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Effects of system parameter and fractional order on dynamic behavior evolution in fractional-order Genesio-Tesi system

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ABSTRACT

The object of this paper is to reveal the relationship between dynamics of the fractional-order Genesio-Tesi system and its parameter, especially the order of fractional derivatives. At first, the transcritical bifurcation is carried out based on the stability analysis of equilibrium points. Then, effects of system parameter and fractional order on the dynamics have been investigated deeply and systematically. For commensurate fractional-order system, period-doubling bifurcation, reverse period-doubling bifurcation, period window, transient chaos and steady chaos are found with parameter and fractional order varying simultaneously. For incommensurate fractional-order system, there also exists the route to chaos by period-doubling bifurcation. Furthermore, the effect of different fractional orders on dynamical behavior evolution has been compared. These new findings contribute to successful selecting the most efficient control function, which has been validated by some numerical tools.

1. Introduction

Fractional calculus is a field of mathematics that deals with the research and application of integrals and derivatives of arbitrary order. In other words, it is a generalization of the classical calculus, but with a much wider applicability. Over the past two decades, a number of applications where fractional calculus was employed have rapidly grown. These fractional mathematical models, which introduced a new parameter-differential order, could describe some physical systems more accurately than traditional methods. A typical example of fractional-order system is the heat diffusion through a semi-infinite solid, where heat flow is equal to the half-derivative of the temperature [1]. More examples of fractional-order dynamics can be found in Ref. [2] and the references therein.

In recent years, research on the dynamics of fractional-order systems has attracted more and more attention [3–26]. These studies provide powerful tools to enhance our understanding the complicated behaviors for fractional-order dynamical systems. Meanwhile, they are useful in the design and implementation of fractional-order oscillators [27–30]. Nowadays, it has been known that some fractional-order systems can produce regular motion or chaotic motion. For example, it was shown that limit cycle can be generated in the fractional-order Wien bridge oscillator [3]. Dynamics of fractional-order Duffing and Van der Pol oscillators were studied in Refs. [4–7]. Existence of limit cycle for fractional-order Brusselator and Mathieu systems were reported in Refs. [8,9]. Furthermore, it was found that some fractional-order dynamical system could demonstrate chaotic behavior, such as the fractional-order Chua circuit [10], the fractional-order jerk model [11], the fractional-order Lorenz system families [12–14], the fractional-order Liu system [15], the fractional-order Volta system [16],

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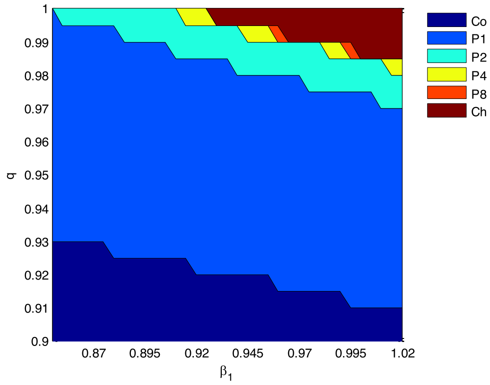

Fig. 1. The evolution of the dynamic behavior for the fractional-order Genesio-Tesi system with different q and β_1, co-convergence, P1-Period 1, P2-Period 2, P4-Period 4, P8-Period 8, Ch-Chaos.

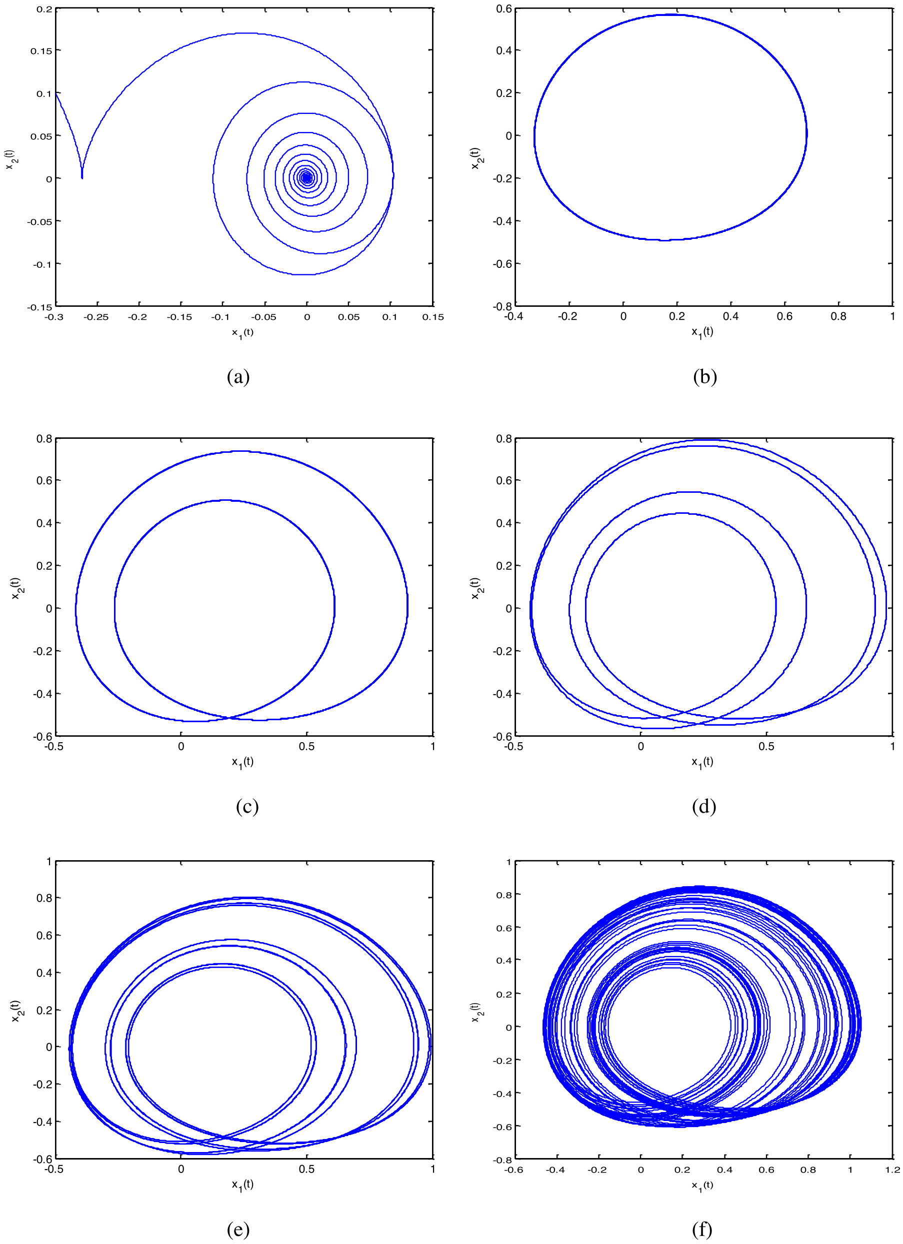

Fig. 2. The route to chaos by period-doubling bifurcation for the fractional-order Genesio-Tesi system with different β_1 for fixed $q = 0.99$. (a) convergence($\beta_1 = 0.40$); (b) Period 1($\beta_1 = 0.88$);(c) Period 2($\beta_1 = 0.96$); (d) Period 4($\beta_1 = 0.99$); (e) Period 8($\beta_1 = 0.996$); (f) Chaos($\beta_1 = 1.02$).