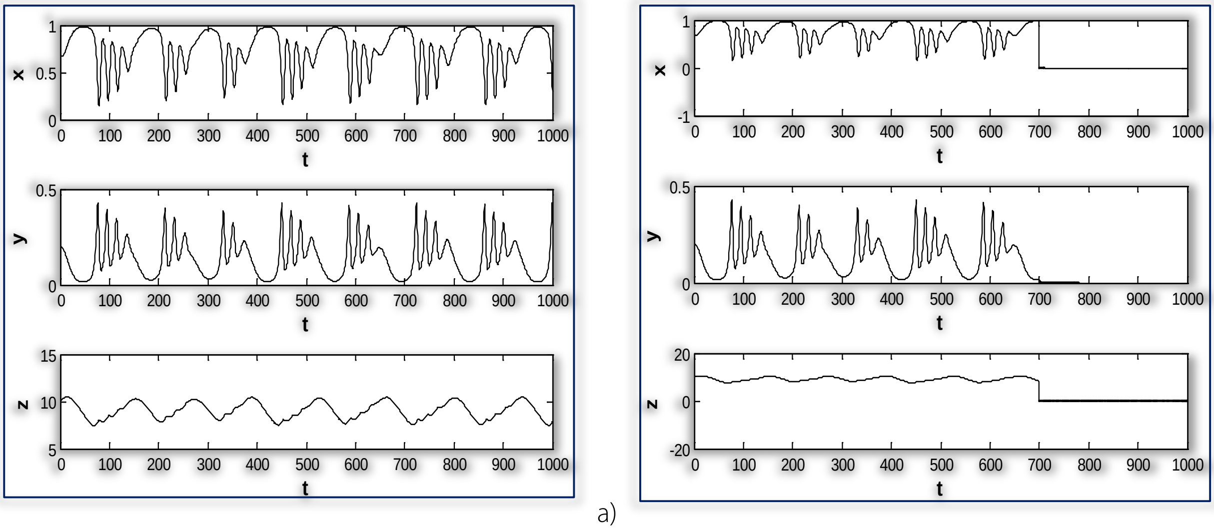

Figure 3. (a) Time series of Multi-Trophic Ecological system model
and (b) controlled Multi-Trophic Ecological system model after the controller is activated at t=700s

As shown in Figure 3, the controlled system (Figure 4) converges to zero equilibrium point. In Figure 4, the clock is used to activate the controller at a specific time. The switch block in Simulink provides zero output before controller activation and also provides controller output when time arrives the activation or set time.

So, in our simulations, when time arrives to 700 s which is set before for controller activation, then controller is activated.

After controller is activated at time t=700s, it can be seen from Figure 5 that system states converge to zero equilibrium point. In Figure 5, red line shows the phase space of the controlled system. After controller is activated, system behaviour is shown as a red line. Black line shows the chaotic behaviour before the controller is activated. As can be seen the Figure 5, after controller is activated, *x* and *z* states converges to zero.

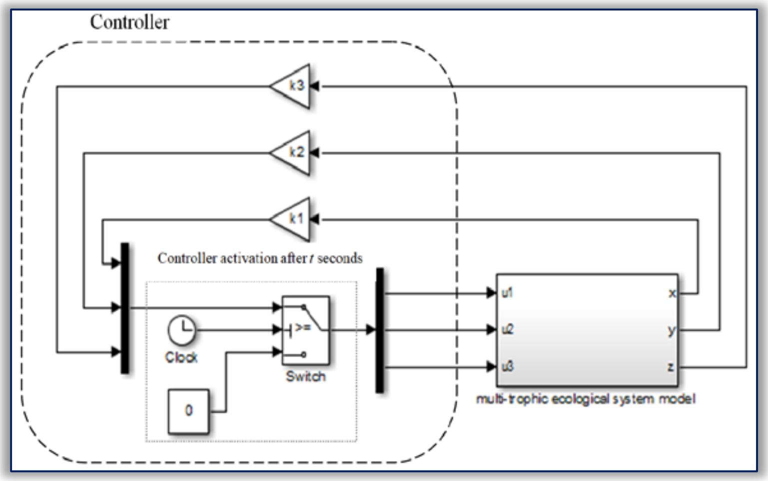

Figure 4. The controlled multi-ecological system model

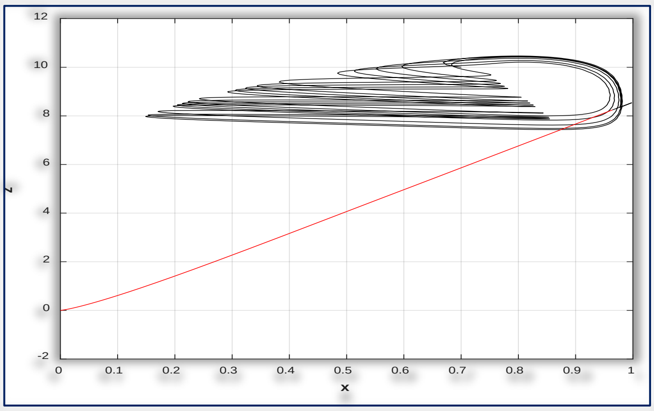

Figure 5. The phase portrait of the system when controller is activated at t=700s

4. CONCLUSION

In conclusion, by using feedback control, control of chaos in Multi-Trophic Ecological system model is studied. Based on the feedback theory, feedback controllers are designed and applied to the system to realize the control of chaos in Multi-Trophic Ecological system model. Numerical simulations show the effectiveness of the proposed control method.

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References

[1] Lorenz E 1963 Deterministic non-periodic flows. *J. Atmos.Sci.*, 20(1) 130–141
[2] C.X. Liu, et al. 2004 A new chaotic attractor *Chaos, Solitons &Fractals* 22(5) 1031–1038
[3] G. Chen, T. Ueta 1999 Yet another chaotic attractor, *Int. J.Bifurcation and Chaos* 9(7) 1465-1466
[4] L.O. Chua, M. Komuro, T. Matsumoto 1986 The double scroll family, *IEEE Trans. Circ. Syst.*, 33(11) 1073-1118
[5] Rössler OE 1976 An equation for continuous chaos, *Phys. Lett. A* 57 397–398
[6] E. Ott C. G 1990 Controlling chaos. *Phys.Rev.Lett*. 64 1196-1199
[7] Wu CW Yang T Chua LO 1996 On adaptive synchronization and control of nonlinear dynamical systems, *Int J Bifurcat Chaos* 6 455–71
[8] Günzay Ablay 2009 Sliding mode control of uncertain unified chaotic systems, *Nonlinear Analysis: Hybrid Systems*, 3 531-535
[9] M. T. Yassen 2005 Controlling chaos and synchronization for new chaotic system using linear feedback control *Chaos, Solitons and Fractals* 26 913–920
[10] Hastings, A, Powell, T 1991 Chaos in a three-species food chain *Ecology* 72 896–903.
[11] Lewi Stone, Daihai He 2007 Chaotic oscillations and cycles in multi-trophic ecological systems, *Journal of Theoretical Biology* 248 382–390
[12] A.E. Matouk, 2008 Dynamical analysis, feedback control and synchronization of Liu dynamical system, *Nonlinear Analysis* 69, 2008, 3213–3224
[13] Juan Ding, Weiguo Yang, Hongxing Yao 2009 A New Modified Hyperchaotic Finance System and its Control, *International Journal of Nonlinear Science* 8(1) 59-66
[14] Chengdai Huang, Liming Cai, Jinde Cao, 2018 Linear control for synchronization of a fractional-order time-delayed chaotic financial system, *Chaos, Solitons & Fractals*, 113 326-332, ISSN 0960-0779, https://doi.org/10.1016/j.chaos.2018.05.022.
[15] Guanghan Peng, Hua Kuang, Li Qing, 2018 Feedback control method in lattice hydrodynamic model under honk environment, Physica A: *Statistical Mechanics and its Applications* 509 651-656, ISSN 0378-4371,https://doi.org/10.1016/j.physa.2018.06.080.

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