Multi-FMAV time-varying formation control method with hybrid time delay

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Abstract / In the past decade, researchers have analyzed the flight mechanism of flying organisms, carried out in-depth attitude control, position control design, and system stability analysis of FMAVs, and proposed several state estimation models and control methods to realize the autonomous formation flight of flapping-wing flying robots. Among them, in the distributed information interaction network environment, which comprises multiple FMAVs, the internal system and communication process are inevitably influenced by factors such as network topology, sampling methods, and flight conditions. Consequently, this interaction may lead to information incompleteness phenomena, including time-varying delays, random packet losses, and signal attacks. These phenomena, in turn, degrade the estimation performance of the desired state during FMAV cruise accompaniment, standoff tracking, and encircling flight, ultimately affecting the overall formation effectiveness. To address these issues, this study introduces a novel multi-FMAV time-varying formation control approach, considering the presence of multiple time delays in dynamic feedback control. By employing appropriate system transformations using free power matrices, combined with an augmented multiproduct Lyapunov-Krasovskii functional that captures more time delay information and an improved Wirtinger and Relaxed integral inequality method, the resolution error is reduced. This approach leads to stability conclusions with reduced conservatism and design conditions for the distributed H_∞ state estimator. These advancements expand the stable operation domain of the system and provide a more intuitive understanding of the formation's convergence ability. The validity of these conclusions is demonstrated through simulation examples, providing insights into the future research directions of FMAV flight control.

Keywords / time delay; formation control; flapping-wing micro aerial vehicle; Lyapunov-Krasovskii functional

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