



Coupling INDI and H_∞ control to improve robustness of multirotor aerial systems

Soutenance de thèse – Mohamad HACHEM

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Amphi Bréguet, ENAC, 7 avenue Marc Pégélin, Toulouse

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Résumé

This thesis provides a comprehensive study of the modeling, control, and trajectory optimization of multirotor aerial systems, focusing on robustness against disturbances and full-pose tracking (position and orientation control). A complete cascaded control architecture is proposed, compatible with real-time implementation and applicable to several types of multirotors, whether under-, fully-, or over-actuated. The Newton–Euler framework serves as the foundation for control strategies, with modeling simplifications handled using robust techniques and validated experimentally. At first, trajectory optimization is formulated as an open-loop optimal control problem, generating feasible flight paths for different multirotor configurations. A key contribution is then the development of a complete control architecture involving a set of reduced-order H_∞ controllers, which is validated in nonlinear simulations in the presence of disturbances, including a scenario with a cable-suspended payload. However, limitations arise from equilibrium-based linearization and input allocation constraints considering the ability of the fully-actuated multirotors to independently control its dynamics. To address these limitations, an advanced control architecture is introduced that combines Incremental Nonlinear Dynamic Inversion (INDI) with structured reduced-order H_∞ control, with the primary goal of improving disturbance rejection. Initially developed for under-actuated systems, this framework is then extended to fully- and over-actuated multirotors by introducing a suitable control allocation module in the guidance loop, enabling full-pose tracking while handling actuator constraints. Real-time validation on a customized ENAC platform confirms its effectiveness, with comparative analyses on maneuverability and ability to reject disturbances. Overall, the thesis establishes a robust generic control framework for multirotors, validated through simulations and experiments, and paving the way for more reliable autonomous systems in uncertain environments.

Mots clés

Robust control, Incremental Nonlinear Dynamic Inversion, control allocation, multirotors.

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