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# State Constraints-Based Fuzzy Adaptive Finite-Time Position Tracking Control for DC Motor

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## Introduction

Direct current (DC) motor has been widely used in the fields of electric servo drive, national defense science and technology because of its high efficiency, good starting and speed regulating performance. The traditional DC motor control system is treated as a linear system, but it cannot accurately express the change of motor excitation. In recent years, with the research of nonlinear system, a large number of control theories and control methods related to nonlinear system have been used to study the drive control of DC motor, such as backstepping control, fault-tolerant control, adaptive control and fuzzy control. Among them, the fuzzy logic system is used to approximate the unknown nonlinear term in the system, and the adaptive control based on the fuzzy logic approximation system is widely used to deal with the parameter uncertainty in the nonlinear system. The traditional adaptive fuzzy backstepping method can be applied to the research of DC motor to meet the stability of system response. However, the state constraints are ignored on the aforementioned control methods of DC motor. In the DC motor servo system, the state of the system needs to be limited within a reasonable range, and beyond the constraint range, the performance of the system may deteriorate, fail, or even threaten personal safety. Therefore, the state constraints are considered in the control of the angle speed and position of the DC motor. In addition, due to the real-time control of DC motor in some special occasions, the system must be stable in a short time, so the finite-time technology is introduced to assist the design of the controller. Finite-time control technology has the advantages of fast response, short convergence time and strong anti-interference ability. The application of finite-time control technology in tracking control of DC motor can achieve remarkable effect. However, to the best of authors' knowledge, there are few results about finite-time technology to control the DC motor with state constraints.

## Research Questions

Based on the above analysis, a state constraints-based fuzzy adaptive finite-time position tracking control scheme is proposed in this paper. By using adaptive fuzzy technology to approximate unknown nonlinear functions in the system, the finite-time technology is introduced to improve the convergence speed and control accuracy of the system while retaining the advantages of fuzzy adaptive backstepping. The state variables of DC motor are constrained by the Lyapunov function to ensure that the angular position and angular speed of the DC motor are limited within the given constraint range, which ensures the safety of the system and realizes the fast tracking control of the DC motor. The Lyapunov stability theorem proves that the proposed control method ensures that the position tracking error converges to the desired neighborhood in a finite time, and all signals in the closed-loop system are bounded in a finite time. The simulation results show the effectiveness of the theoretical results.

## Mathematical Formulas

The mathematical model of DC motor without vibration mode is established as follows

$$\begin{cases} \dfrac{\mathrm{d}\Theta}{\mathrm{d}t} = \omega, \\ J\dfrac{\mathrm{d}\omega}{\mathrm{d}t} + B\dfrac{\mathrm{d}\Theta}{\mathrm{d}t} + T_f + d(t) = T, \\ y = \Theta, \end{cases} \tag{1}$$

$$\begin{cases} \dot{x}_1 = x_2, \\ \dot{x}_2 = \dfrac{u - B\dot{x}_1 - T_f - d(t)}{J}, \\ y = x_1. \end{cases} \tag{2}$$

$$z_1 = x_1 - x_{1d} \tag{3}$$

$$z_2 = x_2 - \alpha_1 \tag{4}$$

$$\alpha_1 = -k_1 \frac{z_1^{2l-1}}{(k_{b_1}^2 - z_1^2)^{l-1}} + \dot{x}_{1d}, \tag{5}$$

$$u = -k_2 \frac{z_2^{2l-1}}{(k_{b_2}^2 - z_2^2)^{l-1}} - K_{z_1}(k_{b_2}^2 - z_2^2) - \hat{\theta}_2^T \phi_2(Z) - K_{z_2}, \tag{6}$$

$$\dot{\hat{\theta}}_2 = K_{Z_2} \phi_2(Z) - m\hat{\theta}_2, \tag{7}$$

## Figures

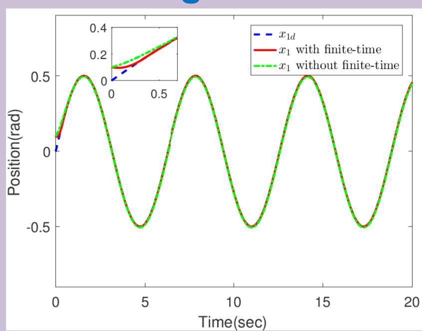


Figure 1: The trajectory of $x_1$ and $x_{1d}$

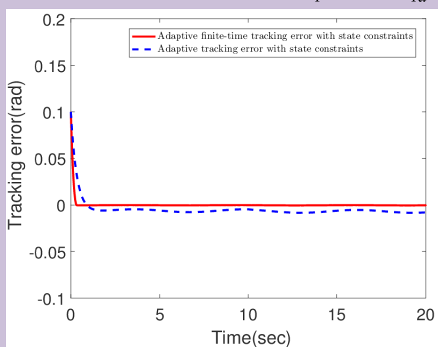


Figure 2: Tracking error $(x_1 - x_{1d})$