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# LIST OF PUBLICATIONS

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[1] Finite-time stability of nonlinear fractional systems with damping behavior, Malaya Journal of Matematik, 8 (2020) 2122-2126.

[2] Finite-time stability of multiterm fractional nonlinear systems with multistate time-delay, Advances in Difference Equations, 2021 (2021) 1-15.

[3] On finite-time stability of nonlinear fractional-order systems with impulses and multi-state time delays, Results in Control and Optimization, 2 (2021) 100010 (Not included in this thesis).

[4] Finite-time stability of impulsive fractional-order time delay systems with damping behavior, Discontinuity, Nonlinearity, and Complexity (To appear).

[5] Finite-time stability results for fractional damped dynamical systems with time delay, Nonlinear Analysis: Modelling and Control (Revised).

[6] Finite time stability of higher order fractional impulsive system with nonlinear multiple time varying delay (Communicated).

# PRESENTATIONS IN CONFERENCES

1. Presented a paper entitled "Finite time stability of fractional-order nonlinear delayed system: Gronwall's approach" in the National Conference on Differential Equations and Dynamical Systems held at National Institute of Technology Puducherry during April 05-06, 2019.

2. Presented a paper entitled "Finite time stability of impulsive fractional order system with multi state time delay: Gronwall's approach" in the International Conference on Emerging Ideas in Pure and Applied Mathematics held at Vellalar College for Women, Erode during August 16-17, 2019.

3. Presented a paper entitled "Finite-time stability of impulsive fractional-order delayed system with variable coefficients" in 15th Biennial Conference of Indian Society of Industrial and Applied Mathematics held at Bharathiar University and Anna University Regional Campus, Coimbatore during December 05-07, 2019.

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# Finite-time stability of multiterm fractional nonlinear systems with multistate time delay

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**Abstract**
This work is mainly concentrated on finite-time stability of multiterm fractional system for $0 < \alpha_2 \leq 1 < \alpha_1 \leq 2$ with multistate time delay. Considering the Caputo derivative and generalized Gronwall inequality, we formulate the novel sufficient conditions such that the multiterm nonlinear fractional system is finite time stable. Further, we extend the result of stability in the finite range of time to the multiterm fractional integro-differential system with multistate time delay for the same order by obtaining some inequality using the Gronwall approach. Finally, from the examples, the advantage of presented scheme can guarantee the stability in the finite range of time of considered systems.

**MSC:** 34D20; 34K37

**Keywords:** Fractional order; Finite time stability; Integro-differential system; Multistate time delay

## 1 Introduction

Fractional calculus has been utilized as a key to the description of discontinuity and singularity formation. After several years of development, it has gained a lot of attention from physicists and mathematicians. We notice that fractional derivatives can be composite in perspective of pure mathematics and attract increasing interest in establishing the theoretical results and numerical approaches. Since the analysis and synthesis of fractional derivatives have been recognized in a wide-ranging field of practical applications in various applied sciences and have produced tremendous results. The core advantage of fractional derivatives is that numerous interdisciplinary practical applications can be easily formulated [1, 16, 25, 31].

Finite-time stability (FTS) is a more practical idea which is valuable to analyze the nature of a system within a finite interval of time and it is an essential part in the study of transient behavior of systems. Thus, it was extensively studied in both integer and fractional differential systems. Time delay can occur in input, output, or the state variable. The delay of state has appeared several times in physical systems and control problems [15, 24, 29, 32, 34, 35, 40]. On the other hand, in a multistate system the conversion between the behaviors in each state will depend on the passage of time and on inputs of

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# Finite-time stability of nonlinear fractional systems with damping behavior

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**Abstract**
This paper concentrates with the problem of stability in the finite range of time for nonlinear system with multi term fractional-order and damping behavior. Utilizing the Mittag Leffler functions and generalized Gronwall inequality (GI), a sufficient criteria that ensure the finite time stability (FTS) for both condition $0 < \alpha_1 - \alpha_2 < 1$ and $1 \leq \alpha_1 - \alpha_2 < 2$. Finally, two numerical examples are carried out to verify the obtained results.

**Keywords**
Finite-time stability; Damped system; Fractional system.

**AMS Subject Classification**
26A33, 30E25, 34A12, 34A34, 34A37, 37C25, 45J05.

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## Contents



## 1. Introduction

Calculus of fractional order (FO) is an extension for a traditional calculus which deals with functionals containing integer-order differentiation and integration. This notion has been developed by Leibniz and L'Hopital in 1695 where fractional derivatives was described. In recent years, FO systems have considerable attraction due to their capability to model complex phenomena. By using fractional derivative formulations, physical systems can be modeled more accurately. Also, fractional derivative can be used to modeling the structures in mathematical biology, several chemical processes and problems related to engineering. In real situations, the models generated by FO are more suitable rather than integer order. Since it is possible to model a higher order system by low order system by using FO derivatives. Application of fractional calculus established in stochastic dynamical systems, controlled thermonuclear fusion and plasma physics, image processing, nonlinear control theory [1, 7, 12, 19]. In [2, 3, 5, 13, 17], one can refer the potential applications of FO systems in physical problems description and control, complex practical systems, etc.

The traditional stability concepts like asymptotic stability, Lyapunov stability have been widely studied and these are deals with the problem whose operations described over the infinite interval of time [4, 10, 11, 18]. The concept of asymptotic and exponential stability imply the convergence of system's state to an equilibrium position over the infinite period. Most of the aforementioned results in many fields consider the problems correlate to the performance of convergency described over an interval of infinite period. But in practical process, the predominant analysis is that the characteristic of system in an interval of finite period, since it is too many phyisically usable than concerning infinite time. In such case, the traditional methods are not appropriate. For such kind, the FTS method is proposed in 1950s. There are two kinds of stability concept over the interval of finite time. One is FTS i.e., the system's state of an asymptotic system reach the equilibrium position in a finite period and another one is fixed-time stability, that means the convergence time intervals have an identical upper-bounds in domain. FTS method is more practical and less conservative than the traditional stability methods. Also, this method is more applicable for analyzing the path of a system's state remains within the prescribed bounds over a finite interval of time. In comparison with asymptotic and other type of stability, the FTS has been

# Biographical Sketch

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