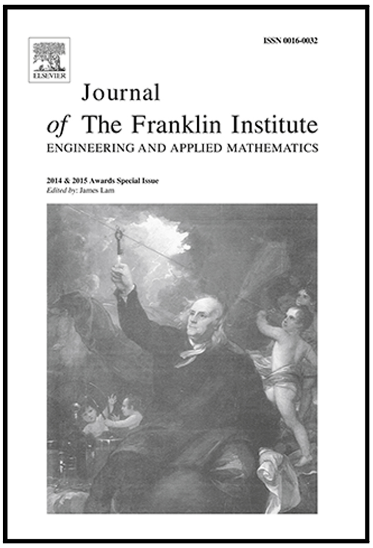

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Zewei Zheng, Liang Sun

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Adaptive Sliding Mode Trajectory Tracking Control of Robotic Airships with Parametric Uncertainty and Wind Disturbance

Zewei Zheng[1], Liang Sun[2,*]

1. The Seventh Research Division, Science and Technology on Aircraft Control Laboratory, School of Automation Science and Electrical Engineering, Beihang University, Beijing 100191, P.R.China

2. School of Automation and Electrical Engineering, University of Science and Technology Beijing, Beijing 100083, P. R. China

Abstract

An adaptive sliding mode trajectory tracking controller is developed for fully-actuated robotic airships with parametric uncertainties and unknown wind disturbances. Based on the trajectory tracking model of robotic airships, an adaptive sliding mode control strategy is proposed to ensure the asymptotic convergence of trajectory tracking errors and adaptive estimations. The crucial thinking involves an adaptive scheme for the controller gains to avoid the off-line tuning. Specially, the uncertain physical parameters and unknown wind disturbances are rejected by variable structure control, and boundary layer technique is employed to avoid the undesired control chattering phenomenon. Computer experiments are performed to demonstrate the performance and advantage of the proposed control method.

Keywords: Airship control, trajectory tracking, sliding mode control, adaptive control, parametric uncertainty, wind disturbance

1. Introduction

As a typical lighter-than-air aircraft driven by propulsion and steering systems, robotic airships are viewed as important platforms for many missions, such as surveillance, earth observation, region navigation, telecommunication, and environmental monitoring [1][2]. Because of many distinguishing features of airships with long endurance, high payload-to-weight ratio, and low fuel consumption, the problem of autonomous trajectory controller design becomes more popular research topic in recent years [3][4]. However, since the model of robotic airships is an inherently nonlinear and highly coupled multi-input multi-output system, so that the design of trajectory controller for robotic airships is very difficult. Moreover, unknown dynamics, parametric variations and external disturbances in the model also lead to greater challenges of controller design.

In order to achieve the goal of autonomous trajectory tracking, a robust guidance and control system capable of autopiloting and controlling the airship flight is required [5]. Successful design of such a system necessitates an accurate model of airship dynamics. As a basis, a six-degrees-of-freedom dynamic model of robotic airships is required [6]. Many efforts have been directed to the development of airship dynamics and autonomous controllers. In [7], the conceptual design, dynamics modeling and attitude control of a stratospheric airship were presented, where dynamics of airships were derived form the Newton-Euler formulation, and an adaptive fuzzy sliding mode controller was developed to achieve the station-keeping missions. A simple open-loop controller was proposed in [8] for airships to track a planed feasible trajectory. Because of the limitations of linear control and open-loop control, many nonlinear closed-loop controllers were developed to achieve some complex missions of airships in recent years, such as hover stabilization, station keeping, vertical ascent and descent, trajectory tracking, and path following. In [9], a backstepping control approach was proposed to solve an airship hover stabilization problem, and then input saturation was also considered in the design of backstepping controller in [10]. Station keeping controller was developed for a large high-altitude airship in [11]. Using feedback linearization technique and fuzzy sliding mode control method, a station-keeping controller was redesigned in [12] to enhance the robustness of airship flight systems. Then, a fuzzy adaptive backstepping controller was redesigned to solve the parametric uncertainties and external disturbances in [13]. Based on Lyapunov theory, integrator backstepping controllers for under-actuated airships were developed in [14] to achieve pose tracking and flight maneuvers. An intelligent controller was designed in [15] based on adaptive neural networks. An adaptive nonlinear dynamic inversion controller was proposed based on nonlinear model of an autonomous airship in [16]. In [17] and [18], the authors report a dynamic inversion controller and navigation scheme for a robotic airship flight path following, experimental results for the airship flight path following were also presented. In [19], a backstepping control law was developed based on the Lyapunov design for a fin-less airship, while attitude and velocity control of the entire airship flight regime were provided to achieve multiple flight missions by a single controller. Based on trajectory linearization control technique, a trajectory tracking controller was designed for an under-actuated airship in [20], where typical two-loop control

*Corresponding author.
Email: zeweizheng@buaa.edu.cn;solosunliang@163.com