A Demonstration of Planar Dragging of a Hose with Obstacles

Peter Mitrano[1] and Alison Ryckman[1] and Dmitry Berenson[1]

***Abstract*— We demonstrate a pipeline for planar dragging of a deformable one-dimensional object (DOO) in the presence of obstacles. When stuck on obstacles, the robot plans an untangling motion to change the topology of the DOO. The pipeline is validated on a vacuum hose dragging task using a Boston Dynamics Spot robot, equipped with the Spot Arm.**

I. INTRODUCTION AND RELATED WORK

Planar dragging of hoses or wires can be a useful capability in fire-fighting, inspection, agriculture, or manufacturing settings. These objects can be approximated by DOO models in 2D, but most prior work considers only small DOOs in a table-top setting. With longer DOOs, there may be a need for a mobile base. Additionally, top-down views fully containing the object may not be possible. The closest prior work is [1], which frames feeding long belts into industrial machinery as a planar planning problem involving dragging and regrasping. However, their task does not allow moving over obstacles by leaving the plane, whereas ours does.

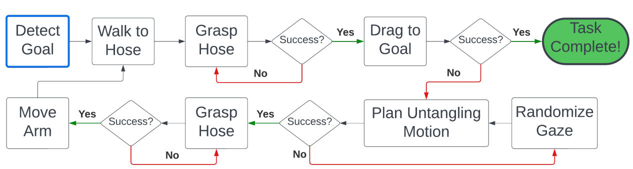

Fig. 1: Flow chart of pipeline, including loops to check for and handle failures, such as missed grasps.

II. PROBLEM AND METHODS

Figure 1 shows the perception and planning primitives, as well as the high-level control flow. The pipeline includes several retry loops, such as for failed grasps, or when obstacles or the hose are not detected. If the hose gets stuck on large or heavy obstacles while dragging to the goal, which is detected by high torque at the wrist, the robot plans an untangling motion. We define untangling as a topological planning problem with additional constraints on reachability and DOO length. After untangling, it retries dragging to the goal. Dragging and untangling alternate until the task is complete, or the operator intervenes.

The untangling motion is parameterized by a pick position p_0, lift height z, and a place position p_1. As an approximation to untangling, the motion should change the topology of the DOO. Let s be a list of points representing the state of the hose before picking. Let s' be the state after placing, $l(s)$ be the DOO length, and $\mathcal{H}(s)$ be the homotopy class, which is unique for different topological states, and is given by the winding number. The planner searches for collision-free positions p_0, z, p_1 such that $l(s) = l(s')$, but $\mathcal{H}(s) \neq \mathcal{H}(s')$.

[1]Department of Robotics, University of Michigan

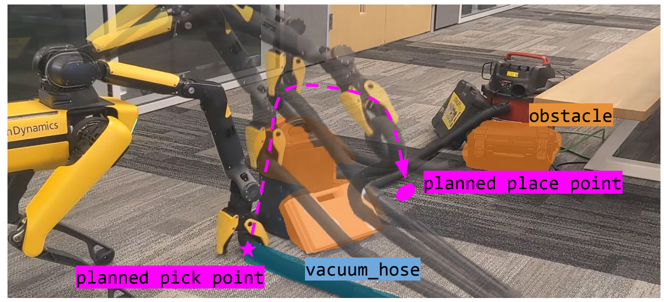

Fig. 2: Annotated image of an untangling motion. Transparency shows motion over time. A Mask R-CNN network gives the obstacle and hose masks.

To solve this problem, p_0 is chosen to be the point in s whose distance to the nearest obstacle is closest to a given clearance distance (5cm). The lift height z is set to be the obstacle height plus the clearance distance. Finally, p_1 is chosen by randomly sampling and choosing the first sample that satisfies the homotopy and length constraints. The state of the hose is estimated using CDCPD [2]. An annotated close-up of the untangling behavior is shown in Figure 2. The perception pipeline, which uses a Mask R-CNN network and an RGB-D in the robot's hand, provides the state of the hose, and the 2D position and height of obstacles, enabling generalization over obstacle and hose positions. Generalization to different obstacles or backgrounds is achieved by additional labeling and fine-tuning.

III. RESULTS

A video showing the task execution and demonstrating robustness to perturbations can be found on our Project Website. Although it often completes the task without intervention, we observed failures where the robot was stopped by the operator. For instance, standing on top of the hose while lifting caused unstable behavior from the walking controller. The task was also terminated when the retry loops ran unsuccessfully for > 10 iterations. In conclusion, we demonstrate a pipeline for planar dragging of a DOO using a mobile manipulator that is robust to disturbances such as obstacles or failed grasps.

REFERENCES

[1] Yili Qin, Adrien Escande, Fumio Kanehiro, and Eiichi Yoshida. Dual-arm mobile manipulation planning of a long deformable object in industrial installation, 2023.

[2] Yixuan Wang, Dale McConachie, and Dmitry Berenson. Tracking Partially-Occluded Deformable Objects while Enforcing Geometric Constraints. *ICRA*, 2021.

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