Trajectory Tracking of Quadrotor Unmanned Aerial Vehicle Using Neural Network Based Adaptive Sliding Mode Control

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Background

1. Introduction

Quadrotors: popular unmanned aerial vehicles

Applications:

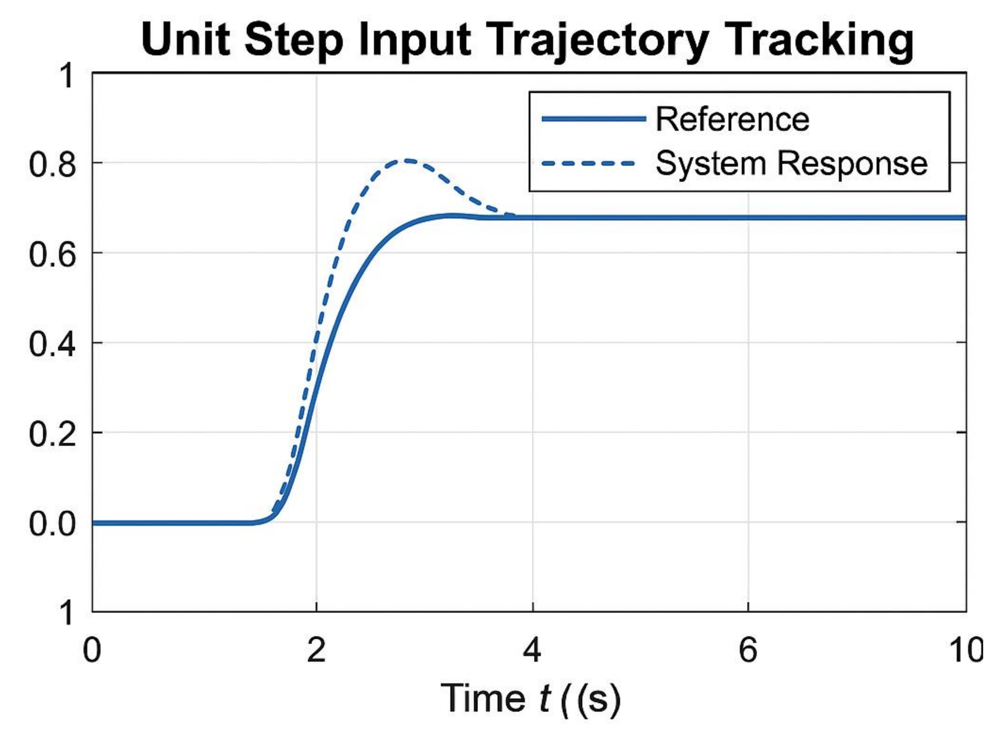
❖Surveillance,

❖Delivery,

❖Mapping,

❖Pest control, Crop Monitoring

❖Trajectory tracking critical for performance and safety.



K. Ogata, *Modern Control Engineering*, 5th ed. Upper Saddle River, NJ, USA: Prentice Hall, 2010, pp. 168–170.

Fig. 1 *Unit Step Input Trajectory Tracking*

2. Problem statement

A: Quadrotor control design is very difficulty due to:

❖Nonlinear &Highly coupled dynamics

❖Under actuation

❖Parametric uncertainties

❖Disturbances

B: Despite linear, optimal and robust controllers such as PID,LQR,MPC and SMC there exist:

❖Limited robustness, Adaptation and Chattering effects respectively

C: However to tackle these challenges its better to design:

❖An adaptive, intelligent control strategies that are robust (NN-ASMC)

Current Work

1. Objectives

Main objective:

❖To develop a Neural Network-based Adaptive Sliding Mode Control (NN-ASMC) strategy for a quadrotor Unmanned Aerial Vehicle (UAV) that enhances trajectory tracking accuracy and robustness against external disturbances and model uncertainties.

❖**Specific Objectives**

i. To develop a dynamic mathematical model of quadrotor taking into account disturbances.

ii. To develop an Adaptive Sliding Mode Control(ASMC) based on adaptive sliding surface using neural network.

iii. To evaluate perfomance of designed controller by doing simulations and experiments.

2. Methodology

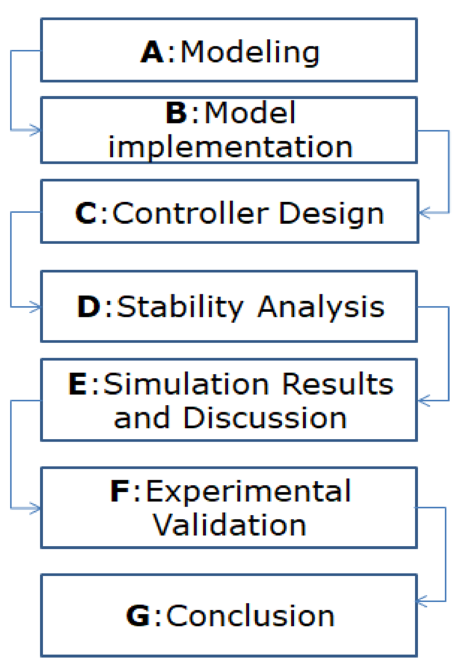


Fig. 2 *Methodology block diagram*

2.A:Mathematical Model:Zhang et al.(2019)

$$\ddot{\phi} = a_1\dot{\theta}\dot{\psi} + a_2\dot{\theta}\Omega_m + U_2 b_1 + \delta_\phi(t) \quad (1)$$

$$\ddot{\theta} = a_3\dot{\phi}\dot{\psi} + a_4\dot{\phi}\Omega_m + U_3 b_2 + \delta_\theta(t) \quad (2)$$

$$\ddot{\psi} = a_5\dot{\phi}\dot{\theta} + U_4 b_3 + \delta_\psi(t) \quad (3)$$

$$\ddot{Z} = -g + \frac{\cos(\phi)\cos(\theta)}{m}U_1 + \delta_z(t) \quad (4)$$

$$\ddot{X} = \frac{(\cos(\theta)\sin(\phi)\cos(\psi) + \sin(\phi)\sin(\psi))U_1}{m} \quad (5)$$

$$\ddot{Y} = \frac{(\cos(\phi)\sin(\theta)\cos(\psi) - \sin(\phi)\sin(\psi))U_1}{m} \quad (6)$$

2. Methodology

2.C1: Sliding surface design

$$\dot{e}_j = \dot{j}_d - \dot{j} \quad (7)$$

$$S_j = \dot{e}_j + \lambda_j e_j \quad (8)$$

2.C2: *Reaching law*

$$\dot{S}_j = -\varepsilon_j \tanh(S_j) \quad (9)$$

2.C3: *Control law*

$$u = \frac{1}{B}\left(\dot{S}_j + \dot{\Lambda}_j(x_j) - Ax\right) \quad (10)$$

2.D1: *Stability proof-Lyapunov*

$$V_j = \frac{S_j^2}{2} \quad (11)$$

$$\dot{V}_j = S_j\dot{S}_j = -S_j\varepsilon_j\tanh(S_j) \quad (12)$$

Fig. 3 *Neural Network Adaptive Sliding Mode Controller:Fatemi et al.(2025)*

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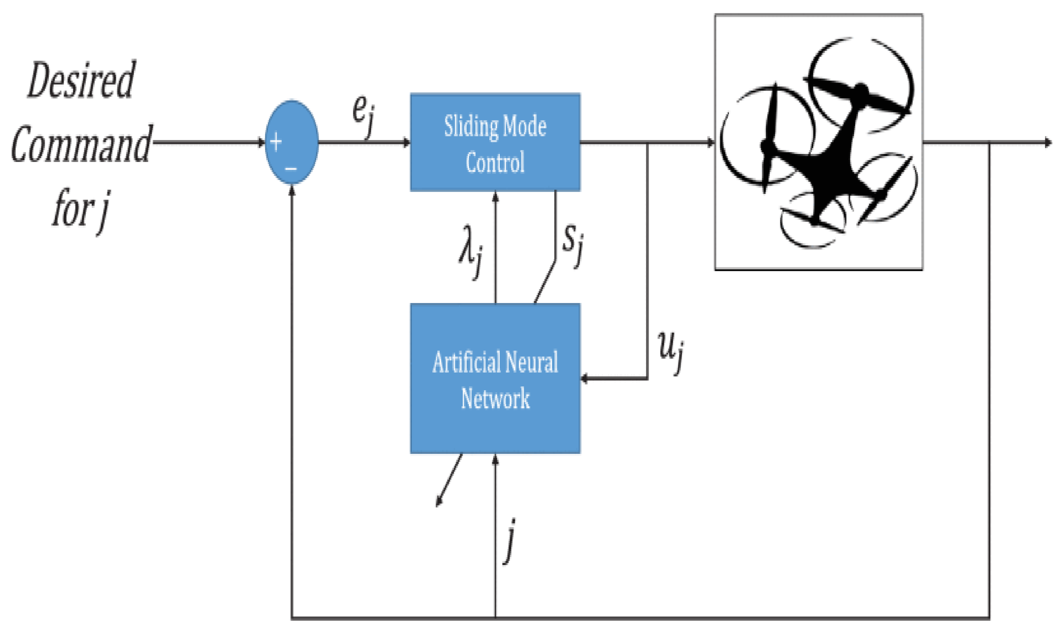

Expectations

❖ A mathematical model that incorporates disturbances will be obtained.

❖ An adaptive Sliding Mode Control capable of rejecting disturbances and model uncertainties for proper tracking will be obtained.

❖ Perfomance evaluation of designed controller will be achieved via experiments.

References & Acknowledgment.

1. J. Zhang, Z. Ren, C. Deng, and B. Wen, "Adaptive fuzzy global sliding mode control for trajectory tracking of quadrotor uavs," Nonlinear Dynamics, vol. 97, pp. 609 627, 2019.
2. Fatemi, M. M., & Akbarimajd, A. (2025). Adaptive sliding mode control for quadrotor UAVs under disturbances using multi-layer perceptron. *IEEE Access*.

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