Safe Motion Planning and Control with Dynamic Obstacle Avoidance

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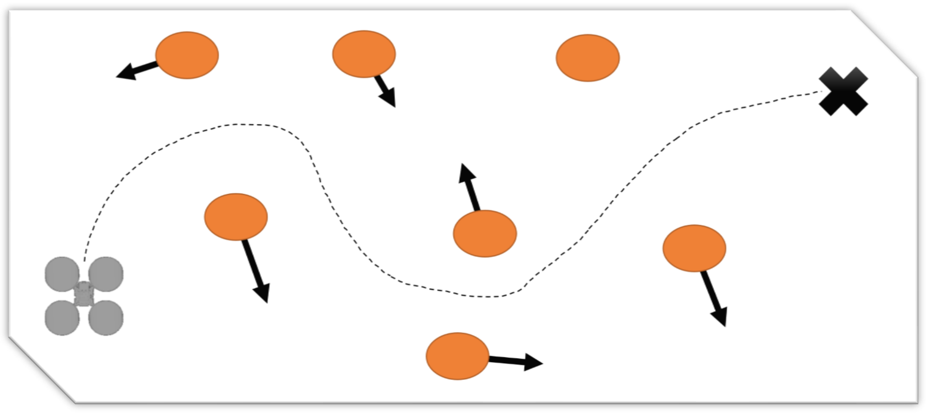
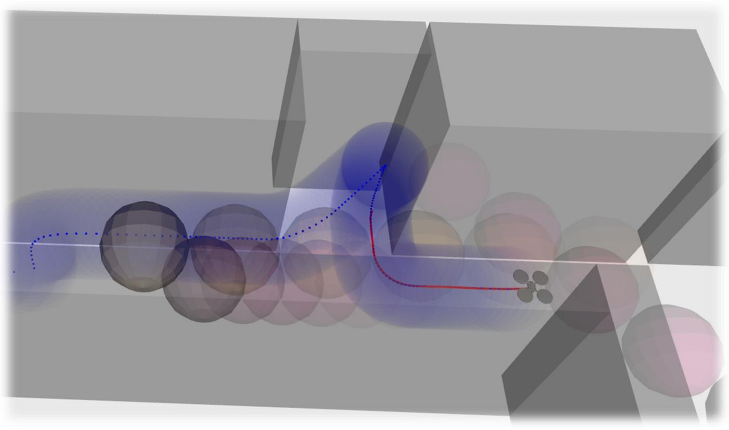
*A key requirement of autonomous vehicles is the capability to safely navigate in their environment. However, outside of controlled environments, safe navigation is a very difficult problem. In particular, the real-world often contains both complex 3D structure, and dynamic obstacles such as people or other vehicles. Dynamic obstacles are particularly challenging, as a principled solution requires planning trajectories with regard to both vehicle dynamics, and the motion of the obstacles. Additionally, the real-time requirements imposed by obstacle motion, coupled with real-world computational limitations, make classical optimality and completeness guarantees difficult to satisfy. We present a unified optimization-based motion planning and control solution, that can navigate in the presence of both static and dynamic obstacles.**

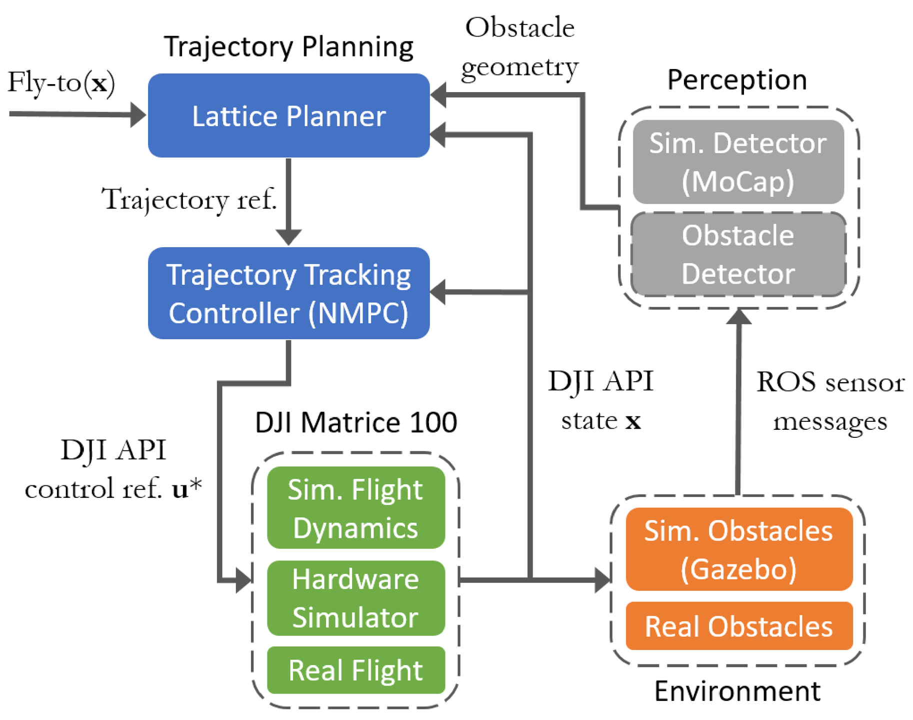
WARA-PS Scenario

Safe navigation with uncertain dynamic obstacles in complex environments. Specifically in tight spaces such as at low altitudes (e.g. at the street level in a city) or indoors (a home or warehouse).





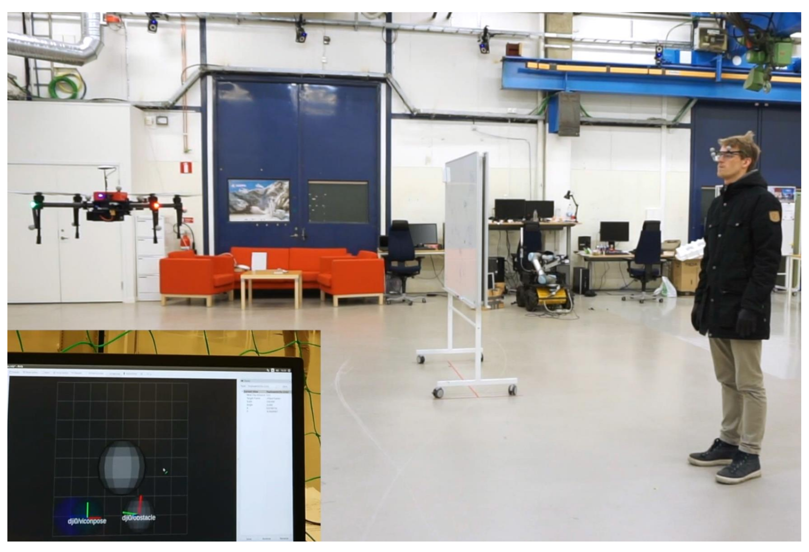
System Overview

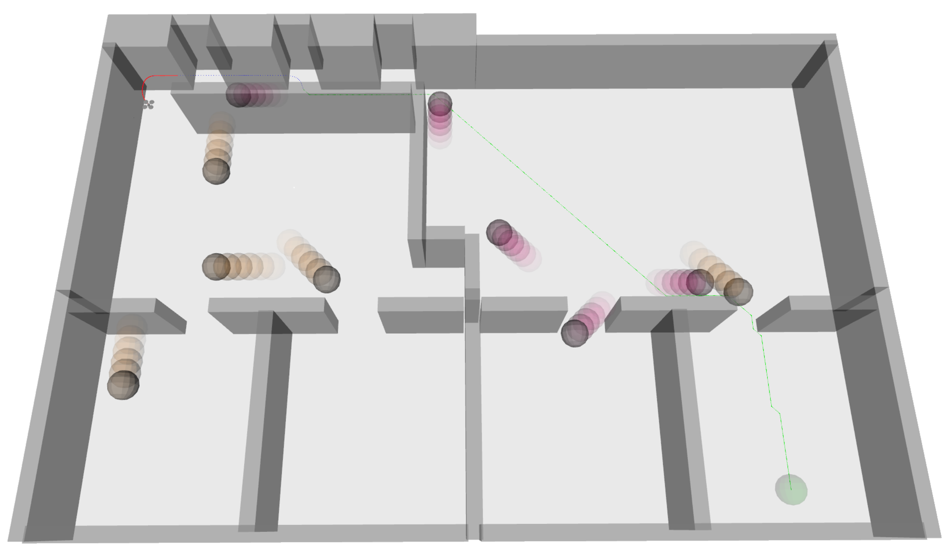


Platform: DJI Matrice 100

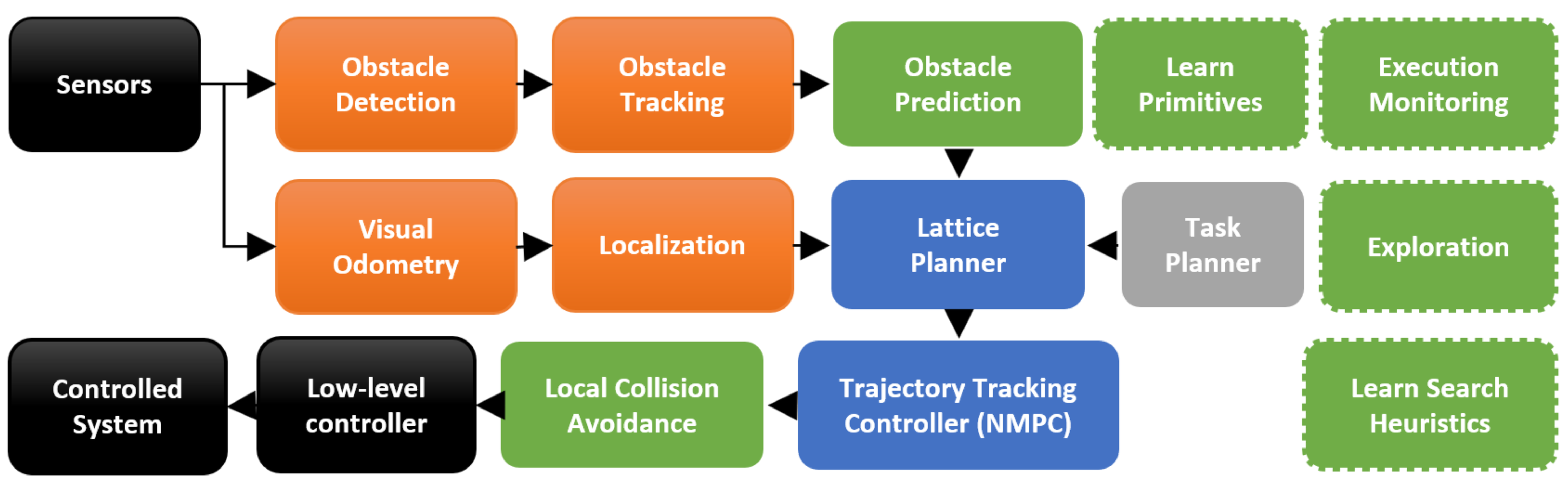
ROS-based software stack

Experiments

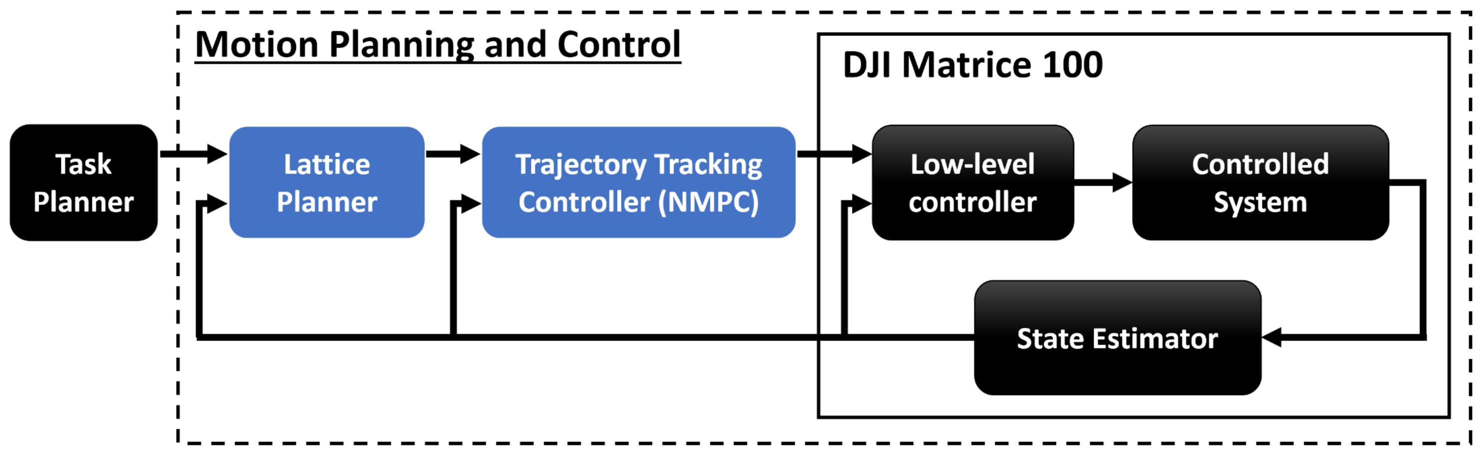




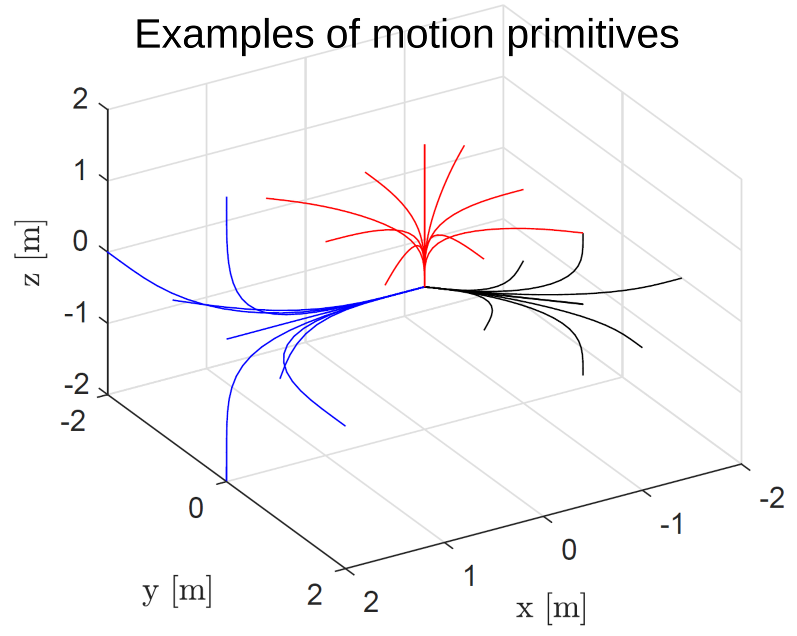
The Next Step

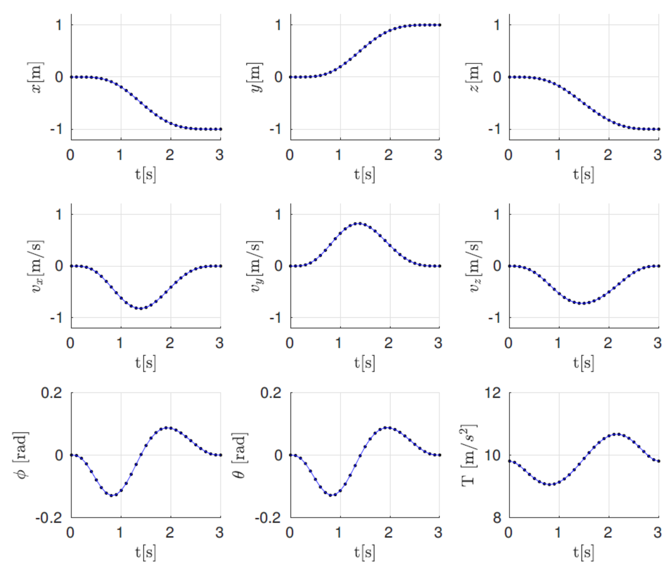


Receding-Horizon Lattice-based Motion Planning with Dynamic Obstacle Avoidance



We propose [1] a principled solution to this problem (*) by using a unified optimization-based motion planning and control architecture, where both layers use the system dynamics to generate and execute feasible trajectories in real-time. In particular, we present a novel receding-horizon motion planner which has similarities to multi-resolution state lattices. A set of dynamically feasible trajectories (motion primitives) are generated offline by the use of numerical optimal control. These motion primitives are then used in an online graph-search to find a dynamically-feasible and cost efficient solution to the dynamic motion planning problem. These motion primitives can then be efficiently tracked by a receding-horizon controller.

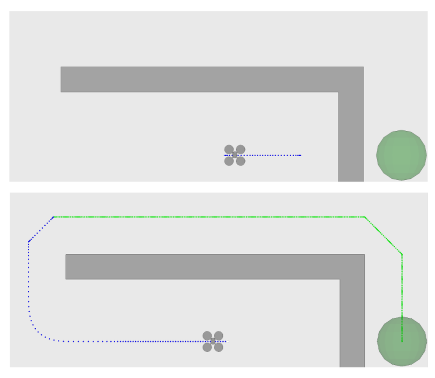


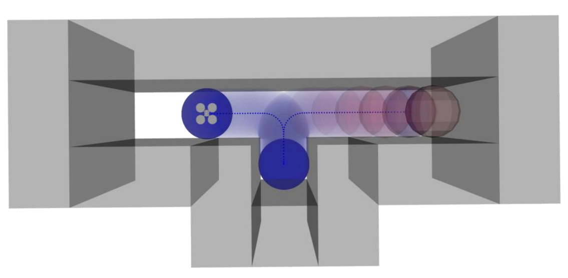


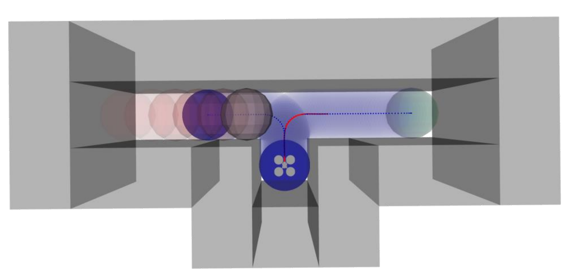
Full trajectory planning and tracking.
State: 3D position, 3D velocity, roll, pitch, thrust

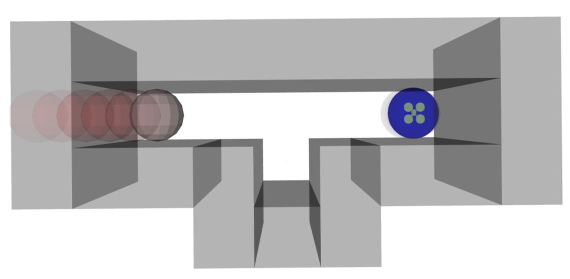
Capabilities:

- ✓ Real-Time performance: *Planner: 2-5Hz, MPC: 50Hz*
- ✓ Finds global solution: *Not getting stuck locally*
- ✓ Physically feasible plans from start to goal
- ✓ Supports uncertain state of self and of obstacles
- ✓ Forward simulates dynamic obstacles: Temporally safe plans using predictions with uncertainty
- ✓ Plans across time – can plan to wait to let obstacles pass









[1] O. Andersson, O. Ljungqvist, M. Tiger, D. Axehill, F. Heintz, *Receding-Horizon Lattice-based Motion Planning with Dynamic Obstacle Avoidance*, in Proc. CDC, 2018