# Safe Lattice Planning for Motion Planning with Dynamic Obstacles

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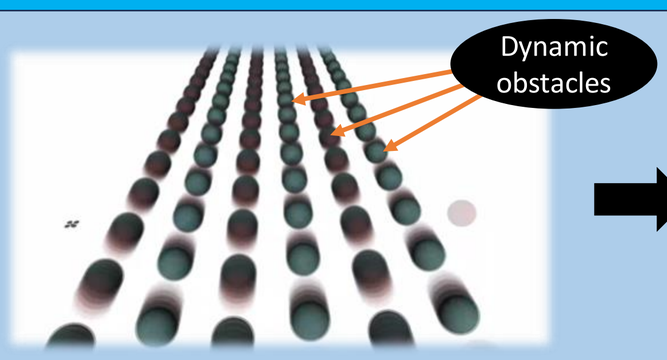
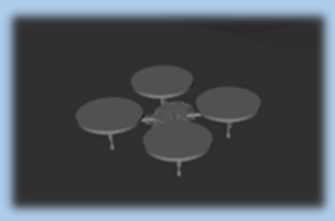
## 1 Introduction

Motion planning in dynamic and uncertain real-world environments remains a critical challenge in robotics, as it is essential for the effective operation of autonomous systems [1]. One strategy for motion planning has been to introduce a state lattice where pre-computed motion primitives can be combined with graph-based search methods to find a physically feasible motion plan. However, introducing lattice planning into dynamic, uncertain settings remains challenging. It is nontrivial to incorporate uncertain dynamic information into the planning process in real time. Thus, in this paper we propose a lattice planning framework for dynamic environments with extensions to handle safety-critical edge-cases that can arise with the uncertain nature of the environment. The proposed method, Safe Lattice Planner (SLP), extends the Receding Horizon Lattice Planner (RHLP) [2] with enhanced replanning and survival capabilities to handle the dynamic habitat. We thoroughly evaluate SLP in a new benchmark suite against provided baselines. SLP is found to outperform the baselines in terms of safety and resilience in the dynamic environment while reaching the goal state in an efficient manner. We release the benchmark and SLP to accelerate the field of safe robotics.

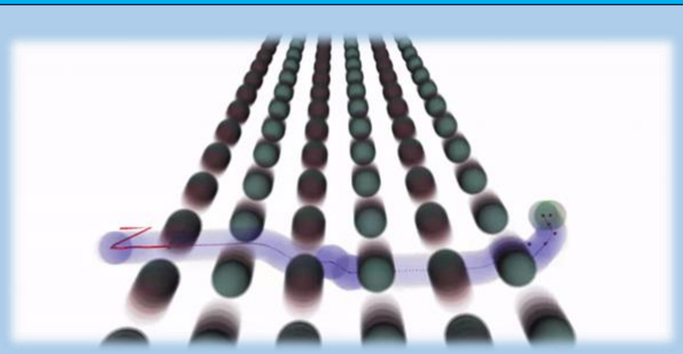
## 2 Problem Scenario




**Complex environment with multiple dynamic obstacles**

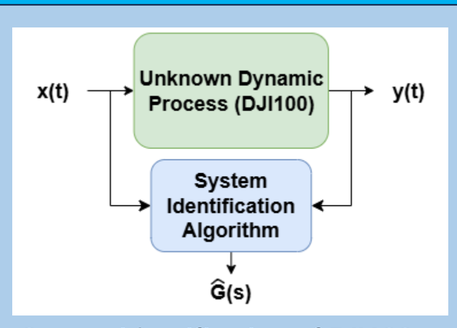


**Simulated DJI100 Quadcopter**

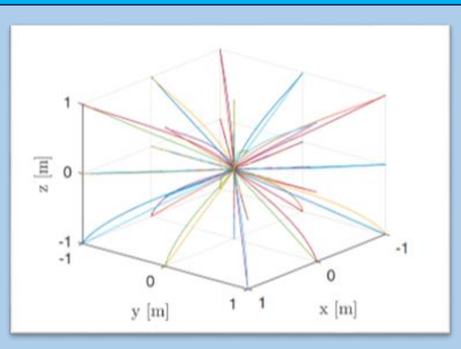


**Real-time spatio-temporal motion planning while obeying safety constraints**

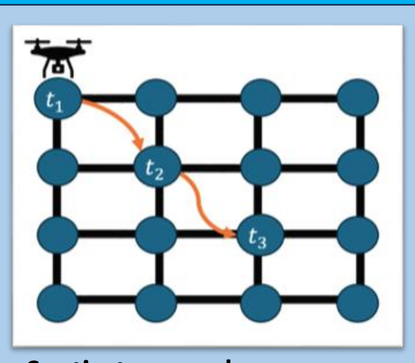
## 3 Background



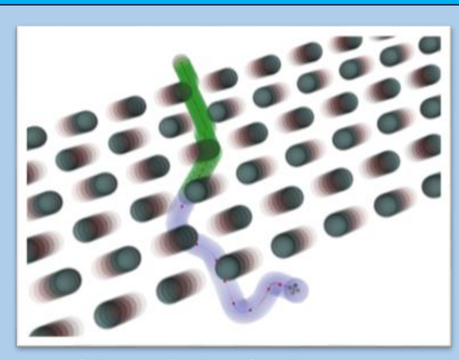

**System identification of DJI100**




**Generate Motion Primitives using Numerical Optimal Control**

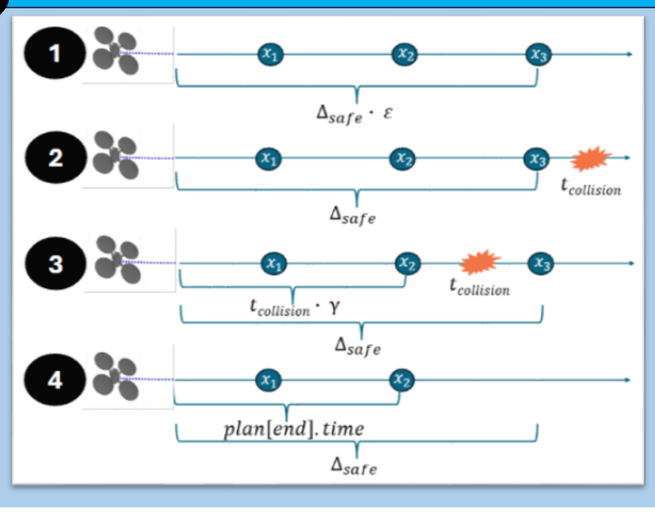



**Spatio-temporal concatenation of MPs**



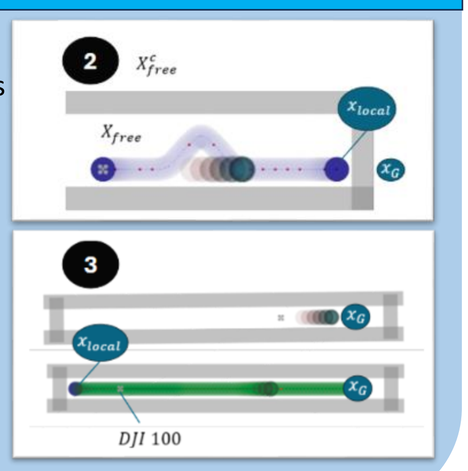
**Multi-resolution lattice in receding-horizon fashion**

## 4a Adaptive replanning



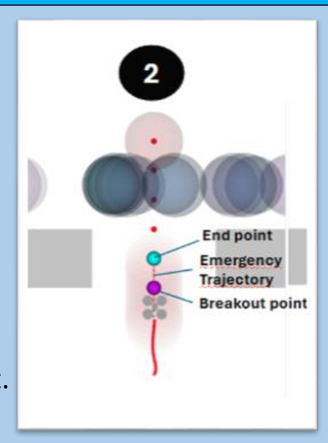

## 4b Local planning

Hazardous situations should be avoided at all times, even if a feasible plan can not be found. Local planning adresses this issue by introducing survival capabilities.

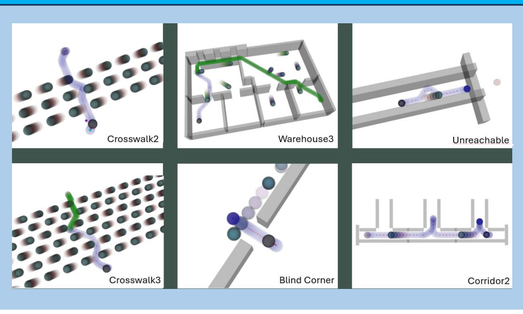


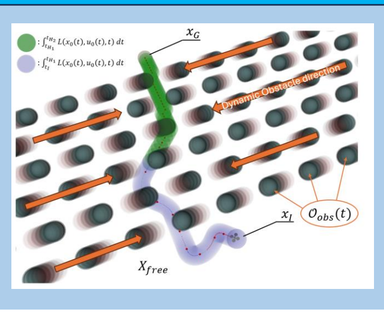

## 4c Emergency Traj.

Previously, if a plan becomes infeasible while traversing a motion primitive, there is no way to abort the execution. In this work, we introduce emergency trajectories to break out from the motion primitive as a last resort.




## 5 Evaluation/Benchmark




To assess the motion planner(s), has a benchmark been constructed that contains 19 different scenarios of varying size, geometry and dynamic obstacles. Evaluating SLP against baselines in this benchmark suggests that SLP outperforms the baselines in terms of effectivnes, resilience and safety. For future work we aim to combine SLP with a dynamic exploration planner, DAEP [3], to perform real-world safe 3D exploration.

BENCHMARK

[1] M. Tiger, ”Safety-Aware Autonomous Systems: Preparing Robots for Life in the Real World”, Frontiers in Artificial Intelligence and Application, Vol. 402. IOS Press 2025
[2] O. Andersson et al. , "Receding-Horizon Lattice-Based Motion Planning with Dynamic Obstacle Avoidance”, IEEE, CDC, 2018
[3] E. Wiman et al. , ”Autonomous 3D Exploration in Large-Scale Environments with Dynamic Obstacles, IEEE, ICRA, 2024