Optimizing Multi-Follower Formation in Leader-Follower Strategies for UAV Swarms

ATHRAA S. HASAN
Department of Mechanical Engineering, East China University of Science and Technology ECUST-Shanghai200237, China. Department of Electromechanical Engineering, University of Technology , Baghdad, Iraq.

JIANJUN YIa
Department of Mechanical Engineering, East China University of Science and Technology ECUST-Shanghai200237, China.
jjyi@ecust.edu.cn

HAIDER M. ALSABBAGH
Department of Electrical Engineering, College of Engineering, University of Basrah, Basrah-Iraq

LIWEI CHEN
Department of Mechanical Engineering, East China University of Science and Technology ECUST-Shanghai200237, China.

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***Abstract*— The unmanned aircraft vehicle named shortly (UAV) functions akin to a programmed human brain, serving as a tool discovered by humans to overcome various challenges in life. As it excelled in its assigned tasks, researchers and developers began exploring the potential of utilizing swarms of UAVs to accomplish multiple tasks or even sub-tasks within a larger objective. To harness the benefits of these capabilities exhibited by UAV flocks, researchers devised different control strategies that focused on optimizing the distribution of swarm agents for optimal performance. Among these strategies, the leader-follower approach emerged as one of the most prominent and significant methods for distributing UAV flocks, which researchers have applied across various scenarios. In the present study, the objective is to investigate the optimal of the follower's position and distribution relative to the leader according the swarm's task. The researchers conducted a comparison of two distribution patterns and employed MATLAB to test the swarm's ability to navigate around static obstacles. The final results demonstrated that adopting a distribution pattern resembling the Diamond Formation "Triangle and M-shape distribution " with the leader yielded the best and least erroneous outcomes. Conversely, the Follower Formation "Linear Distribution" exhibited the poorest performance and the highest number of errors.**

Keywords*— *UAVs formation, swarm tracking, swarm intelligence algorithms, distributed leader-follower, flocking rules, obstacle avoid.

I. Introduction

The formation control of many UAVs has emerged as a hot topic in the study of multiple UAVs. The growing interest in formation control is driven by its numerous advantages over single UAV operations, such as increased adaptability, flexibility in unfamiliar environments, and robustness. Formation control involves organizing a group of UAVs into specific formations, like: Triangles, V- shape, Linear, M- shape, Squares and so on, and finds applications in search and rescue, reconnaissance, object tracking, and satellite array management [1,2].

Various strategies have been proposed by researchers for managing multiple UAV formations. These strategies include behavior-based approaches, leader-follower methods, and virtual formation structures [3,4]. Each strategy has its own set of pros and cons. For instance, the leader-follower method designates one UAV as the leader while the others follow. However, this approach lacks instantaneous feedback between the leader and followers [5].

Feng et al [6] proposed a tactic that takes into account the gap between the leader and their following. However, another researcher has devised a method that keeps the formation together without needing information about the leader UAV's dynamic model and velocity[7]. Any UAV in the formation can take on the role of "virtual leader" and be followed by the others [8].

Each UAV's flight path is determined using a weighted average of all aircraft and the chosen route in the behavior-based approach [9]. The virtual leader UAV's dynamics direct the followers to keep the fixed virtual configuration, hence the formation itself can be thought of as a rigid body [10, 11]. One disadvantage of the virtual formation is that it is centrally controlled, thus problems with just one plane might throw off the entire formation [12]. As part of our ongoing research, we want to find new ways to deal with these issues.

Formation control of several UAVs has been the subject of a great deal of study. One study [13] a vision-based method is proposed for commanding a fleet of UAVs. Another study [14] demonstrates a control architecture that integrates the leader-follower and virtual-leader methods. In [15] demonstrates a control architecture that integrates the leader-follower and virtual-leader methods . Time lags in communication between members of a formation have also been studied because of the instability, volatility, and decreased efficiency they might cause.[16,17].

The objective of this study is to directly examine the optimal followers' positions and distributions relative to their leader in a hypothetical swarm using the leader-followers strategy. In conclusion, the control of multi-UAV formation is an active research area with various strategies being explored. Researchers are continuously working on enhancing formation control techniques to improve adaptability, robustness, and efficiency in diverse applications..