Adaptive Motion Control of Quadrotors under Parametric Uncertainties with Stability

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Abstract

In this paper, an adaptive control strategy is presented for quadrotors under parametric uncertainties. The adaptive control scheme learns the quadrotor’s inverse model with a Lyapunov-based adaptation law. For that, a robustness feedback loop is used to stabilize the quadrotor at startup. Therefore, the controller achieves accurate motion tracking with parametric uncertainties. Unlike many controllers, the proposed adaptive control scheme’s stability is guaranteed by Lyapunov direct method. The proposed controller’s performance in coping with parameter variations is highlighted in different operating conditions.

Introduction

Unmanned Aerial Vehicles (UAVs) have attracted the attention of the scientific community from diverse disciplines due to their versatile applications. Their popularity has increased exponentially, particularly in many applications such as surveillance, exploration, rescue missions and payload transportation.

Dynamics

\[
\begin{align*}
\ddot{x} &= \frac{1}{m} (L_y - L_x) \sin \theta \cos \phi + g \sin \theta, \\
\ddot{y} &= \frac{1}{m} (L_y - L_x) \sin \theta \sin \phi + g \cos \theta, \\
\ddot{z} &= \frac{1}{m} (L_z - L_x) \cos \theta + g \sin \theta, \\
\ddot{\phi} &= \frac{1}{I_x} (m g \cos \theta + \tau_x - \tau_y), \\
\ddot{\theta} &= \frac{1}{I_y} (m g \sin \theta \cos \phi + \tau_y - \tau_z), \\
\ddot{\psi} &= \frac{1}{I_z} (m g \sin \theta \sin \phi + \tau_z - \tau_x), \\
\end{align*}
\]

Where

\[
\begin{align*}
\tau_x &= 0, \\
\tau_y &= 0, \\
\tau_z &= 0, \\
\end{align*}
\]

The control law is defined as,

\[
\begin{align*}
\dot{\hat{\phi}} &= \frac{1}{I_x} (m g \cos \theta + \tau_x - \tau_y), \\
\dot{\hat{\theta}} &= \frac{1}{I_y} (m g \sin \theta \cos \phi + \tau_y - \tau_z), \\
\dot{\hat{\psi}} &= \frac{1}{I_z} (m g \sin \theta \sin \phi + \tau_z - \tau_x), \\
\end{align*}
\]

Adaptive Law

Consider a nonlinear system in the form (2.1)-(2.2) with the control law (3.7). The closed loop system’s stability is guaranteed by the Lyapunov direct method. The proposed controller’s performance in dealing with parametric uncertainties is made possible with computational intelligence tools, such as artificial neural networks and fuzzy logic systems. The approximation capabilities have been the main driving force behind the increasing popularity of such methods as they are theoretically capable of uniformly approximating any continuous real function to any degree of accuracy. This has led to the recent advances in the area of intelligent control. Satisfactory performance is achieved with various neural network models for complex systems such as state, federal, industry, university, or other support go here.