Chapter 56
Aerial Robot Formation Control via Pigeon-Inspired Optimization

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ABSTRACT

Formation flight for aerial robots is a rather complicated global optimum problem. Three formation flight control problems are introduced in this chapter, respectively, underlying controller parameter optimization, basic formation control and formation reconfiguration control. Two methods, Model Prediction Control (MPC) and Control Parameterization and Time Discretization (CPTD), are applied to solve the above problems. However, the selection of appropriate control parameters is still a barrier. Pigeon-Inspired Optimization (PIO) is a new swarm intelligence optimization algorithm, which is inspired by the behavior of homing pigeons. Owning to its better performance of global exploration than others, the thoughts of PIO are applied to the control field to optimize the control parameters in the three aerial robot formation problems, to minimize the value of the cost function. Furthermore, comparative experimental results with a popular population-based algorithm called Particle Swarm Optimization (PSO) are given to show the feasibility, validity and superiority of PIO.

1. INTRODUCTION

Aerial robots are attracting the interest of many researchers all over the world (Derafa et al., 2012). This popularity may be attributed to deep studies in theoretical analysis (Wang, 2014; Maqsood, 2012) and potential use in many applications such as, search and rescue missions, surveillance, law enforcement, inspection, mapping, and aerial cinematography.

Compared with a single aerial robot, formation of the aerial robots can leverage the capabilities of the team to have more effective performance in missions such as cooperative Simultaneous Localization and Mapping (SLAM), coverage and recognizance, and security patrol (Karimoddini et al., 2013). Hence, recent years have seen an increasing interest in the study of aerial robot formation control from both theoretical and experimental points of view (Chang, 2011; Giulietti, 2000; Binetti, 2003).

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The hierarchical structure of aerial robot formation control is illustrated in Figure 1. There is a three-level hierarchical structure in the aerial robot formation control. The low-level is the underlying control to aerial robots in which the position and attitude of aerial robot will be controlled directly. The control parameter optimization problem is solved in Section 4. In the middle-level, the decisions for collision avoidance, formation keeping and reconfiguration will be made. The formation control and formation reconfiguration control are the focus of this chapter and described in Section 5 and 6 in turn. The top-level is situational awareness layer which contains threat assessment and obstacle detection mainly. In this chapter, threats and obstacles aren't under consideration temporarily.

For the control parameter optimization problem, Model Prediction Control (MPC) is introduced as the background. The MPC approach is also adopted to solve the formation control problem for fixed-wing aerial robots. Another method called Control Parameterization and Time Discretization (CPTD) is applied to solve the aerial robot formation reconfiguration problem. Intelligent optimization algorithm will play an active role in whether aerial robot control parameter optimization problem or formation control and formation reconfiguration control.

With the development of science and technology, many practical optimization design problems have been raised, which give rise to the booming of bio-inspired computation algorithms (Duan & J.N. Li, 2014). Inspired by the behavior of a swarm of pigeons, Pigeon-Inspired Optimization (PIO) algorithm is proposed recently by Duan, which is a brand new swarm intelligence algorithm (Duan & Qiao, 2014). Pigeons are the most popular bird in the world, and they were once used to send the message by Egyptians, which also occurred in many military affairs. Pigeons have nice senses of orientation, which contributes to their superior ability to find the most efficient way to the destination. The main tools they use to find their way home are map, compass and landmarks. Pigeons can sense the earth magnetic field and they take the sun position as a compass to form a map in their memories which guides them to the right direction. Meantime, pigeons also have the ability to recognize the landmarks they have met before so that they can obtain the best path to their destination. PIO algorithm completely reproduces these processes. The

Figure 1. Hierarchical structure of aerial robot formation control