

Over the past decade, multirotor aircraft have gained significant attention across various industries due to their ability to hover and maneuver in three-dimensional space. These capabilities make them invaluable for numerous applications, driving substantial advancements in unmanned aerial vehicles (UAVs) and contributing to their widespread adoption.

This work focuses on enhancing the flight robustness of small and medium UAVs, an aspect that is well-established in conventional aerospace operations but often overlooked in low-computation platforms. To address this challenge, we develop a multi-layered control structure that integrates low-level motor control with high-level path planning and collision avoidance.

At the core of our approach, we employ analytical feedback linearization to introduce critical linearity to the system, enabling the use of computationally efficient control techniques. A key contribution of this work is the utilization of zonotopes, a set-based representation, to perform reachability analysis. This method allows us to study system dynamics and determine a safe flight envelope, ensuring that any maneuver can be reversed to maintain operational safety.

To integrate this analysis into the control framework, we explore two upper-layer strategies: reference governors and their extension into tube model predictive control. These approaches enhance robustness against disturbances, such as wind perturbations, ensuring stable flight under challenging conditions.

Furthermore, we enhance existing path-planning algorithms by leveraging zonotopes to efficiently navigate cluttered environments. By constructing an expansive search tree over the available space while accounting for obstacles, our method enables reliable motion planning. Finally, we extend our framework to multi-agent UAV systems by partitioning the fleet into smaller groups that communicate through distributed model predictive control.

Through experiments, we validate the effectiveness of our multi-layered approach across various real-world scenarios.