Anti-control of Hopf bifurcation for a chaotic system

Abstract: The anti-control of Hopf bifurcation is a method used for bifurcation control. It can be used to realize the occurrence or delay of bifurcation at the specified position to meet the needs of engineering applications. In this study, a 4D chaotic system is studied, and a dynamic state feedback control method is proposed to realize the anti-control of Hopf bifurcation for the system. By adjusting the control parameters of the controller, the system Hopf bifurcation can be generated or delayed at the specified position to realize the anti-control of Hopf bifurcation. This control method avoids complicated calculation processes and has remarkable control effects. Through numerical simulation analysis, the correctness of this control method is verified.

Keywords: anti-control of Hopf bifurcation, chaotic system, dynamic state feedback control method, hybrid controller, nonlinear dynamics

1 Introduction

With its unique dynamic characteristics of irregularity and randomness, chaos has been widely used in chemical engineering [1,2], biological engineering [3,4], communication engineering [5], and other fields. Bifurcation is one of the ways for dynamical systems to enter chaos. Bifurcation control has been widely studied in control theory [6,7]. Bifurcation control and anti-control have become an important part of the research on bifurcation control of chaotic systems. Bifurcation control is to realize the delay or advance of bifurcation by adjusting control parameters to stabilize the bifurcation periodic solution and control the limit cycle amplitude [8–10]. Through effective control methods, beneficial bifurcations can be generated or delayed at specified positions to achieve the purpose of bifurcation anti-control [11–15].

Anti-control of Hopf bifurcation is a inverse problem of Hopf bifurcation control. It is not to eliminate or avoid Hopf bifurcation but to generate bifurcation. It uses the Hopf bifurcation characteristics of nonlinear systems to actively use bifurcation phenomena to serve engineering technology and science.

In recent years, the research results for the anti-control of Hopf bifurcation have been presented. To make the 3D system appear codimension 1, codimension 2, and codimension 3 Hopf bifurcations in a larger range of parameters, a nonlinear control strategy is proposed. The degenerate Hopf bifurcation for the system remains stable at the desired position, while the equilibrium points for the chaotic system remain unchanged [12]. Without changing the equilibrium point, a polynomial function feedback controller is set for discrete mapping to achieve the control and anti-control of bifurcation for the system [13]. Researchers use display criteria and other control methods to perform anti-control of Hopf bifurcation for the Shimizu–Morioka system [16,17]. A controller is set for the logistic system to realize the anti-control of the two-period double bifurcation so that two-period bifurcation appears at the specified position [18]. By using Poincaré map bifurcation, the anti-control of three degrees of bilateral vibration system with clearance is carried out [19]. Using a general and practical anti-control method, the bifurcation anti-control of general continuous time autonomous chaotic systems is realized [20]. In this research, the anti-control of Hopf bifurcations to 4D chaotic systems is studied. With the Routh–Hurwitz criterion and the high-dimensional Hopf bifurcation theory, we analyze the existence of Hopf bifurcation for the system. A dynamic state feedback control method is used to realize the Hopf bifurcation anti-control of the system. This control method avoids complex calculation processes and is easier to understand.

This article is organized into six sections. Section 1 analyzes the literature on bifurcation anti-control to nonlinear dynamical systems; Section 2 proposes the dynamic state feedback control method; Section 3 provides a 4D
chaotic system model and analyzes the characteristics of Hopf bifurcation; Section 4 uses the dynamic state feedback control method to anti-control the Hopf bifurcation of the system; Numerical simulation analysis is used to verify the correctness of the anti-control of Hopf bifurcation in Section 5, and Section 6 presents the conclusion of the article.

2 Dynamic state feedback control

The high-dimensional dynamic system is generally expressed as follows:

$$\dot{x} = f(x, \mu)$$  \hspace{1cm} (1)

where \( f : \mathbb{R}^{n+1} \rightarrow \mathbb{R}^n \), \( x \in \mathbb{R}^n \), and \( \mu \in \mathbb{R} \) is a state variable of the system, \( \mu \) is the real parameter of the system, and \( f \) is continuously differentiable for \( x \) and \( \mu \) in the domain. \( f(x, \mu) \equiv 0 \) when \( \mu \) is taken within a certain range. We assume that the equilibrium point is \( E_i = (x_i^0, x_j^0, \cdots, x_{j-1}^0, x_{j+1}^0, \cdots, x_n^0) \), \( 1 \leq i \leq n \), \( 1 \leq j \leq n \), and the critical value of the parameter \( \mu \) in case of system bifurcation is \( \mu = \mu_i \). Eq. (2) represents the Jacobian matrix of the system:

$$A(\mu) = D_x(E_i, \mu)$$  \hspace{1cm} (2)

Based on the high-dimensional Hopf bifurcation theory, we know that the characteristic equation of matrix (2) has a pair of conjugate complex roots:

$$\lambda(\mu) = a(\mu) \pm i\omega(\mu)$$  \hspace{1cm} (3)

where \( \omega(\mu) > 0 \), \( a(\mu_i) = 0 \), and \( a'(\mu_i) \neq 0 \), and the real parts of other \( n-2 \) characteristic roots of \( A(\mu) \) are negative. When \( \mu = \mu_i \), the Hopf bifurcation of the system arises. Nearby \( \mu_i \), the system has periodic solutions.

We get the characteristic equation of the matrix \( A(\mu) \):

$$\lambda^n + a_1\lambda^{n-1} + a_2\lambda^{n-2} + \cdots + a_{n-1}\lambda + a_n = 0$$  \hspace{1cm} (4)

where \( a_i(i = 1, \cdots, n) \) is a function expression containing \( \mu \).

The Routh–Hurwitz determinant of polynomial (4) is as follows:

$$\Delta_k = \begin{vmatrix} a_1 & 1 & 0 & 0 & 0 & \cdots & 0 \\ a_2 & a_1 & 1 & 0 & 0 & \cdots & 0 \\ a_3 & a_4 & a_3 & a_2 & a_1 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ a_{2k-1} & a_{2k-2} & a_{2k-3} & a_{2k-4} & a_{2k-5} & \cdots & \cdots & a_k \end{vmatrix}$$  \hspace{1cm} (5)

where \( k = 1, \cdots, n \) and \( a_i = 0 \) if \( i > n \).

Therefore, we propose the following lemmas.

**Lemma 1.** [21] If and only if \( a_i > 0(i = 1, 2, \cdots, n) \), \( \Delta_i > 0(j = n-1, n-3, n-5, \ldots) \), the real parts of all characteristic roots of the equation are negative.

**Lemma 2.** [21] The equation has a pair of conjugate pure imaginary roots. If and only if \( a_1 > 0, \Delta_i > 0(j = n-1, n-3, n-5, \ldots) \), and \( \Delta_{n-1} = 0 \), the real parts of other roots are negative.

A hybrid controller is designed, which consists of a linear controller and a nonlinear controller:

$$\begin{align*}
  \dot{u}_i(x, y) &= k_{ij} (x_j - \hat{x}_j^p) + k_{ij} (x_i - \hat{x}_i^p)^3 - k_{ij} y_j \\
  \dot{y} &= u_i(x, y)
\end{align*}$$  \hspace{1cm} (6)

where \( y \in \mathbb{R}^m(1 \leq m \leq n) \). \( y \) is a newly added state variable. The control parameters in the controller are

$$k_{ij} = [k_{i1}, k_{i2}, \ldots, k_{in}], \quad k_j = [k_{j1}, k_{j2}, \ldots, k_{jm}],$$

$$k_{ij} = [k_{i1}, k_{i2}, \ldots, k_{in}].$$

\( u(x, y) \) is the hybrid controller which is continuous and smooth for \( x \) and \( y \) is derivable everywhere. \( \hat{x}_j^p \) is the value of the state variable for the system (1) equilibrium point. When the controller is set up in the system, the system becomes a control system and its expression is as follows:

$$\begin{align*}
  \dot{\chi} &= f(x, y) + u(x, y) \\
  \dot{y} &= h(x, y)
\end{align*}$$  \hspace{1cm} (7)

where \( u(x, y) = [u_1(x_1, y_1), \cdots, u_m(x_m, y_m), 0, \cdots, 0]^T \),

$$h(x, y) = [u_1(x_1, y_1), \cdots, u_m(x_m, y_m)]^T.$$

It can be seen that the control system (7) has increased from the \( n \) dimension of the system (1) to the \( n + m \) dimension, and the equilibrium points of the control system (7) are also the equilibrium points of the system (1). Generally, only one controller \( u_j \) \( 1 \leq j \leq m \) is set for the system (1). When controller parameters \( k_{ij} ≠ 0 \), \( k_{ij} ≠ 0 \), \( k_{ij} ≠ 0 \), \( k_{ij} ≠ 0 \), and \( k_{ij} ≠ 0 \), the other parameters are set to 0. This method can set up a variety of controllers as required.

Let \( z_j = k_{ij}(x_j - \hat{x}_j^p) + k_{ij}(x_i - \hat{x}_i^p)^3 \) be a function of \( x_j \). According to the Laplace transform, we can obtain Eqs. (8) and (9):

$$u_i(s) = z_j(s) - k_{ij}y_j(s)$$  \hspace{1cm} (8)

$$z_j(s) = (s + k_{ij})y_j(s)$$  \hspace{1cm} (9)

The expression of the transfer functions is

$$G_j(s) = \frac{u_i(s)}{z_j(s)} = \frac{s}{s + k_{ij}}$$  \hspace{1cm} (10)

where \( k_{ij} \) is a positive real number.

We calculate the control parameters in the controller and define the control system as follows:

$$\dot{X} = F(X, \mu)$$  \hspace{1cm} (11)

where \( X = [x, y]^T \), \( F = [f(x, y) + u(x, y), h(x, y)]^T \).
The Jacobian matrix of the control system (11) is

\[ J_c(X, \mu) = \frac{\partial f(X, \mu)}{\partial X} = \begin{bmatrix} J(x) + P_1(x) & P_2(x) \\ P_3(x) & P_4(x) \end{bmatrix} \]  

(12)

where

\[ J(x) = \frac{\partial f(x, \mu)}{\partial x}, \quad P_i(x) = \frac{\partial h_i(x, y)}{\partial x}, \quad P_4(x) = \frac{\partial h_4(x, y)}{\partial y}. \]

Let

\[ M = \begin{bmatrix} k_{11} + 3k_{21}(x_1 - X_1^e)^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & k_{m1} + 3k_{2m}(x_m - X_m^e)^2 \end{bmatrix} \]

\[ N = \begin{bmatrix} k_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & k_{m1} \end{bmatrix} \]

Then,

\[ P_1(x) = M 0_{(n-m)\times(n-m)} \]

\[ P_2(x) = 0_{(n-m)\times(n-m)} N \]

\[ P_3(x) = \begin{bmatrix} M 0_{(n-m)\times(n-m)} \\ 0_{(n-m)\times(n-m)} \end{bmatrix}, \quad P_4(x) = [M 0_{(n-m)\times(n-m)}] \]

Therefore, when the control system is at the equilibrium point \(E_0\), the characteristic equation is defined as

\[ Q(\lambda, \mu) = q_0(\mu)\lambda^{n+m} + q_1(\mu)\lambda^{n+m-1} + \cdots + q_{n+m}(\mu) \]  

(13)

The coefficient of Eq. (13) is used to construct the Routh–Hurwitz determinant. The determinant form is as follows:

\[ H_{n+m} = \begin{bmatrix} q_0(\mu) & q_1(\mu) & \cdots & 0 \\ q_1(\mu) & q_2(\mu) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ q_{2(n+m)-1}(\mu) & q_{2(n+m)-2}(\mu) & \cdots & q_{n+m}(\mu) \end{bmatrix} \]

Based on Lemmas 1 and 2, we can obtain Theorem 1. The value of controller parameters is determined by the following formula in scientific research:

\[ H_{n+m-k}(\mu) = 0 \]

**Theorem 1.** When the real coefficient equation satisfies \(q_i(\mu_i) > 0 (i = 0, 1, 2, \ldots, n), \quad H_{j}(\mu_j) > 0 (j = n + m - 3, \ldots, n + m - 5, \ldots)\), and \(H_{n+m-k}(\mu) = 0\), the system has a pair of conjugate pure imaginary roots, and the real parts of other roots are negative, then the control system has Hopf bifurcation.

### 3 A 4D chaotic system

Here, we will introduce the Hopf bifurcation characteristics of a 4D chaotic system, and give the existing conditions.

Feng and Yinlai [22] analyzed a 4D chaotic system, which is defined as follows:

\[ \begin{aligned}
\dot{x} &= a(y - x) \\
\dot{y} &= cx - yz + w \\
\dot{z} &= -bz + xy + dx^2 \\
\dot{w} &= -ey
\end{aligned} \]  

(14)

where \(a, b, c, d, e\) are system parameters and \(x, y, z, w\) are system variables. They also analyzed the system parameter selection condition (14) when the system generates Hopf bifurcation [22]. In addition, the properties of Hopf bifurcations and periodic solutions of the system are analyzed.

We use the control method to analyze the dynamic properties of the system (14), such as Hopf bifurcation. Through analysis, we obtain the existence and stability conditions of Hopf bifurcation at the equilibrium point of the system (14). The only equilibrium point of the system (14) is \(E_0(0, 0, 0, 0)\). When the state variable of the system (14) is at the equilibrium point \(E_0(0, 0, 0, 0)\), its Jacobian matrix is as follows:

\[ J = \begin{bmatrix} -a & a & 0 & 0 \\ c & 0 & 0 & 1 \\ 0 & 0 & -b & 0 \\ 0 & -e & 0 & 0 \end{bmatrix} \]

The characteristic equation of the Jacobian matrix is obtained as in Eq. (15):

\[ \lambda^4 + p_1\lambda^3 + p_2\lambda^2 + p_3\lambda + p_4 = 0 \]  

(15)

where \(p_1 = a + b, \quad p_2 = ab - ac + e, \quad p_3 = -abc + ae + be, \quad p_4 = abe\). The Routh–Hurwitz determinant \(\Delta_n\) is established with the coefficients of Eq. (15):

\[ \Delta_n = \begin{bmatrix} p_1 & 0 & 0 & 0 \\ p_2 & p_1 & 0 & 0 \\ p_3 & p_2 & p_1 & 0 \\ p_4 & p_3 & p_2 & p_1 \end{bmatrix} \]  

(16)

With Lemma 2, if the equation has a pair of purely imaginary roots and two other roots with negative real parts, the equation needs to meet the following conditions:

\[ p_i > 0, \quad i = 1, 2, 3, 4 \\
\Delta_j > 0, \quad j = 3, 2, 1 \]  

(17)
When all the previous conditions are met, the system is stable.

When $a > 0$, the system is unstable. Under $a = 2.5$, $b = 10$, $c = 10$, $d = 12$, $e = -0.5$ and the initial condition of $(1,0,0,0)$, the roots of the characteristic Eq. (15) is $\lambda_1 = -10$, $\lambda_2 = -0.05$, and $\lambda_{3,4} = 1.27 \pm 4.79i$. Therefore, at the equilibrium point $E_0(0, 0, 0, 0)$, the system (14) is in an unstable state, as shown in Figure 1.

4 Anti-control of Hopf bifurcation

In this section, we will use the dynamic state feedback control method to set a hybrid controller to achieve the anti-control of Hopf bifurcation for the system. Through analysis, we can get the expected Hopf bifurcation characteristics.

By the dynamic state feedback control method, a hybrid controller which consists of a linear controller and a nonlinear controller is set up to the system. The control system is expressed as Eq. (18):

$$
\begin{align*}
\dot{x} &= a(y - x) \\
\dot{y} &= cx - xz + w + k_1 y + k_2 y^3 - k_3 u \\
\dot{z} &= -bz + xy + dx^2 \\
w &= -ey \\
\dot{u} &= k_3 y + k_2 y^3 - k_3 u
\end{align*}
$$

The equilibrium point of the control system (18) is still $E_0(0, 0, 0, 0)$, the same as that of the original system (14). According to the dynamic state feedback control method, we can obtain the matrices as follows:

$$J(x) = \begin{bmatrix} -a & a & 0 & 0 \\ c & 0 & 0 & 1 \\ 0 & 0 & -b & 0 \\ 0 & -e & 0 & 0 \end{bmatrix}, \quad P_1(x) = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & k_1 - k_3 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix},$$

$$P_2(x) = \begin{bmatrix} k_3 \\ 0 \\ 0 \end{bmatrix}, \quad P_3(x) = [0 \ k_3 - k_1 \ 0 \ 0], \quad P_4(x) = [k_3].$$

When the state variable of the control system is (18) at the equilibrium point $E_0(0, 0, 0, 0)$, the Jacobian matrix is

$$J'(E_0) = \begin{bmatrix} -a & a & 0 & 0 & 0 \\ c & k_3 - k_1 & 0 & 1 & -k_3 \\ 0 & 0 & -b & 0 & 0 \\ 0 & -e & 0 & 0 & 0 \\ 0 & k_1 - k_3 & 0 & 0 & -k_3 \end{bmatrix}.$$
The Jacobian matrix of the control system does not appear \( k_3 \). Therefore, the nonlinear controller in the hybrid controller cannot change the Hopf bifurcation critical value of the control system (18), and the linear controllers can determine the Hopf bifurcation characteristics.

The characteristic equation expression of the Jacobian matrix is as Eq. (19):

\[
\lambda^5 + q_4\lambda^4 + q_3\lambda^3 + q_2\lambda^2 + q_1\lambda + q_0 = 0
\]  

(19)

where

\[
q_4 = a + b - k_3
\]

\[
q_3 = ab - ac + e - ak_1 - bk_3 + 2k_3k_1 - 2k_3^2
\]

\[
q_2 = abc + ae + be - abk_1 + ack_3 - ek_1 + 2(a + b)k_1k_3 - 2(e + b)k_3^2
\]

\[
q_1 = abck_3 - aek_1 - bek_3 - 2abk_3k_3 - 2abk_3^2 + abe
\]

\[
q_0 = -abe k_3.
\]

The Routh–Hurwitz determinant \( A_{n+m} \) is established with the coefficients of Eq. (19):

\[
A_{n+m} = \begin{vmatrix}
q_1 & 1 & 0 & 0 & 0 \\
q_3 & q_2 & q_1 & 1 & 0 \\
q_5 & q_4 & q_3 & q_2 & q_1 \\
0 & 0 & q_5 & q_4 & q_3 \\
0 & 0 & 0 & 0 & q_5
\end{vmatrix}
\]  

(22)

According to Lemmas 1 and 2, Theorem 2 is proposed.

**Theorem 2.** The characteristic equation of the Jacobian matrix has a pair of purely imaginary roots, and the real parts of other roots are negative. The necessary and sufficient conditions are as follows:

\[
\begin{cases}
q_i > 0, & i = 1, 2, 3, 4, 5 \\
\Delta_j > 0, & j = 3, 2, 1 \\
\frac{d(\Delta_j)}{d\mu} \bigg|_{\mu=\mu^*} \neq 0
\end{cases}
\]  

(23)

When \( \Delta_4 = 0 \), the control parameters of the linear controller in the hybrid controller can be determined from Eq. (24):

\[
q_4 q_3 q_2 - q_4 q_4^2 q_3^2 - q_2^2 q_3^2 q_3 q_5 + q_4 q_2 q_4 q_3 - q_3^2 q_4^2 + q_2 q_3 q_4 q_2 - q_3^2 q_4 = 0
\]  

(24)

Of course, Eq. (24) involves the system parameters \( a, b, c, e \), and the system control parameters \( k_1, k_3 \). We can obtain the corresponding relationship between control parameters \( k_1, k_3 \). It is found that the critical value of the bifurcation parameter of the system is only determined by the control parameters of the linear controller. Therefore, under the given system parameters \( a, b, c, e \), the control parameter \( k_1, k_3 \) can be obtained. The objective of anti-control of Hopf bifurcation is achieved.

### 5 Numerical Simulation

In this section, using the control method, the anti-control of Hopf bifurcation for a 4D chaotic system is carried out, and the control results are obtained.

To realize the anti-control of Hopf bifurcation for the system (14), and verify the correctness of the control method, we give the system parameters values and carry out numerical simulation analysis.

**Example.** We set \( a = 2.5, b = 10, c = 10, d = 12, \) and \( e = -0.5 \). Then, the 4D chaotic system (14) can be expressed as Eq. (25):

\[
\begin{align*}
\dot{x} &= 2.5(y - x) \\
\dot{y} &= 10x - xz + w \\
\dot{z} &= -10z + xy + 12x^2 \\
\dot{w} &= 0.5y
\end{align*}
\]  

(25)

The control system (25) is

\[
\begin{align*}
\dot{x} &= 2.5(y - x) \\
\dot{y} &= 10x - xz + w + k_3 y + k_3 y^3 - k_3 u \\
\dot{z} &= -10z + xy + 12x^2 \\
\dot{w} &= 0.5y
\end{align*}
\]  

(26)

When \( a = 2.5, b = 10, c = 10, \) and \( e = -0.5 \), the coefficients of Eq. (19) are obtained:

\[
q_4 = 12.5 - k_1 + 2k_3
\]

\[
q_3 = -0.5 - 12.5k_1 + 25k_3
\]

\[
q_2 = -256.25 - 25k_1 + 24.5k_3
\]

\[
q_1 = -12.5 - 256.25k_3
\]

\[
q_0 = -12.5k_3
\]

According to the previous theorems, the value ranges of the control parameters can be obtained:

\[
k_1 < -10.3, \quad k_3 < -0.048
\]

When \( k_3 = -1.5 \), we can obtain \( k_3 = -12.08, -0.779, 5.39, 8.99 \). Since \( k_3 < -10.3 \), we choose \( k_3 = -12.08 \). With \( a = 2.5, b = 10, c = 10, e = -0.5 \) and the initial value of the system (26) \((1, 0, 0, 0, 0)\), the sequence diagram and phase diagram of the system are shown in Figures 2–4.
We can see from Figures 2–4 that when $k_{11} = -12.08$ and $k_{31} = -1.5$, the system (26) is in a Hopf bifurcation period state at the equilibrium point and generates Hopf bifurcation. Figure 2 shows the change of a system state variable in time, and Figures 3 and 4 show the phase diagrams of the $xyz$ and $yzw$ spaces for the system. By using the dynamic state feedback control method, the Hopf bifurcation of the system can be delayed or generated, and then the system can enter a period state. Figures 2–4 verify this.

When the values of the system parameters and the control parameters of the linear controller remain unchanged, we consider $(1, 1, 1, 1, 1)$ and $(2, 0, 0, 0, 0)$ for the initial values of the system, respectively, and obtain the system phase diagram as shown in Figures 5 and 6.

It can be seen from Figures 5 and 6 that when the initial value of the system (26) changes and the system (25) parameters and control parameters remain unchanged, the system (26) remains in a period state, and the Hopf bifurcation still occurs.

When $a = 2.5$, $b = 10$, $c = 10$, and $e = -0.5$, the value range of control parameters of the linear controller for the system (26) can be determined by Eq. (24); therefore, $k_{11} = -12.08$ and $k_{31} = -1.5$. $k_{31}$ is determined by the system (26) parameters $a$, $b$, $c$, and $e$. It is an effective and simple process to adopt the dynamic state feedback control method for the anti-control of Hopf bifurcation to high-dimensional chaotic systems.

From the above experimental results, we can conclude that the Hopf bifurcation of the high-dimensional chaotic system control by the dynamic state feedback control method can be used to achieve our expected goals. Under different initial values of system state variables, the Hopf bifurcation characteristics of the system are effectively
controlled by the controllers. This proves that the control method adopted in this study applies to complex high-dimensional chaotic systems.

6 Conclusion

In our work, we study a 4D chaotic system, analyze the bifurcation characteristics, and verify the existence of Hopf bifurcation of the system. According to the high-dimensional Hopf bifurcation control theory, a dynamic state feedback control method is proposed. From the analysis process, it can be seen that the Hopf bifurcation can occur at the expected position by changing the control parameters, realizing the anti-control of Hopf bifurcation. The Hopf bifurcation control method proposed in our work enriches the high-dimensional Hopf bifurcation theory of chaotic systems and verifies the rationality of the bifurcation anti-control control method.

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References


