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Application of Antisynchronization in Agricultural systems: Fractionl order Complex system approach

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ABSTRACT
The utilization of advanced control techniques in agricultural systems has become imperative for enhancing productivity, sustainability, and resource efficiency. This paper proposes a novel approach employing antisynchronization in the context of agricultural systems, utilizing fractional order complex systems. Antisynchronization, a concept derived from chaos theory, involves achieving an anti-phase synchronization between two or more coupled dynamical systems. By the use of stability theory of fractional system in this paper antisynchronization between different fractional order complex system is achieved. Feasibility of the study is shown in the numerical results.
Keywords:-*Antisynchronization, Complex system, Fractional order, Numerical simulation*

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INTRODUCTION

In recent years, the integration of advanced control methodologies with agricultural systems has gained significant attention due to the potential enhancement in productivity, resource management, and sustainability. One such innovative approach is the application of antisynchronization, a concept derived from chaos theory and nonlinear dynamics, in agricultural systems. Antisynchronization offers a promising framework for regulating the dynamics of interconnected subsystems within agricultural environments, facilitating optimal control and management practices. Antisynchronization involves the suppression of chaotic dynamics between coupled systems, leading to the establishment of desired patterns or states in one or more subsystems. This concept has been successfully applied in various fields such as communications, electronics, and physics. In the context of agricultural systems, antisynchronization presents unique opportunities for improving key aspects such as crop yield optimization, water resource management, pest control, and environmental sustainability.

Many branches of applied science as physics, fluid geometry and in optical waves this system has a great advantage. There is worthy study about the chaotic nature and synchronization of the fractional order complex system. One of the properties of the complex system is that it increases the contents and the security of the transformation system so it is widely used in the secure communication [1-10]. Recently more focus of researcher on complex network. As a dynamical system, fractional order system is described by the derivatives and integrals. Many research have been done in the field of fractional order system through the OPCL control [11-13].

As in the recent years fractional calculus and its application have attracted much attention [14-17] as it is verified that to eliminate the chaos behavior fractional controller are stronger than the traditional controller. This paper aims to explore the application of antisynchronization in agricultural systems from a fractional order complex system perspective. From these studies this chapter study the antisynchronization between the different fractional order complex systems. For the achievement of antisynchronization taking fractional order complex master system and slave system by assuming that the derivative order $(\alpha < 1)$ in master slave system, the paper is divided into different sections. In the first part (1) , gives methodology used, part (2) define the solution of the problem ,simulation part is shown in the part (3), concluding result is given in the section(4).

METHODOLOGY USED

The master complex system is considered as

$D_*^{\alpha} x = Ax + f(x)$ (1.1)

Where $x = (x_1, x_2, \dots x_n)^T$ is the complex state vector

$x = x^r + jx^i$, r, i here represents real and imaginary part of the system.

In the equation (1.1) the function $f = (f_1, f_2, \dots f_n)^T$ is a vector of nonlinear complex function

Define

$x_1 = m_1 + jm_2$

$x_2 = m_3 + jm_4$

………………..

$x_n = m_{2n-1} + jm_{2n}$ (1.2)

The system parameter matrix is $A \in R^{n*n}$ corresponding to equation (1.1)

$D_*^{\alpha} y = By + g(y) + u$ (1.3)

Where $y = (y_1, y_2, \dots y_n)^T$ is the complex state vector

$y = y^r + jy^i$, r, i here represents real and imaginary part of the system.

Define

$y_1 = s_1 + js_2$

$y_2 = s_3 + js_4$

………………..

$y_n = s_{2n-1} + js_{2n}$ (1.4)

The designed controller is

$u = u^r + ju^i$

$u^r = (u_1, u_3, \dots u_{2n-1})^T$

And $u^i = (u_2, u_4, \dots u_{2n})^T$

Theorem: Between the master and slave system (1.1) and (1.3) antisynchronization will be achieved if the controller is desgined as

$u = u^r + ju^i = -f(x) - g(y) + (B - A)x - Ke$ (1.5)

The real and imaginary part of the system (1.5) is

$u^r = -f^r(x) - g^r(y) + (B - A)x^r - Ke^r$

$u^i = -f^i(x) - g^i(y) + (B - A)x^i - Ke^i$ (1.6)

Here k is control gain matrix which satisfy $|arg\ arg(\tau_i(B - K))| > \frac{\alpha\pi}{2}$

For all the eigen values of $B - K$

Proof: For all the values of the equation (1.1) and (1.3) the error vector is

$e(t) = y(t) + x(t)$(1.7)

The derivative is

$D_*^{\alpha} e(t) = D_*^{\alpha} y(t) + D_*^{\alpha} x(t) = B(y) + g(y) + u + Ax + f(x)$

(1.8)

Put (1.5) into (1.8) then the system is

$D_*^{\alpha} e(t) = (B - K)e(t)$ (1.9)

Since $|arg\ arg(\tau_i(B - K))| > \frac{\alpha\pi}{2}$ according to the lemma, as $t \to \infty$ the error vector converges, so that there is antisynchronization between the system (1.1) and (1.3) using equation (1.5)

Lemma: Autonomous linear system of the fractional order $D_*^{\alpha} = Ax$ with $x(0) = x_0$ is stable iff

$|arg\ arg(\tau_i(B - K))| > \frac{\alpha\pi}{2}$ $(i = 1,2,3 \dots)$

In this state components are decay to 0 like $t^{-\alpha}$, also system stability is there iff

$|arg\ arg(\tau_i(B - K))| > \frac{\alpha\pi}{2}$ have geometric multiplicity.

1. **SOLUTION OF THE PROBLEM**

The input system is considered as

$x_1' = a(x_2 - x_1)$

$x_2' = (\Upsilon - a)x_1 - x_1x_3 + \Upsilon x_2$
$x_3' = -\beta x_3 - \delta x_4 + x_1x_2$
$\dot{x}_4 = -dx_4 + fx_3 + x_1x_2$ (1.10)
The output system is
$y_1' = a(y_2 - y_1)$
$y_2' = by_1 - cy_2 - y_1y_3$
$y_3' = y_1^2 - dy_3$
$y_4' = -y_1y_3 - \delta y_4$ (1.11)

The fractional order derivatives of the systems (1.10) and (1.11) are
$D_*^{\alpha}x_1 = a(x_2 - x_1)$
$D_*^{\alpha}x_2 = (\Upsilon - a)x_1 - x_1x_3 + \Upsilon x_2$
$D_*^{\alpha}x_3 = -\beta x_3 - \delta x_4 + x_1x_2$
$D_*^{\alpha}x_4 = -dx_4 + fx_3 + x_1x_2$ (1.12)
And
$D_*^{\alpha}y_1 = a(y_2 - y_1) + u_1 + ju_2$
$D_*^{\alpha}y_2 = by_1 - cy_2 - y_1y_3 + u_3 + ju_4$
$D_*^{\alpha}y_3 = y_1^2 - dy_3 + u_5 + ju_6$
$D_*^{\alpha}y_4 = -y_1y_3 - \delta y_4 + u_7 + ju_8$ (1.13)
The matrix A = $(-\propto \propto\ 00\ \gamma - \alpha\ \gamma\ 0000 - \beta - \delta 00 f\ - d)$
And $f(x) = (0 - x_1x_3x_1x_2x_1x_2)$ (1.14)
For the slave system
B = $(-\propto \propto\ 00b - c0010 - d0000 - \delta)$
And $f(x) = (0 - y_1y_3 0 y_1 y_3)$ (1.15)
Now the controller is
$u=$
$(0x_1x_3 - y_1y_3 + (b - \gamma + \alpha)x_1 + (c - \gamma)x_2 - 180(y_1 + x_1) - x_1x_2 + x_1 + (\beta - d)x_3 + \delta x_4 - x_1x_2 + y_1y_3 - fx_3 + (-\delta - d)x_4)$
(1.16)
Now as from the system (1.2)
$D_*^{\alpha}x_1 = \propto(x_3 - x_1)$
$D_*^{\alpha}x_2 = \propto(x_4 - x_2)$
$D_*^{\alpha}x_3 = (\Upsilon - \propto)x_1 - x_1x_5 + \Upsilon x_3$
$D_*^{\alpha}x_4 = (\Upsilon - \propto)x_2 - x_2x_6 + \Upsilon x_4$
$D_*^{\alpha}x_5 = -\beta x_5 - \delta x_7 + x_1x_3$
$D_*^{\alpha}x_6 = -\beta x_6 - \delta x_8 + x_2x_4$
$D_*^{\alpha}x_7 = -dx_7 + fx_5 + x_1x_3$
$D_*^{\alpha}x_4 = -dx_8 + fx_6 + x_2x_4$ (1.17)
And
$D_*^{\alpha}y_1 = \propto(y_3 - y_1) + u_1$
$D_*^{\alpha}y_2 = \propto(y_4 - y_2) + u_2$
$D_*^{\alpha}y_3 = by_1 - cy_3 - y_1y_5 + u_3$
$D_*^{\alpha}y_4 = by_2 - cy_4 - y_2y_6 + u_4$
$D_*^{\alpha}y_5 = y_1^2 - dy_5 + u_5$
$D_*^{\alpha}y_6 = y_2^2 - dy_6 + u_6$
$D_*^{\alpha}y_7 = -y_1y_5 - \delta y_7 + u_7$
$D_*^{\alpha}y_8 = -y_2y_6 - \delta y_8 + u_8$ (1.18)
The error dynamical system is
$D_*^{\alpha}e_1(t) = \propto(y_3 - y_1) + u_1 + \propto(x_3 - x_1)$
$D_*^{\alpha}e_1(t) = \propto(e_3 - e_1) + u_1$
$D_*^{\alpha}e_2 = \propto(y_4 - y_2) + u_2 + \propto(x_4 - x_2)$

$D_*^{\alpha} e_2 = \propto(e_4 - e_2) + u_2$

$D_*^{\alpha} e_3 = by_1 - cy_3 - y_1 y_5 + u_3 + (\Upsilon - \propto)x_1 - x_1 x_5 + \Upsilon x_3$

$D_*^{\alpha} e_3 = be_1 - ce_3 - e_1 e_5 + u_3 + (\Upsilon - \propto)x_1 - x_1 x_5 + \Upsilon x_3 - bx_1 + cx_3 + x_1 e_5 + e_1 x_5 - x_1 x_5$

$D_*^{\alpha} e_4 = be_2 - ce_4 - e_2 e_6 + u_4 + (\Upsilon - \propto)x_2 - x_2 x_6 + \Upsilon x_4 - bx_2 + cx_4 + x_2 e_6 + e_2 x_6 - x_2 x_6$

$D_*^{\alpha} e_5 = y_1^{\,2} - dy_5 + u_5 - \beta x_5 - \delta x_7 + x_1 x_3$

$D_*^{\alpha} e_5 = e_1^{\,2} - de_5 + u_5 + dx_5 - \delta x_7 + x_1 x_3 - \beta x_5 - 2x_1 e_1 + x_1^{\,2}$

$D_*^{\alpha} e_6 = e_2^{\,2} - de_6 + u_6 + dx_6 - \delta x_8 + x_2 x_4 - \beta x_6 - 2x_2 e_2 + x_2^{\,2}$

$D_*^{\alpha} e_7 = -y_1 y_5 - \delta y_7 + u_7 - d\,x_7 + fx_5 + x_1 x_3$

$D_*^{\alpha} e_7 = -e_1 e_5 - \delta e_7 + u_7 - dx_7 + fx_5 + x_1 x_3 + e_1 x_5 + x_1 e_5 - x_1 x_5 + \delta x_7$

$D_*^{\alpha} e_8 = -e_2 e_6 - \delta e_8 + u_8 - dx_8 + fx_6 + x_2 x_4 + e_2 x_6 + x_2 e_6 - x_2 x_6 + \delta x_8$

For the antisynchronization, the error system converges to zero asymptotically as shown in figure

NUMERICAL SOLUTION

Related to the master and the slave system the fractional order system is solved by using the software *MATLAB*. The parametric values of ($\propto, \beta, \gamma, \delta, b, c, d, f$) is (1,1,1,1,1,1,1) and order is (0.98,0.98,0.98,0.98) .

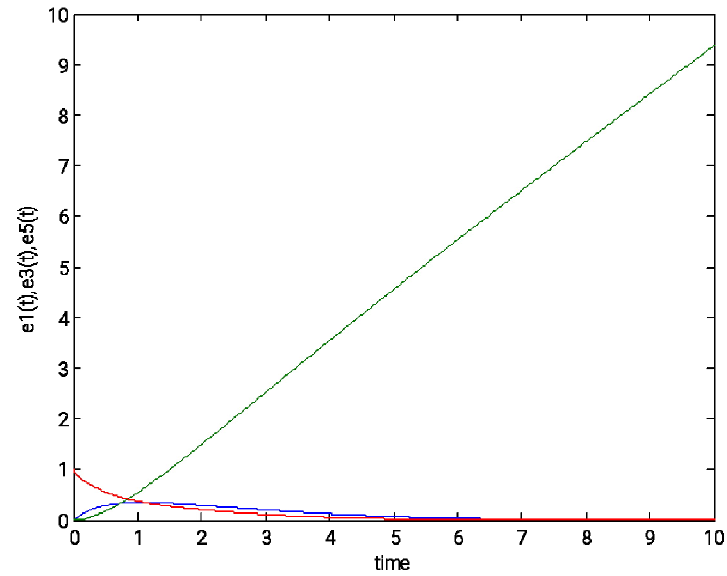

Fig 1 (a).Antisysnchronization of error system with time

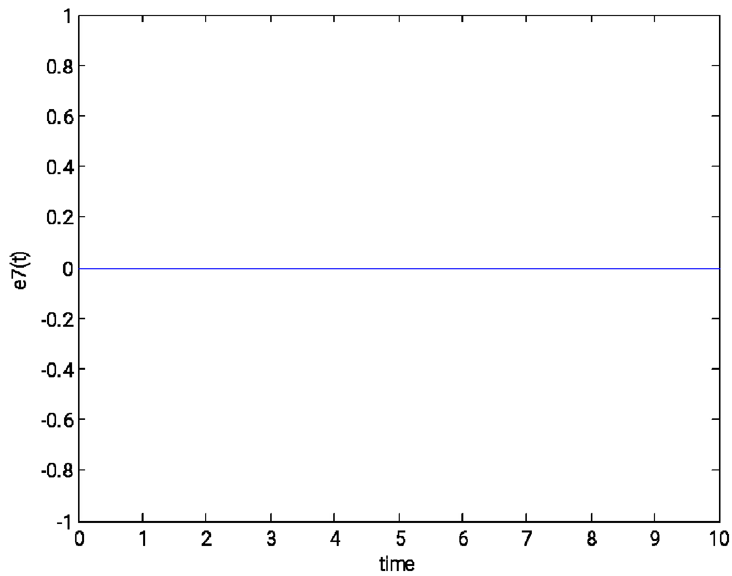

Fig 1 (b).Antisysnchronization of error system with time

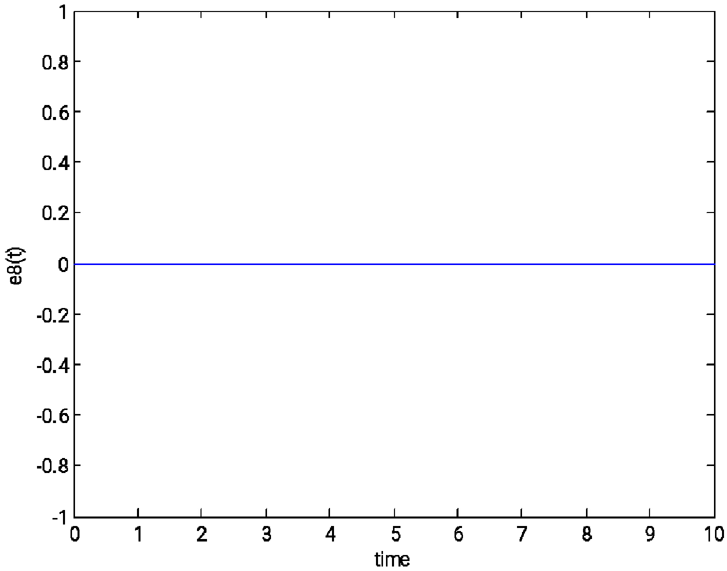

Fig 1 (c).Antisysnchronization of error system with time

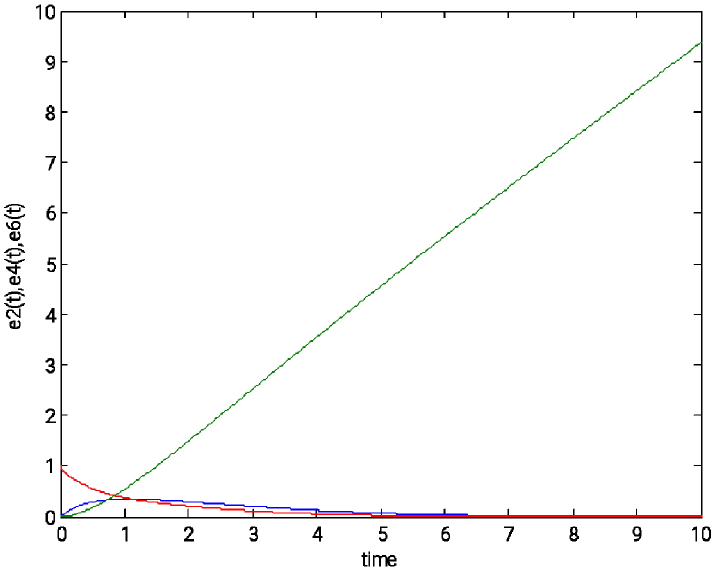

Fig 1 (d).Antisysnchronization of error system with time

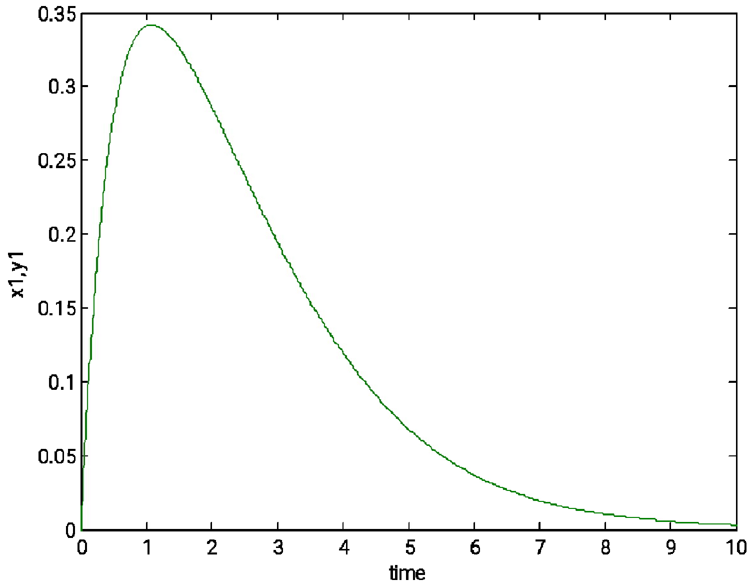

Fig 2 (a).Antisysnchronization of master and slave system with time

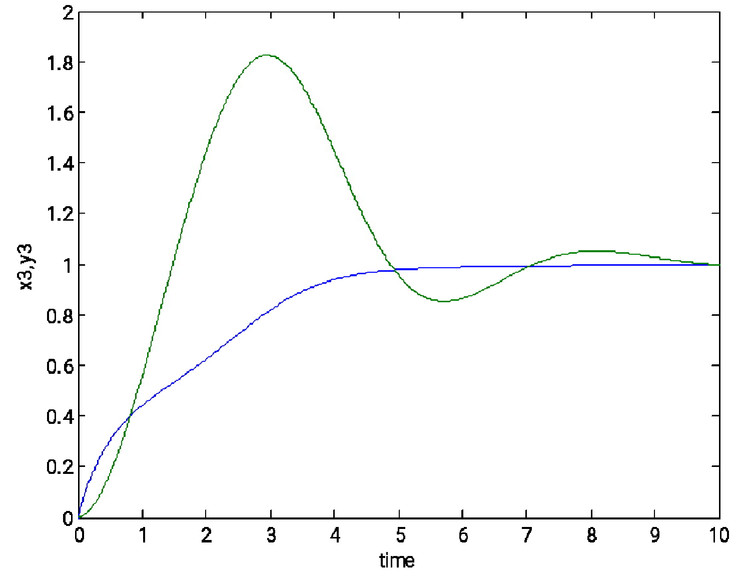

Fig 2 (b).Antisysnchronization of master and slave system with time

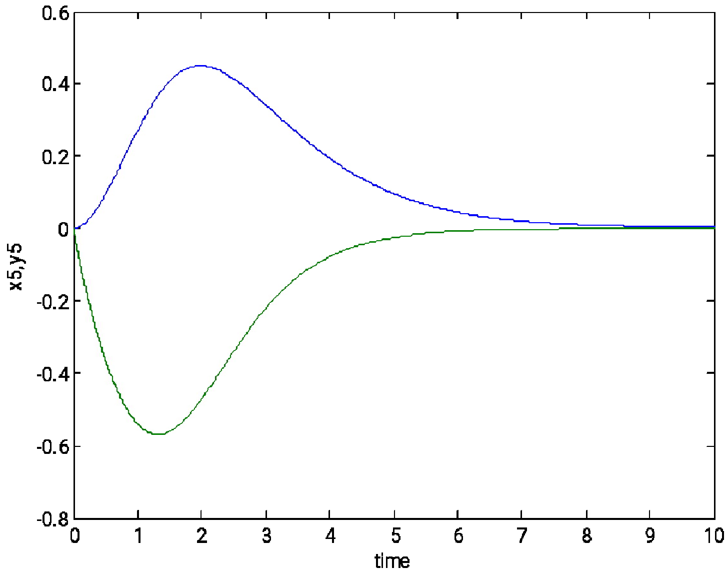

Fig 2 (c).Antisysnchronization of master and slave system with time

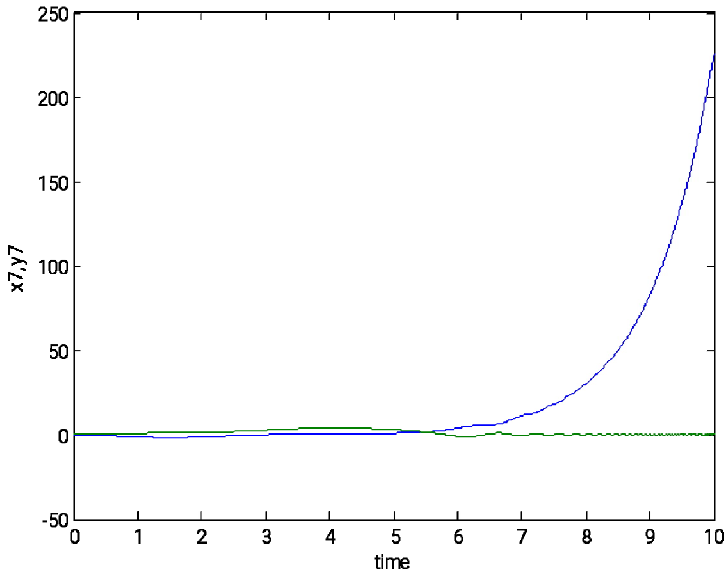

Fig 2 (d).Antisysnchronization of master and slave system with time

CONCLUSION

The proposed study is about antisynchronization of fractional order complex chaotic system, on the basis of the stability theory of the fractional order system antisynchronization is achieved between two different chaotic system. Simulation result gives the effectiveness of analytical results.

CONFLICT OF INTEREST

No conflicts of interest are disclosed by the authors.

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