Mechatronics 21 (2011) 821–830

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

A small unmanned polar research aerial vehicle based on the composite control method

Xusheng Lei [a,*], Lang Bai [a], Yuhu Du [a], Cunxiao Miao [a], Yang Chen [b], Tianmiao Wang [b]

[a] School of Instrument Science and Opto-Electronic Engineering, Beijing University of Aeronautics and Astronautics, Beijing, China
[b] Robotics Institute, School of Mechanical Engineering and Automation, Beijing University of Aeronautics and Astronautics, Beijing 100191, China

ARTICLE INFO

Article history:
Available online 13 January 2011

Keywords:
Unmanned aerial vehicle
Trajectory following control
Vector filed
LQR

ABSTRACT

Focusing on the polar extreme environment, a composite control method is proposed to finish the polar scientific research task in this paper. Based on the vector field and the linear quadratic regulator (LQR) control method, the small unmanned aerial vehicle can realize precise trajectory following control under wind disturbance. Through vector filed method, system constructs the corresponding vector fields for the planed research trajectory, generates the desired course inputs for the small aerial vehicle. Furthermore, the LQR control method is proposed and utilized as the inner control loop to realize the precise attitude control. Lyapunov stability arguments are used to demonstrate the asymptotic decay of trajectory following errors in the presence of wind disturbances. Experimental flight results are given to show that the small unmanned aerial vehicle can get the high trajectory following performance in the polar environment.

1. Introduction

The interaction of ice sheets with the lithosphere, oceans, and atmosphere is the important trace for the earth development. Therefore, the polar science research has become one hotspot in the recent years. With the development of the polar research, the harsh polar environment, such as low temperature, strong wind, blowing snow, have become a big burden for the polar science research [1]. Compared with other land equipments, the aircraft has advantages in cost and efficiency [2].

The small unmanned aerial vehicle (SUAV) is a remotely piloted or self-piloted aircraft that can carry cameras, sensors, communication equipments or the other payloads to carry out observation activity at dangerous area [3]. The SUAV has demonstrated its effectiveness in military and civil applications [4]. There exists a new trend that SUAV assists scientists in the polar region research [5,6]. A small UAV with 2 m wingspan, developed by the British Antarctic Institute and the Technical University of Braunschweig, is used to get the temperature data of Weddell Sea area in the end of 2007. Kansas University developed a Meridian SUAV to study the decomposed speed and the depth of the ice sheet. With the high precision camera, a small Aist-MUAV is developed by NIIPEMKHAI Institute to investigate the links between the arctic change and global processes to anticipate the changes of the earth.

However, the SUAV has payload and power constraints in the flight process. Thus, low performance sensors and control units based on the micro electronic mechanic system (MEMS) are often used in the SUAV. Moreover, there exists wind disturbance in the flight process. The wind speed is commonly 20–50% of the desired airspeed. Therefore, the SUAV may have a poor performance of the flight trajectories. Since wind disturbances vary quickly, it is hard to construct the precise model for wind disturbance. The capability to realize precise trajectory following control in the large wind disturbance environment is a challenging problem for SUAV system [7].

To realize the autonomous trajectory tracking, several control technologies have been proposed [8,9]. Basically, the tracking control methods can be classified into traditional PID control, robust control, intelligent control, etc. [10,11]. Since the PID control method has the simper structure, it is often used in the trajectory tracking [12]. Composite PID control has been used to adapt to the wind disturbance to realize the straight line and the arc line following [13]. However, the PID control has little robustness for environment disturbance. The robust control, H_2, H_∞, LQR, are also used in the SUAV trajectory control [14,15]. The criteria function based on the LQR has been constructed to get optimal matrix parameters for the SUAV to realize stable trajectory following function [16]. But the robust control has its limitation for its parameter uncertainty, real time, and dynamic response characteristics. The intelligent control can cope with parameter uncertainties with a self-organizing capability [17,18]. Fuzzy control and adaptive neural network have been used to realize the precise 3D position control for the SUAV system [19]. However, it requires extensive computation and thus compromises its application for real time.

* Corresponding author. Tel./fax: +86 010 82338734.
E-mail address: xushenglei@buaa.edu.cn (X. Lei).

0957-4158/$ - see front matter Crown Copyright © 2010 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2010.12.002