Model based motion planning for manipulation with heterogeneous robotic systems under constraints

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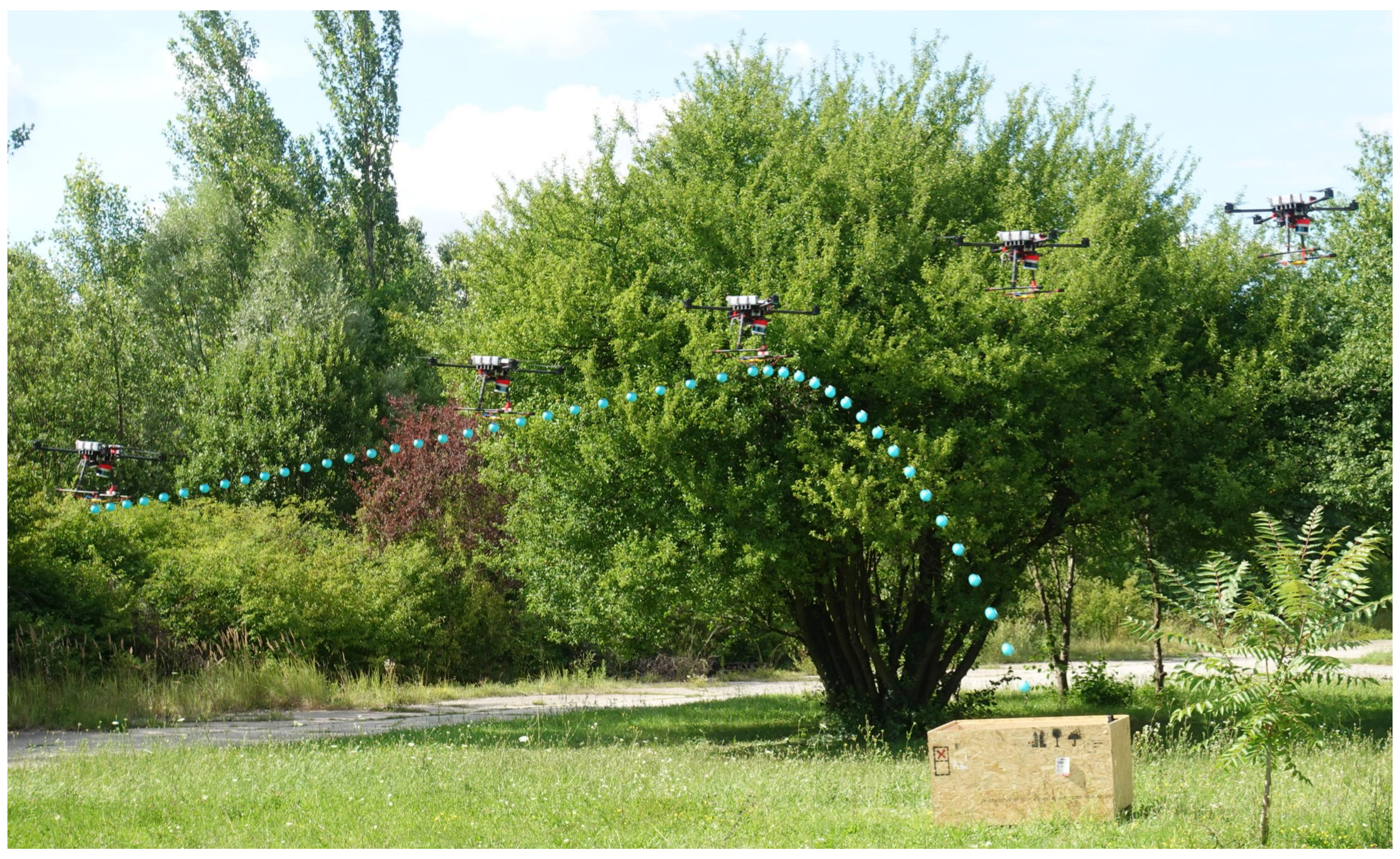
1. Introduction

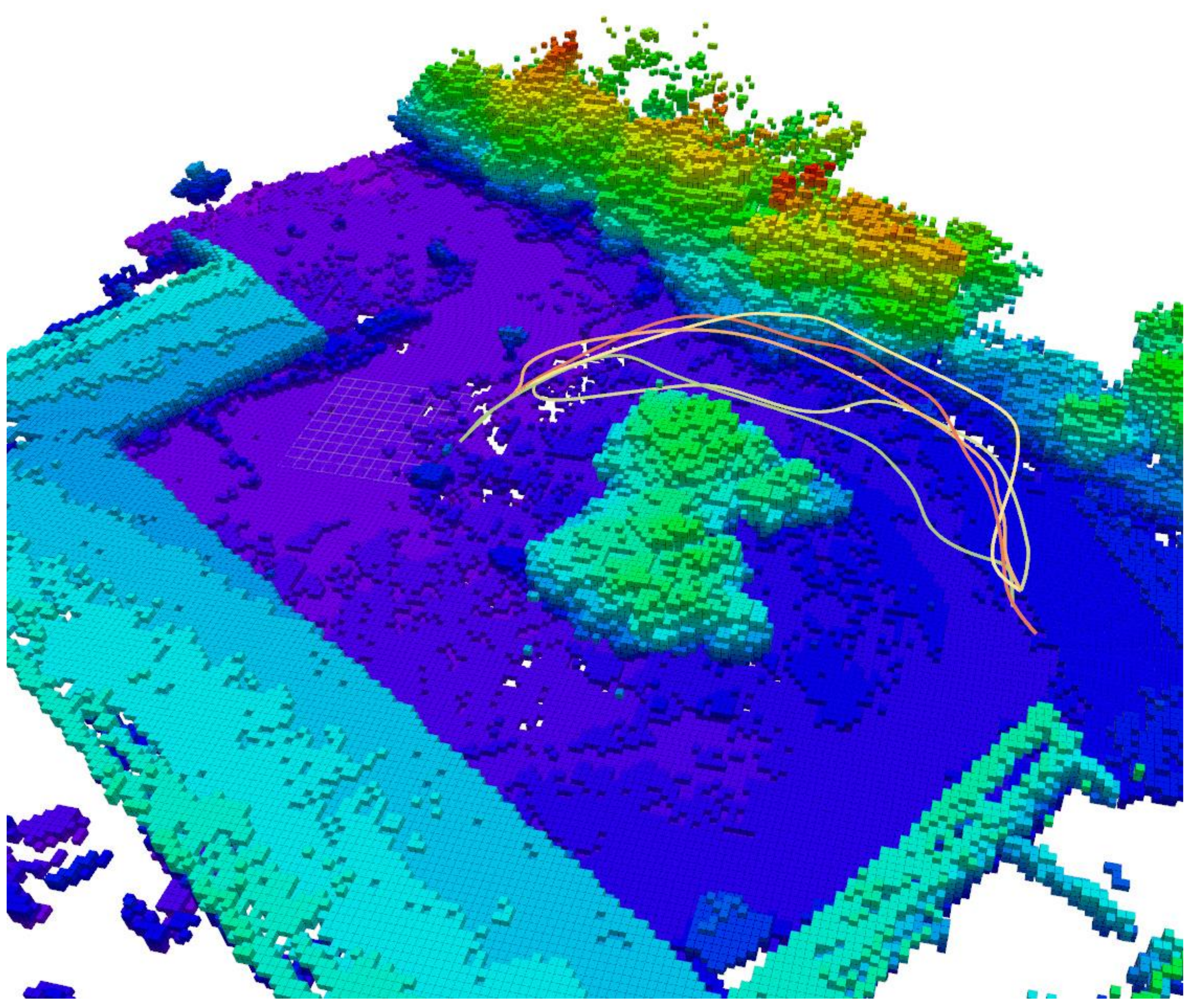
The main objective of this work is to develop, test, and evaluate a trajectory planner suitable for a parabolic airdrop with multirotor Unmanned Aerial Vehicles (UAVs). The task of such a planner is to deliver a payload to a specified target in some environment. One of the possible scenarios for utilizing the parabolic airdrop is fire extinguishing in an obstacle-rich environment. In such a case, this planner can be used for a continuous delivery of the fire extinguishing agent with multiple UAVs.



An illustration of an outdoor experiment. The UAV plans a trajectory to the release point and executes a stopping motion afterwards.

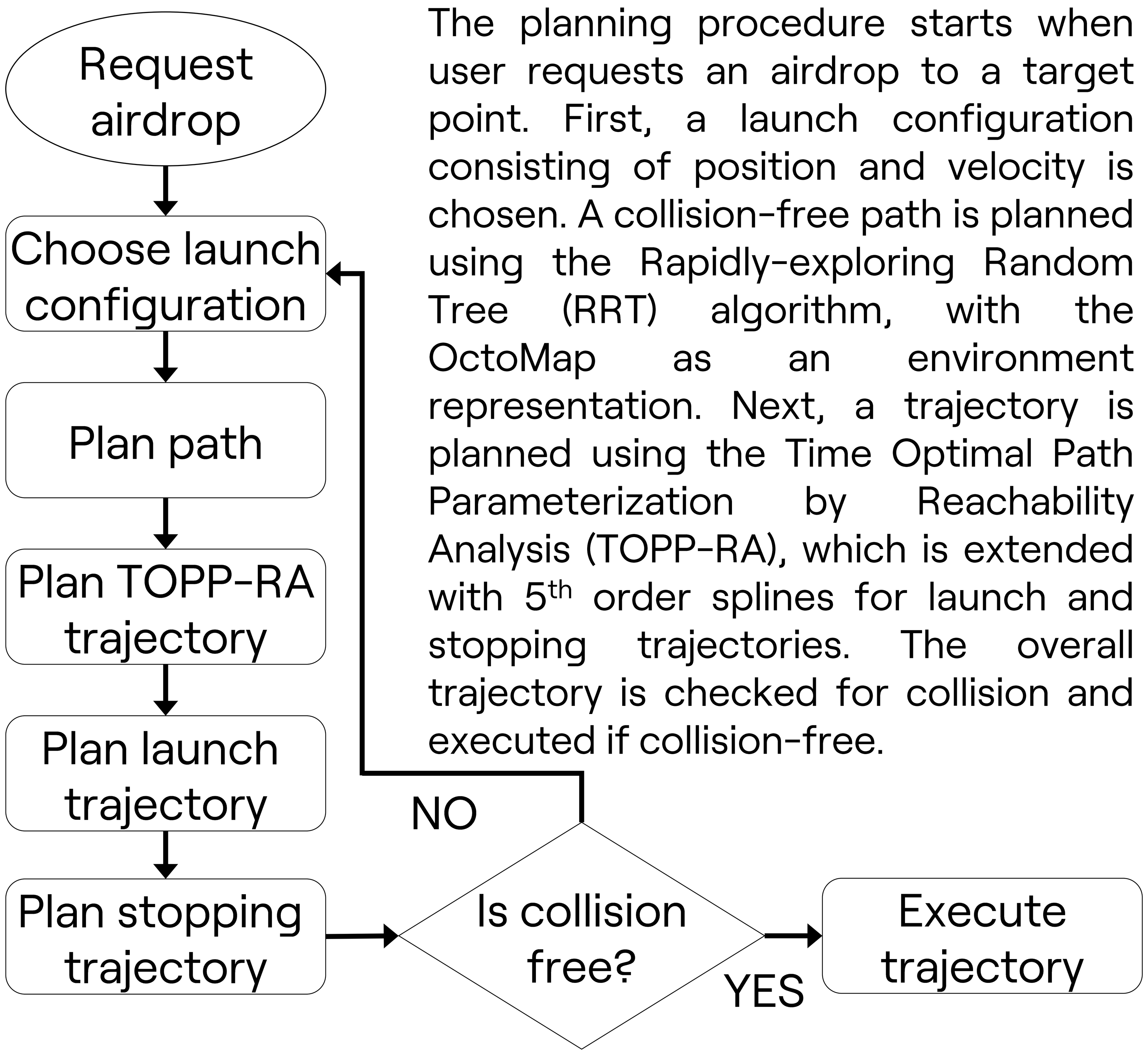
2. Problem Description

After releasing the payload, its motion can be described as a parabolic trajectory. By supplying a target point, one can use this information to calculate the release point and velocity required to reach the target point. As there are numerous release point and velocity pairs, some are eliminated through dynamical constraints of the UAV. Others are eliminated by the configuration of the environment itself, since the UAV must not collide with the environment. Finally, a feasible configuration is selected, and the collision free trajectory is planned.



Several airdrop trajectories planned in an OctoMap representation of a previously mapped outdoor environment.

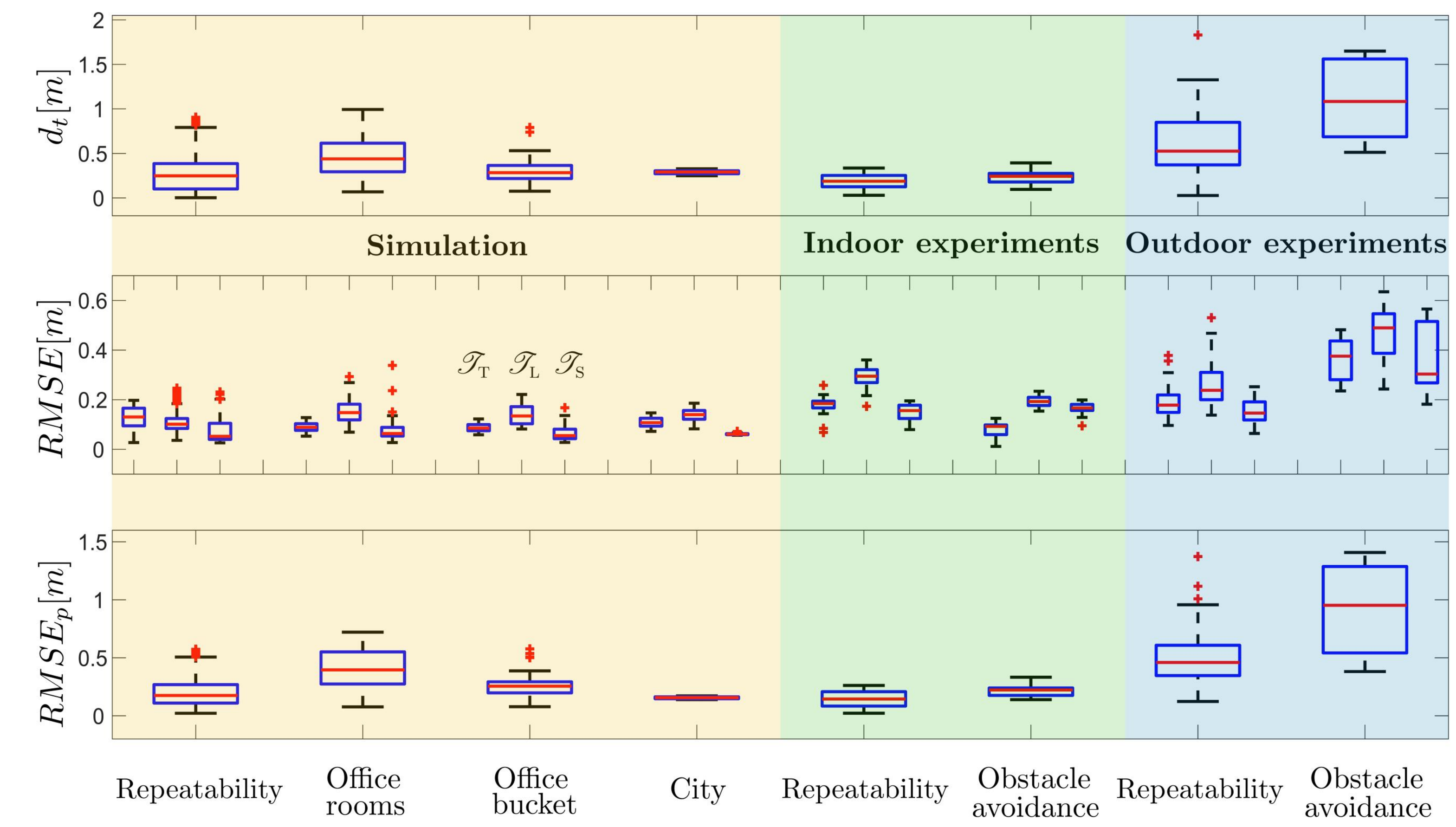
3. Methodology



The planning procedure starts when user requests an airdrop to a target point. First, a launch configuration consisting of position and velocity is chosen. A collision-free path is planned using the Rapidly-exploring Random Tree (RRT) algorithm, with the OctoMap as an environment representation. Next, a trajectory is planned using the Time Optimal Path Parameterization by Reachability Analysis (TOPP-RA), which is extended with 5th order splines for launch and stopping trajectories. The overall trajectory is checked for collision and executed if collision-free.

4. Results

The planner has been tested in several different simulation environments based on Robotic Operating System (ROS) and Gazebo simulator. The simulations were performed in an obstacle-free environment, a dense indoor environment, and in large-scale city environment. Following the simulation, experiments were performed in an indoor laboratory and outdoor environment.



Analysis of the repeatability and obstacle avoidance of the planner in simulation and realistic environments.

5. Conclusion

The results show the potential of applying this approach in the real-world scenarios, such as deploying a fire extinguishing agent. The verification process of the method revealed the high precision and success rate of this approach. To increase the launch distance and overall safety of the system, the plan for future work is to include the angular velocity of the UAV in the planning procedure.

6. Project Acknowledgement

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specularia

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