

Control and Synchronization of Julia Sets of the Discrete Three-Dimensional Fractional HCV Model

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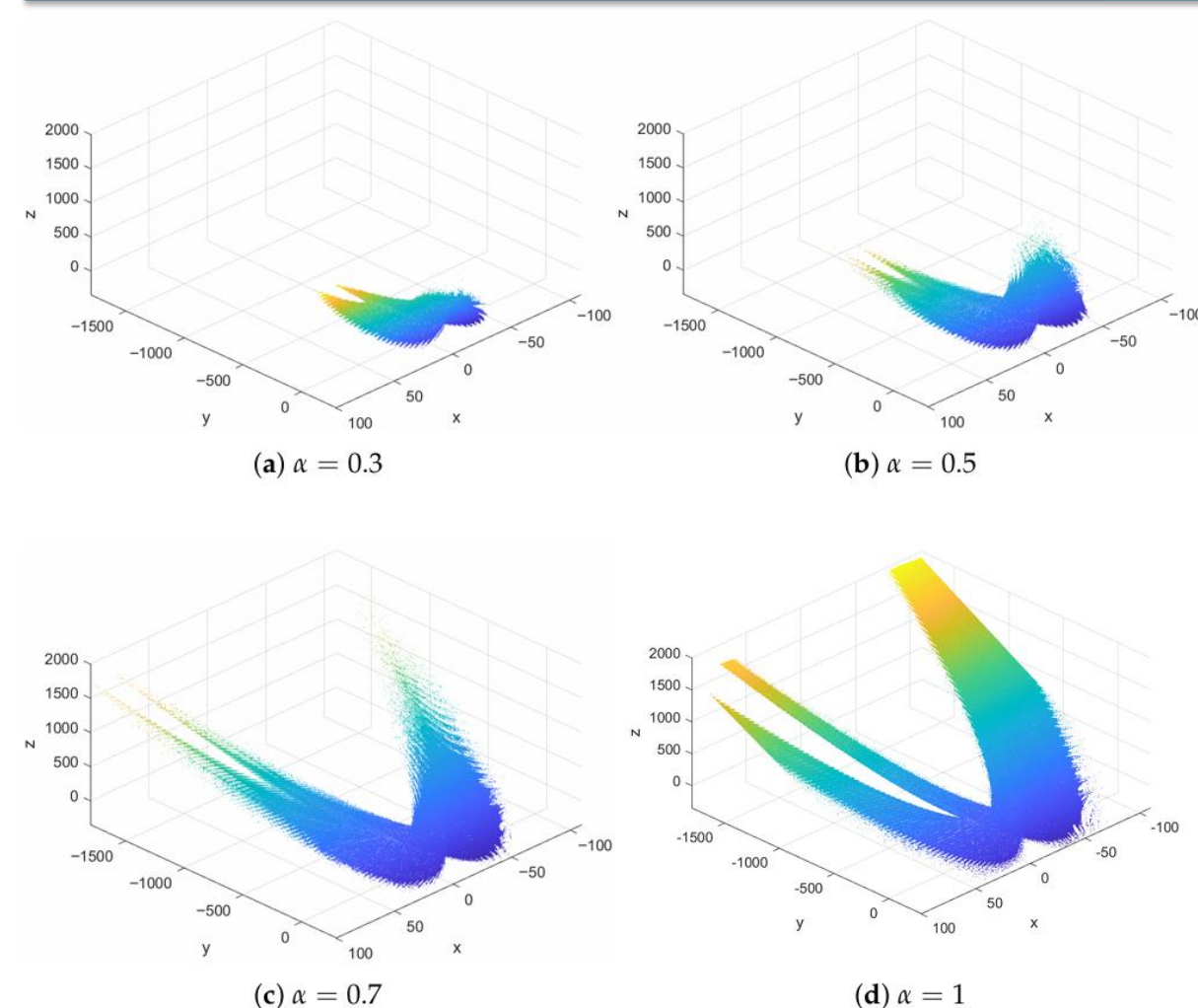
INTRODUCTION & AIM

This paper investigates the fractal dynamical behavior of the discrete three-dimensional Caputo fractional-order hepatitis C virus model. Based on coordinate transformation, a controller is designed to regulate the Julia set. In addition, a nonlinear coupling controller is constructed to achieve synchronization between two HCV models with different parameters and different fractional orders. The aim of this paper is to provide effective strategies for the control and synchronization of Julia sets of the HCV model.

METHOD

First, the Caputo fractional-order operator is introduced into the model, and the model is further discretized. Then, to intuitively demonstrate the influence of the fractional order on the fractal structure of the model, the escape time algorithm is employed to plot the filled Julia sets of the model. Furthermore, a coordinate transformation with memory length N is introduced into the fractional-order model. The stability of the system is then analyzed by using the spectral radius of the Jacobian matrix, and a feedback controller is designed to regulate the Julia set. In addition, a nonlinear coupling controller is proposed to realize synchronization between two HCV systems with different parameters and different fractional orders, and rigorous mathematical proof and numerical simulations validate the effectiveness of the proposed synchronization method.

RESULTS & DISCUSSION



The filled Julia sets of the model expand as the fractional order increases. When $\alpha = 1$, the fractional-order HCV model degenerates into the integer-order one.

Figure 1. Filled Julia sets with different fractional orders.

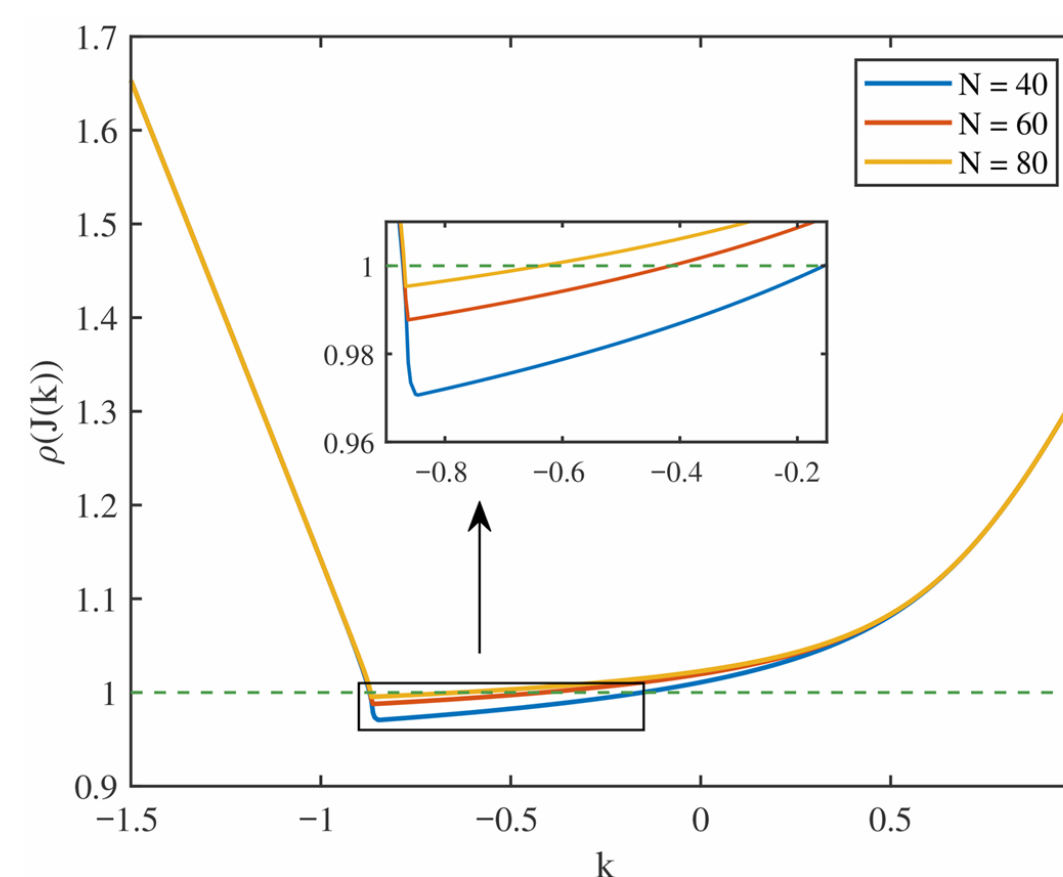


Figure 2. Spectral radius at the fixed point versus k with different N .

When memory length $N = 60$ is chosen, the stable interval is obtained as k in $(-0.8667, -0.4167)$.

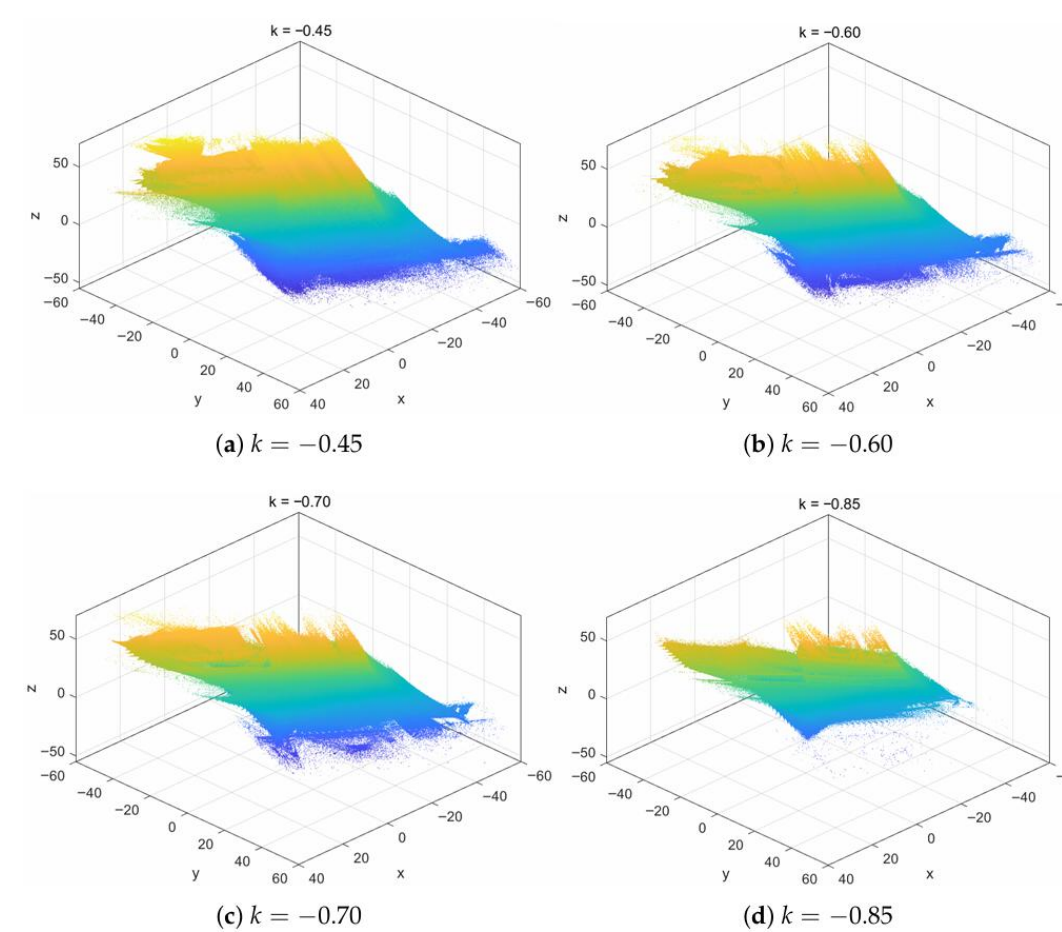


Figure 3. Control of filled Julia sets under different parameters k .

The control terms based on the coordinate transformation are designed. As k decreases, the fractal boundary becomes less irregular, and the filled Julia set shrinks.

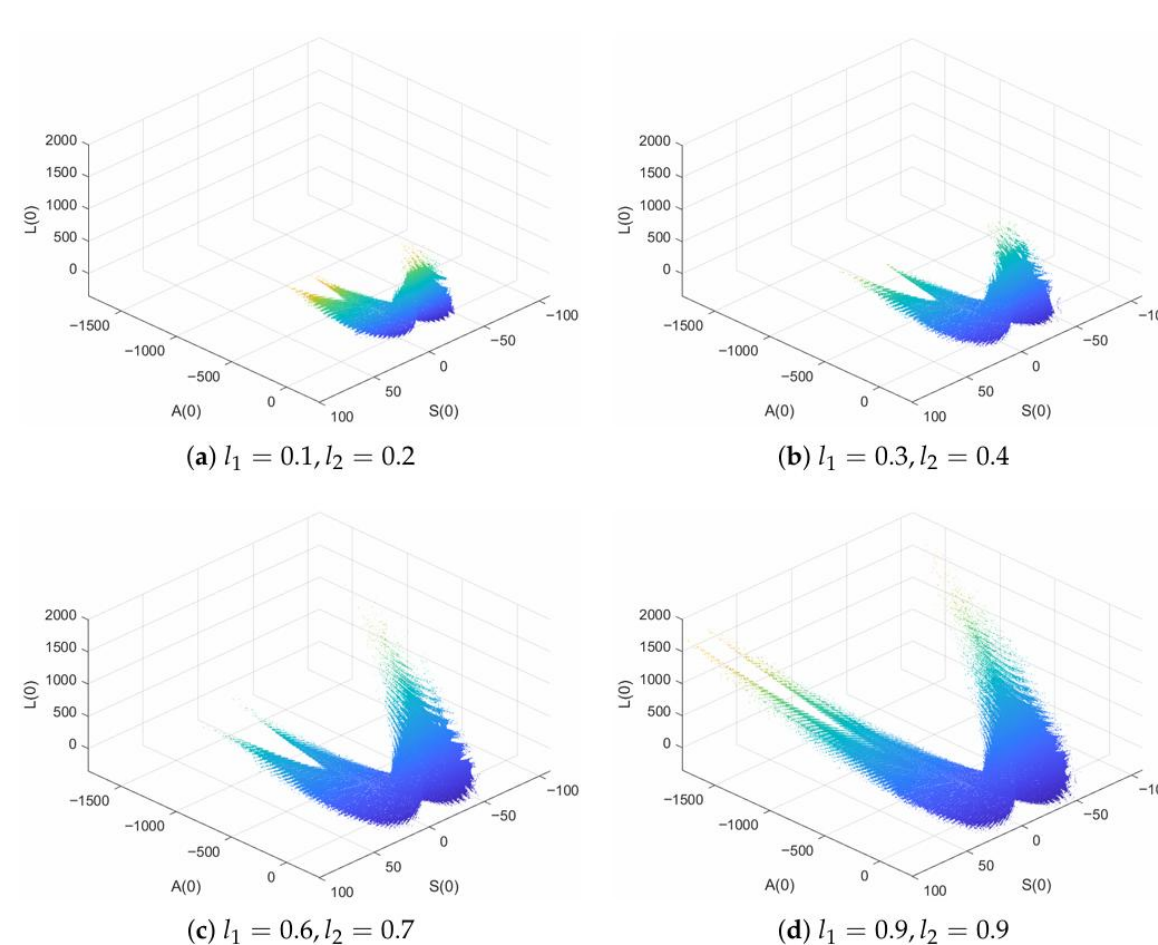


Figure 4. The synchronization between the Julia sets when parameters I_1, I_2 change.

The proposed nonlinear coupling controller drives the fractal structure of the response system toward that of the target system as the control coefficients approach 1.

CONCLUSION

This paper investigates the fractal dynamical behavior of the three-dimensional fractional-order HCV model and explores the control and synchronization of its Julia sets.

FUTURE WORK

The fractal-fractional operator can be considered as an alternative to the Caputo operator. And more control and synchronization methods can be proposed.