Using Contacts During Robot Manipulation to Map and Reconstruct a Scene

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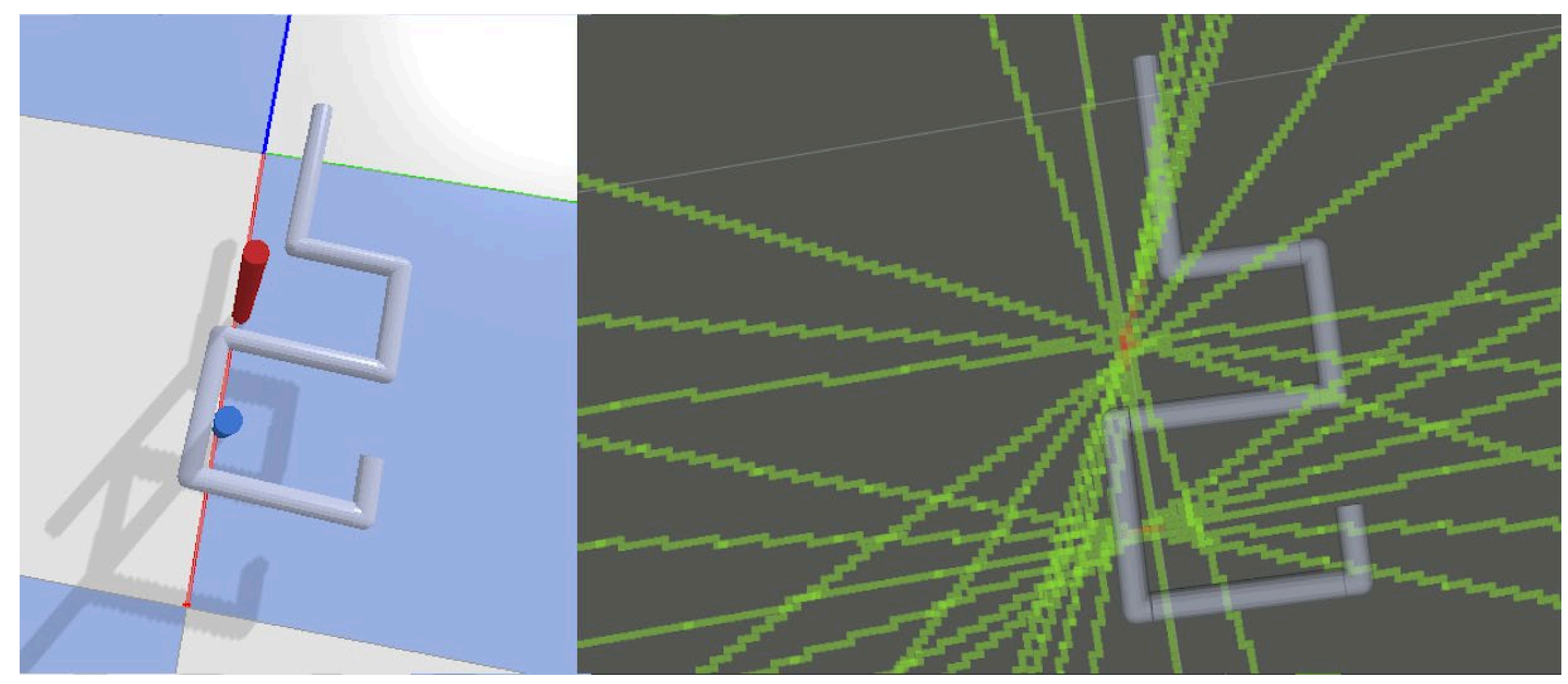
Abstract

- We present an algorithm to **simultaneously reconstruct** the geometry of an unknown **object** and its **environment** via physical interactions.
- Our approach uses **force and torque** measurements at the robot end-effector to solve for possible contact locations and probabilistically determine the occupancy likelihood on a 3D map.
- We build **two occupancy maps**: one represents the environment (fixed), and another reconstructs the grasped object (moves with the robot end-effector)
- Each map informs the probability updates on the other.
- The algorithm is applied and tested on two scenarios: **retrieving** a tangled object from a scene and **reconstructing** the geometry of an object.



Methods

- We create two 3D occupancy maps (octomaps): the voxels contain the probability that it is occupied.
- The maps are **updated sequentially** to reconstruct the geometry of the environment and the shape of the grasped object
- We devise **two probability laws**: one is applied on contact and one when the robot moves in free space.

Probability Law 1 (on contact):

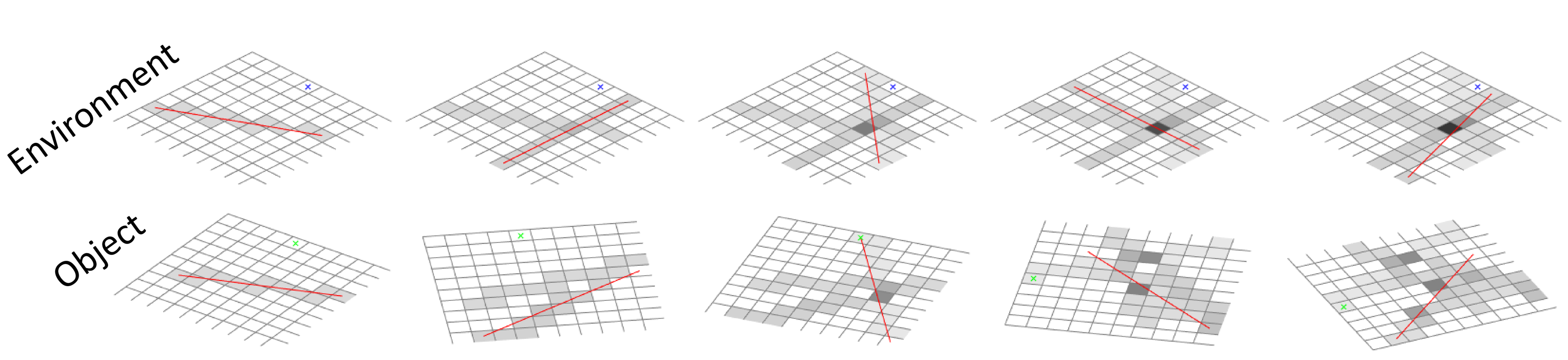
1. We find the force line of action. The intersected voxels are the possible contact locations
2. We compute the probability of contact $P(C^n)$ anywhere on that line:

$$\bigcup_{n\in L} P(C^n) = 1 - \Pi$$

3. We calculate the probability of voxel p being occupied

$$\mathrm{P}(O^p)_{t+1} = \frac{PP' + \left(1 - \frac{\Pi}{1-PP'}\right)\cdot P\overline{P}'}{1-\Pi}$$

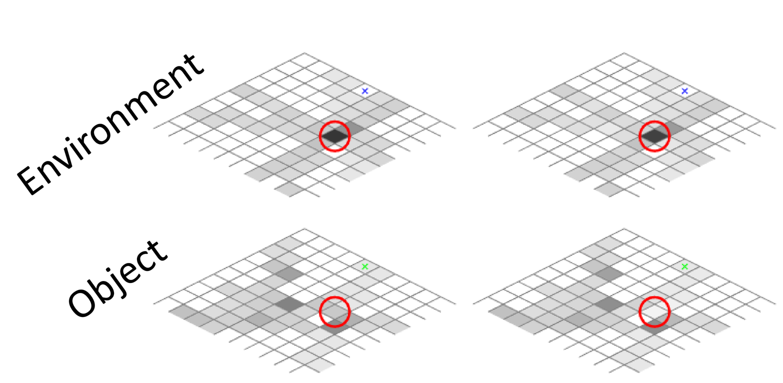
$$P = P(O^p),\ \overline{P}' = P(\neg O^p),\ \Pi = \prod_{n\in L}\left(1 - P(O^n)\cdot P(O^{n\prime})\right)$$



Probability Law 1 (in free space):

1. If there is no measured force, then two overlapping voxels can't both be occupied.
2. Voxel p is occupied only if p' is free:

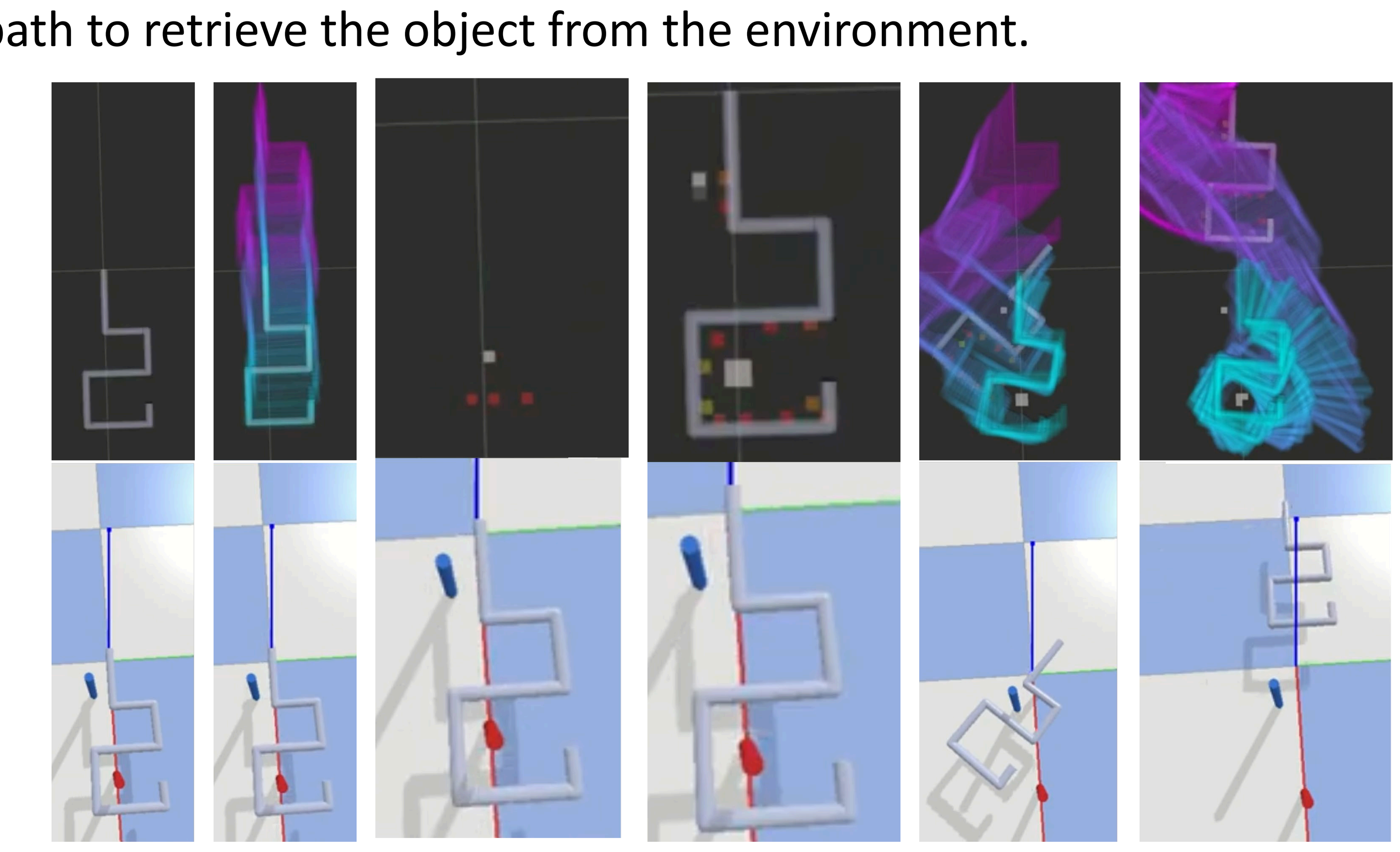
$$\mathrm{P}(O^p)_{t+1} = \frac{P(O^p)\cdot(1 - P(O^{p\prime}))}{1 - P(O^p)\cdot P(O^{p\prime})}$$



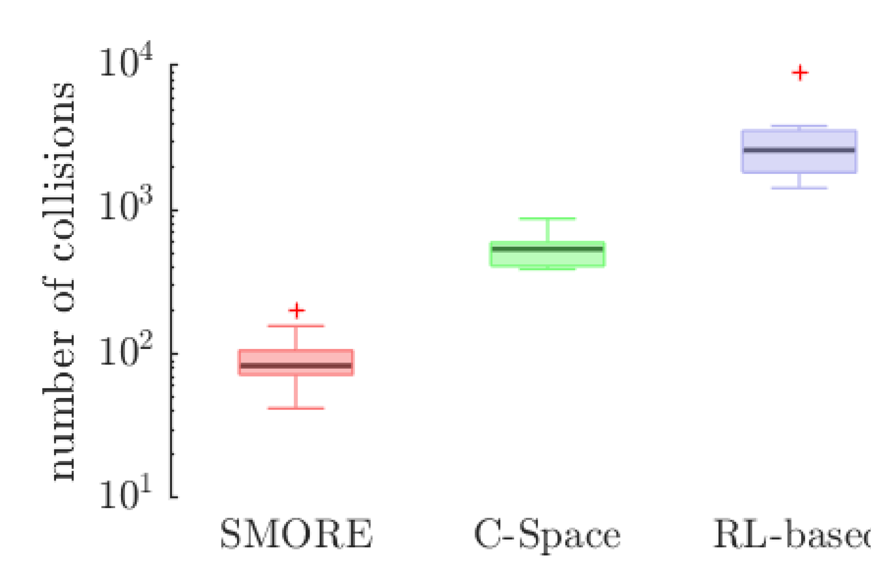
3. And vice-versa

Results

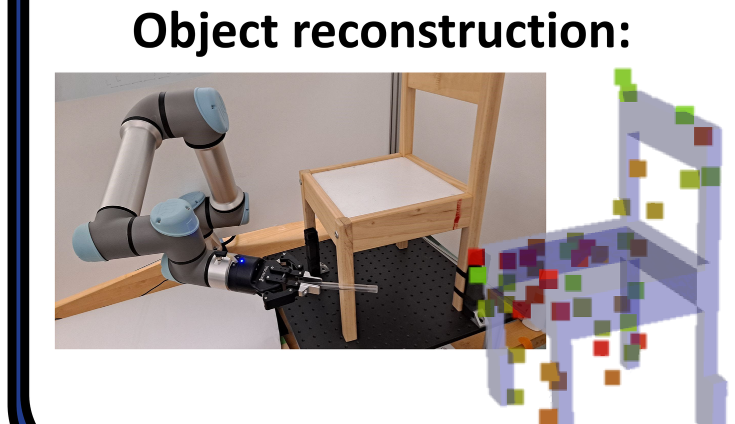
Object untangling: We use an RRT planner to find a collision-free path to retrieve the object from the environment.



Performance: Our approach requires **less collisions** to retrieve object than a configuration-space planner and a reinforcement learning based approach:



Object reconstruction:



Links and Contacts

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