Tool Use via Inverse Kinematics

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This report details a novel approach to known object interaction with a Schunk Arm. A motion planning theorem is applied with a focus on workspace control. The implementation of this system was done in the GRIP/DART simulation environment designed/used by the Golems Lab at Georgia Tech.

I. Introduction

The purpose of this work is to create a methodology for interacting with known objects in a loosely defined workspace. This goal is directly in line with the DARPA robotics challenge to apply humanoid robots to search and rescue applications by using tools and exploration algorithms.

II. Related Work

Tool manipulation in workspace is very common in both research and industry.

What makes our system unique is that we account both for the motion planning for the robot as well as the constraints of the tool. For example, when driving the screw into the target block, we must follow the screw as it threads into the target block by matching 'downward' translation with the rotation of the screw driver, then back the tool out and repeat until the screw is settled into the block.

III. Methods

In the current experiments, there are three interactive objects and one robot arm. The interactive objects are a screwdriver, a bolt, and a goal block, all located within the arm's range of movement.

Our system then follows the following set of actions to generate a plan.

A. Locate screw

After the screw is inserted into the world file, it is passed to the robot as a motion goal point. The robot queries the world to find the object and obtains the transform of the current tool position in the world's coordinate reference frame. The 4x4 affine matrix representing the rotation and translation of the screw is then converted into a 6x1 vector:

$$\dot{q} = \begin{bmatrix} \dot{a} \\ \dot{w} \end{bmatrix} \tag{1}$$

Here, is a three dimensional translation vector and is a roll, pitch, and yaw vector relative the world origin which define the origin of the screw.

B. Grasp the screw

Jacobian workspace control is used to align the robot's manipulator with the coordinate frame of the screw. After matching rotation and position with the target, the robot grabs the screw. Subsequently, the screw is manipulated as though it were an additional link in the arm.

C. Locate goal

1) Move the bolt to alignment with the goal.

D. Release bolt

E. Grasping tool

Grasp the screwdriver; updating the end effector after each interaction.

F. Move tool to screw

After moving the screwdriver into the bolt, update the arm to include the bolt as well

G. Drive screw into goal point

Moving it into the goal position.

H. Release bolt

Release the bolt

I. Release tool

Replace the screwdriver back to its original position.

IV. Experiments

V. Analysis

VI. Discussion