Motion Planning for Mobile Robot Navigation Using a Toyota Human Support Robot

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The HSR is a mobile robot with a 3-dof omnidirectional base that utilizes a dual-caster drive mechanism. The HSR also has a 5-dof arm with a gripper end-effector. Whole-body motion is planned for the 8-dof of the arm and base.

It is common for pick-and-place tasks to be split into navigation and manipulation-while-the-robot is stationary. This method has a discontinuous base motion which makes it less time-efficient compared to a drive-by approach.

This project introduces a drive-by pick-and-place motion planning method in which a robot follows a predefined base trajectory and performs a grasping action without stopping the base motion. In particular, the drive-by pick-and-place method is implemented on a Toyota Human Support Robot to achieve time-efficient, collision-free, whole-body trajectories in a static environment.

The focus of this project is on a drive-by pick-up of a soda can off of a table. We assume that a base trajectory is given and use a simple one that runs parallel to the table. The challenge is to plan a whole-body motion that considers both the binary constraint of collision and differential constraints involved in positioning the end-effector to grasp the soda can at a specified time.

The pick-and-place problem is split into 3 segments: Reaching, Grasping, and Placing. Grasping is planned first. Then the Reaching step brings the HSR to the start pose of the Grasping segment and the Placing segment starts at the end pose of the Grasping segment.

Reaching and Placing need to avoid collision and reach or start from a specified pose. Sampling-based planners such as Rapidly Exploring Random Trees (RRTs), which randomly sample robot configurations to find a valid trajectory with probabilistic completeness are used to solve the Reaching and Placing segments. It is assumed that the actual placing action can take place while the robot is stationary, using existing methods such as Inverse Kinematic planners or RRTs. The drive-by pick-up planner can also be easily extended to a drive-by placing planner.

The Grasping phase is solved using non-linear trajectory optimization using Approximate Inference Control (AICO). AICO uses message-passing that allows for local trajectory updates that converge in less time than similar methods that update the entire trajectory. AICO is implemented in the Extensible Optimization Toolkit (EXOTica). EXOTica creates a cost function from taskmaps, which is minimized to find an optimal trajectory. Taskmaps such as “reaching a desired end-effector pose” and “following the given base trajectory” are activated at various times with varying weights to describe the constraints of the Grasping segment.

Grasping segment trajectories were run in Gazebo, an open-source robotics simulator commonly used for Robot Operating System (ROS)-based simulations. The HSR accomplishes the drive-by pick-up task, but plots of the trajectory show that acceleration limits are exceeded by 2 arm joints at transitions between taskmaps. Further testing is necessary to confirm and reduce the severity of this issue. Further tuning of taskmaps timing and costs may reduce acceleration values.