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

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Abstract

Service robots for home care applications require the ability to perform pick-and-place actions for object manipulation. It is common to split the pick-and-place task into navigation and manipulation-while-the-robot-is-stationary. This project builds on prior work on loco-manipulation planning and demonstrates a continuous pick-and-place motion. This paper 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. Failure modes are documented and analyzed and an outline of future work is provided.

Introduction

Robocup@Home is an international robotics competition that aims to pose a standard problem to further development of robotic technologies in the area of "service and assistance with high relevance for future personal domestic applications"[]. Specifically, the Domestic Standard Platform League (DSPL) of Robocup@Home aims to"assist humans in a domestic environment, paying special attention to elderly people and people suffering from illness or disability."[]. Focus areas of the competition include "Human-Robot-Interaction and Cooperation" as well as "object manipulation".[] A common activity for an autonomous robot to perform is object retrieval or placement, more commonly known as a pick-and-place problem in robotics. This fourth-year project centers on implementing a drive-by pick-and-place algorithm on a Toyota Human Support Robot (HSR), which is the designated robot for the Robocup@Home DSPL.

The HSR software includes a function that commands the robot to position its end-effector to grasp an object and a function that commands the robot to drive to a designated point in the world. The combination of these two functions allows the HSR to complete a pick-and-place task. However, the actions are discontinuous and require the HSR to stop and grasp the target object, see the top of figure 1. The drive-by pick-and-place algorithm outlined in this paper aims to combine the tasks of grasping the object and driving to a target placing location to identify a time-efficient, collision-free trajectory.

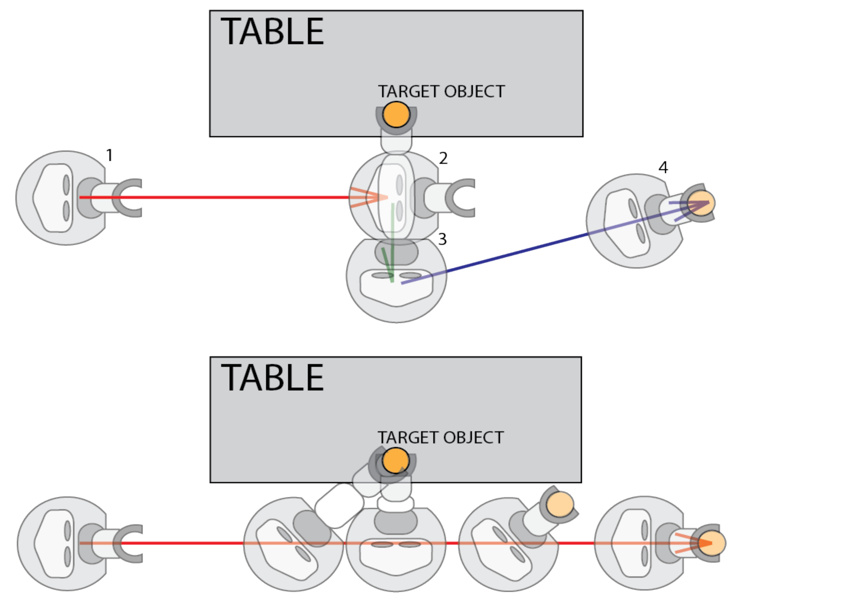

Figure 1: (Top) Pick-and-place action using built-in HSR functions. (Bottom) Drive-by pick-and-place action.

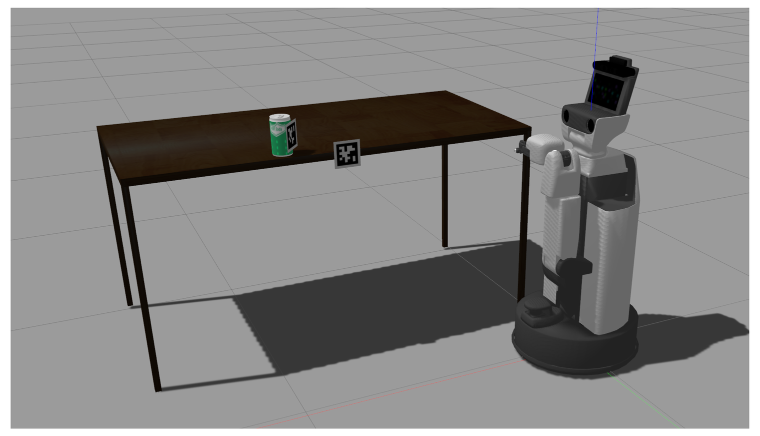

Figure 2: Screen shot of the problem setup in Gazebo

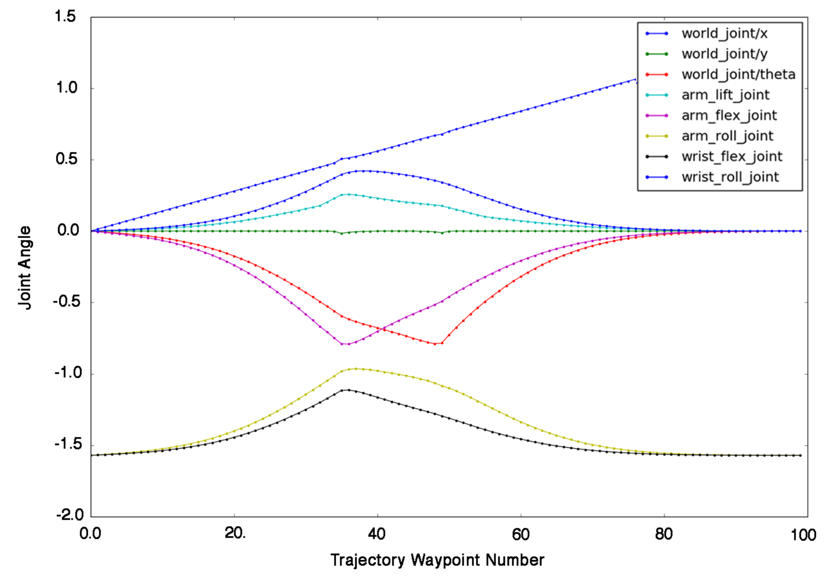

Figure 5: Plot of the joint position values output from the AICO solver. The trajectory has 100 waypoints over a 10 second grasping period. The base trajectory given was a 1.4m linear, linearly spaced trajectory that runs parallel to the Ikea Nyboda table, see bottom of Figure 1 and Figure 2.

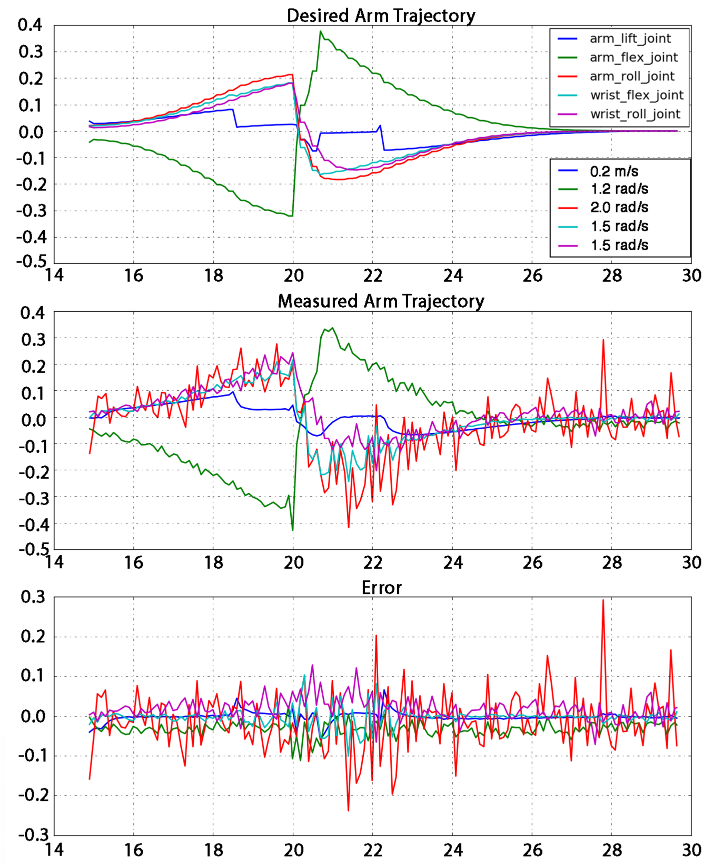

Figure 6: Plots of HSR arm joint velocities at each waypoint. For each plot, the horizontal axis has units of time(sec) and the vertical axis has units of velocity. (Top): expected joint velocity values for the simulated HSR in Gazebo. (Middle): Velocity measurements sampled from the simulated HSR at 10 Hz. (Bottom): Plot of difference between velocity measurements and desired values. This velocity has a duration of 15 seconds, since the time step between the trajectory waypoints shown in Figure 5 was set to 0.15 seconds. The legends denote the HSR arm joints and the velocity limits.

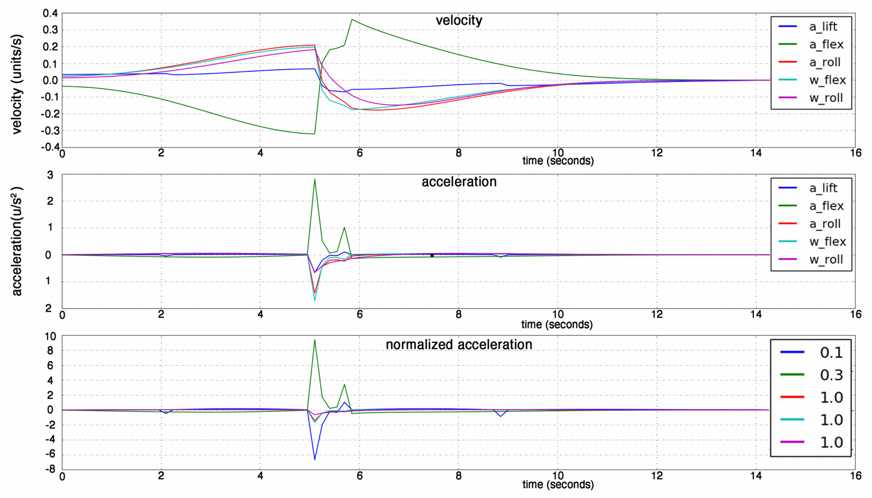

Figure 7: Desired HSR arm joint Acceleration plot. (Top) Desired velocity plot. (Middle): Desired HSR acceleration values calculated by differentiating desired joint velocity values. (Bottom): Acceleration values normalized by the respective HSR arm joint acceleration limits. Acceleration limits are denoted in the legend.

RESULTS

Position Plot

Velocity Plot

Acceleration Plot

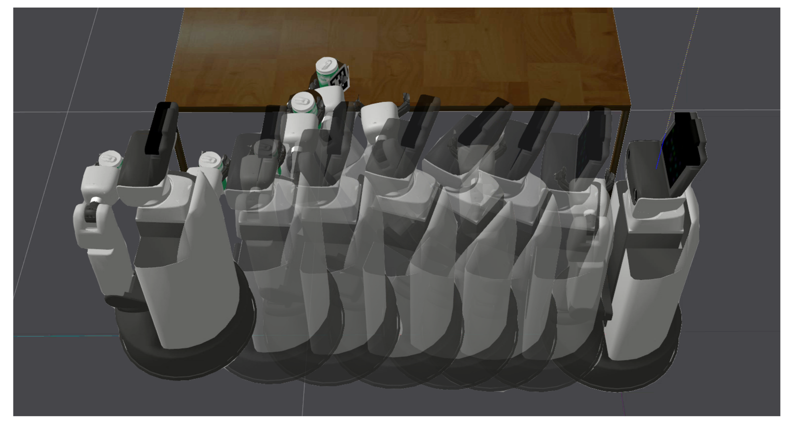

Figure 7: Frames of the grasping phase of the drive-by pice-and-place action simulated in Gazebo.

Approach

Problem Description

The goal of this project is for the HSR to perform a drive-by pick-and-place action. This requires the HSR to drive by a table, following a predefined base trajectory, and pick up a cylindrical object on top of the table without stopping the base motion. The HSR then brings the object to the destination and places it. It is assumed that the base trajectory is given prior to planning and the location of obstacles is known.

Problem Setup

To simplify the problem described previously, a bare-bones world containing an Ikea Nyboda Table and a soda can was created in Gazebo. Gazebo is an open-source robotics simulator commonly used for ROS-based robot simulations.\cite{koenig_design_2004} The objects in the simplified scenario were chosen for convenience. The Ikea Nyboda Table was chosen as it was the model of the table present in the testing space for the HSR. A soda can was chosen as the target pick-and-place object since it is a household item and a representative task for a service robot. Further, the radius of the soda can is larger than items expected to be used in real-world testing, which produces a scenario with a smaller margin for error in terms of end-effector positioning. Figure 1 depicts the HSR following a given base trajectory that is parallel to the table and attempting to grasp the bottle.

Method

This project closely follows the method proposed in \cite{yang_planning_2018}. The trajectory is separated into 3 segments, depicted in Figure 3, with different types of constraints. Reaching and placing consider binary constraints such as avoiding collision with the table. The grasping segment considers both binary and differential constraints, since the end-effector must reach the soda can and maintain alignment until the gripper fingers can close around the cylindrical object, all the while avoiding collision. The drive-by approach differs from [] in that the grasping segment is extended to encompass approaching and leaving the location of the target object, largely due to reachability issues with the HSR. The breakdown of the segments is depicted in Figure 3, as well as the path planning algorithms used. Given the end pose of the reaching segment and the start pose of the placing task, the segments are relatively easily solved by sampling based methods, such as the HSR's built-in CBiRRT2 algorithm.[] This project focuses on the grasping phase, which is solved by Approximate inference control (AICO)[] wrapped in EXOTica []. AICO is used to a whole-body trajectory for the 8 degree-of-freedom robot (5-dof arm and 3-dof base).

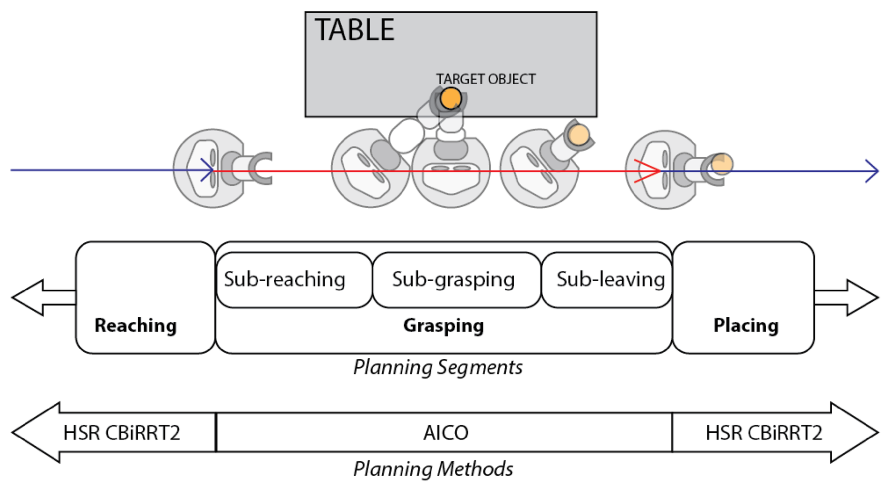

Figure 3: Overview of planning segments. Reaching and placing paths for the HSR base are found with sampling-based planners such as Constrained BiDirectional Rapidly Exploring Random Trees, implemented in the HSR software package.[] The whole-body grasping segment is solved for with Approximate Inference Control (AICO), an non-linear trajectory optimization solver, wrapped in EXOTica. Figure 4 depicts the taskmaps used for the grasping segment.

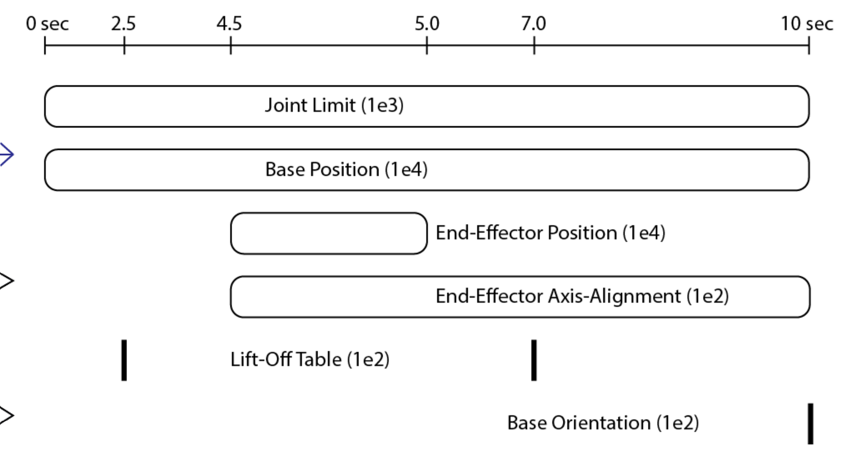

Figure 4: A graphical depiction of the timing of taskmap activation for the AICO solver in EXOTica.[] The graphic depicts the grasping segment, with 4.5-5.0 second interval is the sub-grasping phase shown ing Figure 3. Elongated rounded rectangles denote taskmaps that are active for a duration of time. Bars represent task maps that push the HSR to achieve desired values at a point in time. Associated costs for the taskmaps are listed in parenthesis. Greater costs correspond to a higher priority. The whole-body grasping trajectory is solved for a 10-second trajectory with waypoints every 0.1 seconds. The trajectory is scaled to accommodate for velocity and acceleration constraints imposed by HSR hardware.

EVALUATION

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REFERENCES

Reference 1
Reference 2
Reference 3