Compound Difference Anti-synchronization in Generalized Lotka-Volterra Biological Systems via Active Control Method

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Abstract. In this paper, we describe a systematic approach to investigate compound difference anti-synchronization (CDAS) in four identical chaotic generalized Lotka-Volterra (GLV) biological systems. Initially, a nonlinear active control method (ACM) is proposed which is primarily based on the Lyapunov stability theory (LST). Also, the biological nonlinear control law is designed to achieve the asymptotic stability criterion of the error dynamics of the considered system. In addition, numerical simulations using MATLAB software are presented to illustrate the effectiveness and superiority of the considered scheme. Furthermore, a comparative analysis has been made. Exceptionally, the achieved analytical results are in complete agreement with experimental results. The considered technique has numerous applications in the areas of secure communication and image encryption.

Introduction

The constituting elements in a system may be interacting with each other via competition or cooperation. Illustrations of these systems include biological species, businesses, countries, and others. It is fascinating to investigate numerous biological as well as social interactions between differential species/entities using mathematical modelling. Alfred J. Lotka [1] and Vito Volterra [2] in the 1920s have introduced independently the classical equations on population dynamics, famously known as Lotka-Volterra (LV) equations or Predator-Prey (PP) equations. Initially, LV model was developed as a biological concept, yet it has nowadays found various applications in diverse fields of research. Arneodo, Coullet and Tresser [3] in 1980 have shown that generalized Lotka-Volterra (GLV) model may exhibit chaos phenomenon for a specifically chosen set of parameters. Moreover, Samardzija and Greller [4] in 1988 have shown that GLV model may acquire chaotic regime from the stable state through rise of a fractal torus. Most importantly, it has been over 30 years since the synchronization and control in chaotic systems was firstly put in effect by Pecora and Carroll [5] in 1990 using master- slave configuration. Since then, many researchers and authors have initiated various synchronization and control techniques like complete synchronization, lag synchronization, anti-synchronization, hybrid synchronization, function synchronization, hybrid projective synchronization, combination synchronization, compound synchronization, active control, adaptive control, sliding mode control, feedback control, backstepping control etc. for stabilizing the chaotic systems to gain stability. In [6], authors studied optimal synchronization problem in two identical Lotka-Volterra systems using optimal comtrol technique. In [7], author studied hybrid synchronization in two identical GLV system using adaptive control method. Also, authors discussed combination difference anti-synchronization in three identical chaotic GLV systems using adaptive control method in [8]. Considering the aforementioned discussions, our primal objective in this paper is to investigate compound difference anti-synchronization (CDAS) scheme in four identical chaotic GLV systems using active control method (ACM). We have designed comprehensively the CDAS scheme using ACM. Moreover, based on Lyapunov stability theory, we have explored in detail the biological control laws to achieve the asymptotical stability globally in the error dynamics of the considered model. In addition, numerical simulation are conducted in MATLAB environment to show the efficacy of the proposed method. Furthermore, a comparative analysis has been done depicting the superiority of our proposed method over the existent published literature. Towards the end, we have also mentioned the future scope of the presented work.

References

[1] Lotka A.J.(1926) Elements of Physical Biology. Science Progress in the Twentieth Century 91919-1923), 21(82):341-343.

[2] Scudo F.M. (1971) Vito Volterra and Theoretical Ecology. Theoretical Polulation Biology, 2(1):1-23.

[3] Arneodo A., Coullet P. and Tresser C.. (1980) Occurrence of strange attractors in three-dimensional Volterra model. Physics Letters A, 79(4):259-263.

[4] Samardzija N., and Greller L.D. (1988) Explosive route to chaos through a fractal torus in a generalized Lotka-Volterra model. Bulletin of Mathematical Biology, 50(5):465-491.

[5] Pacora L.M. and Carroll T.L.(1990) Synchronization in chaotic sysyems. Physical review letters, 64(8):El-Gohary A. and Yassen M.T. (2001) Optimal control and synchronization of Lotka-Volterra model. Chaos, Solitons and Fractals, 12:2087-2093.

[6] El-Gohary A. and Yassen M.T. (2001). Optimal Control and Synchronization of Lotka-Volterra Model. Chaos, Solitons and Fractals, 12:2067-2093.

[7] Vaidyanathan S. (2016) Hybrid synchronization of the generalized Lotka-Volterra three species biological system. Int. J. Pharm Tech Res, 9(1):179-192.

[8] Khan T. and Chaudhary H. (2020) Estimation and identifiability of parameters for generalized Lotka-Volterra biological systems using adaptive controlled combination difference anti-synchronization. Differential equations and dynamical systems, 28:515-526.