

SANDO: Safe Autonomous Trajectory Planning for Dynamic Unknown Environments

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Abstract-

This paper presents SANDO, a safe trajectory planner for 3D dynamic unknown environments. Existing soft- constraint planners are fast but do not guarantee collision-free paths, while hard-constraint methods typically ensure safety at the cost of longer computation. SANDO addresses this trade- off through three contributions. First, a heat map-based A global planner steers the path away from high-risk regions, and a spatiotemporal safe flight corridor (STSFC) generator produces time-layered polytopes that inflate obstacles only by their worst-case reachable set at each time layer, rather than over the entire horizon. Second, trajectory optimization is formulated as a mixed-integer quadratic program with hard collision-avoidance constraints, and variable elimination reduces the number of decision variables. Third, a formal safety analysis establishes collision-free guarantees under explicit velocity- bound, size-bound, and estimation-error assumptions. Ablation studies confirm that variable elimination yields up to 7:4 × faster optimization and that STSFCs are critical for feasibility in dense dynamic environments. In simulations against state-of-the- art methods, SANDO achieves a 100% success rate across all forest and dynamic benchmark difficulty levels with no constraint violations, and perception-only experiments demonstrate the full perception-to-planning pipeline. Hardware experiments with fully onboard planning, perception, and localization demonstrate six safe flights in static environments and twelve among dynamic obstacles.

Index Terms- Aerial systems: perception and autonomy, collision avoidance, motion and path planning, optimization and optimal control.

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Citation:

Kondo, K.; Tordesillas Torres, J.; Rached, J.; Sun, L.; Jia, Y.; How, J.P. "SANDO:

Safe Autonomous Trajectory Planning for Dynamic Unknown Environments", IEEE Transactions on Robotics, , .