Optimal Integrated Guidance and Control Design for Line-of-Sight Based Formation Flight

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This paper presents an integrated guidance and control design for a formation flight of multiple Unmanned Aerial Vehicles (UAVs). The guidance law is based on the line-of-sight (LOS) method which has ability to transfer UAVs to different formation patterns through a single parameter change. The guidance law is integrated with the optimal control law and is applied to a linear dynamic model. The problem is formulated as a linear quadratic regulator (LQR) control problem for a line-of-sight based circular coordination formation flight configuration of a leader and three follower UAVs. The mission is to have a coordinated encirclement around a ground maneuvering target. The design objective is to achieve a zero vertical spatial offset (i.e. same commanded altitude) and a 90 degree horizontal angular offset among four UAVs. In order to verify the performance of the proposed system, numerical simulation using a linear coupled six-degree-of-freedom (6-DOF) model is demonstrated for a circular multi-vehicle coordination flight of four UAVs.

I. Introduction

Unmanned vehicles are an effective platform for tracking, surveillance, and reconnaissance missions. The subject of automatic formation flight control is of current interest to the development of unmanned aerial vehicles for the purposes of worldwide deployment and in-theatre operations. Unmanned vehicles are particularly well-suited for multi-agent coordinated missions that require synoptic area coverage with consistent revisit rates. A cooperating team of UAVs can coordinate platforms for data collection and provide persistent coverage of discrete processes like moving ground targets. We’re entering an era in which unmanned vehicles of all kinds will take on greater importance. To successfully complete complex tasks such as reconnaissance, surveillance without human intervention and in the presence of large external disturbances, different threats, and flight critical failures, there is a growing interest in developing highly efficient autonomous intelligent flight control systems for multiple UAVs.

The problem of formation-flight control of UAVs is currently of wide interest, and a large amount of work has been done on the subject. A number of recent studies have examined the problem of close-coupled formation flight for multiple aircraft. Autonomous formation flight control system design has been performed for various types of aircraft. For instance, Lightweight UAVs, research aircraft (YF-22), and fighter aircraft (F/A-18) are the subjects for Ref. 1, 2 and 3 respectively. Many algorithms are proposed for providing control of multiple UAVs with mobility and flight constraints [Ref. 1-4]. Model predictive approach (Ref. 4 and 5), consensus based decentralized approach (Ref.6), and dual controller approach (Ref. 7), are four recent examples.

Ref. 8 has investigated the fuel efficient formation flight control design based on energy maneuverability. String stability analysis of an autonomous formation flight system was performed using linear and nonlinear simulations in Ref. 9. Nonlinear control of multiple UAVs in close-coupled formation flight and 6-DOF nonlinear simulation of vision-based formation flight have been studied in Ref. 10 and 11 respectively. Adaptive control design and its application to the formation flight have been examined in Ref. 12-14.

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