

Goal-Based Teleoperation for Robot Manipulation

Jun Ki Lee and Odest Chadwicke Jenkins

Department of Computer Science
Brown University
Providence RI 02912, USA
{jun.ki_lee, odest.jenkins}@brown.edu

Abstract

As robot algorithms for manipulation and navigation advance and robot hardware is becoming more robust and readily available, industry demands robots to perform more sophisticated tasks in our homes and factories. For many years, direct teleoperation was the most common and traditional form of control for robots. However, due to the complexity of robot motion, human operators must focus most of their attention on solving low-level motion control which leads to their heightened cognitive load. In this abstract, we propose a goal-directed approach to programming robots by providing a tool to model the world and provide goal states for a given task. Operators will be able to set the initial positions of objects and their affordances along with their goal positions by imposing three dimensional (3D) templates on point clouds. Robots will solve the given task using the combination of task and motion planning algorithms.

Introduction

Direct teleoperation (or simply remote control) with no autonomous intervention has been the traditional and most common form of robot control, due to its reliability and adaptability. Especially for manipulation, human operators directly controlled their robots' pose and configuration to accomplish a given task. Due to the complexity of robot motion, human operators must focus most of their attention to solving low-level motion control instead of the goal of task. This leads to heighten the operator's cognitive load. Direct teleoperation becomes even harder when a user is only provided with a computer screen which shows a two dimensional (2D) projection of a three dimensional (3D) scene and a mouse.

In this abstract, we describe a goal based teleoperation interface in which operators provide the model of the world and their goal states to accomplish a given task. Operators will be able to set the initial positions of objects and their affordances along with their goal positions by imposing affordance templates on point clouds. Robots will solve the given task using the combination of task and motion planning algorithms. The goal is to eventually helps average users to

easily operate a highly sophisticated two-armed wheeled robot, such as PR2, without any special devices and consideration of direct joint controls in completing manipulation tasks in highly cluttered environments.

Problem

The main problem is to provide end-users with a goal-driven teleoperation interface to effectively conduct a task in a cluttered environment such as our everyday home. The below are the list of sub problems to be solved.

- How to effectively model the world that task and motion planning algorithms can operate on.
- Provide an effective way to conduct goal-driven tasks using both task and motion planning algorithms.
- Provide a way to measure the effectiveness of a proposed interface in comparison with the existing teleoperation methods.

Related Work

This work revisits and builds upon "put-that-there" modes of user input originally proposed by Bolt (1980) for interactive computer graphics, and applied shared human-robot control by Cannon (1992) and Kemp et al. (2008). In this mode, the operator view and specify goals with respect to an estimate of the robot's environment (as a form of a semantic map). Such an interface would allow improved shared autonomy (Goodrich et al. 2001) such that the robot could autonomously perform low-level control based on sequential goals provided by an operator.

Most of the work in combining task and motion planning algorithms started off from the AAAI 2010 Workshop on 'Bridging the Gap between Task and Motion Planning'. Among them, this work revisits and builds upon hierarchical task and motion planning techniques devised by Kaelbling and Lozano-Perez (2011) and the method by Srivastava et al (2014). which use an extensible planner-independent interface layer to combine task and motion planning.

As a baseline for common approaches to robot motion programming, we picked three recent works which are implemented for PR2.

The interactive marker system developed by Leeper et al. (2012) allows a user to control the robot's end effector's position and elbow posture by dragging a mouse. A pose of a

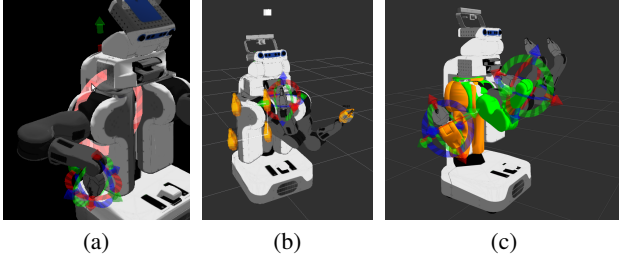


Figure 1: (a) Using only interactive markers (b) Programming by demonstration (c) Using a series of planned motions

robot at a given time is computed using the combination of Jacobian transpose and pseudo inverse. The programming by demonstration interface first introduced in Akgun et al. (2012) learns different trajectories that human teachers perform using the Gaussian mixture model. This interface allows a user to save a series of robot poses and play back the saved ones. The robot’s arms are physically dragged by a human demonstrator, but can be controlled using the same interactive markers introduced by Leeper et al. (2012). The MoveIt framework of Şucan and Chitta allows a user to provide the start and end state of a robot pose and infer a motion plan which avoids obstacles in the environments. In comparison with the programming by demonstration approach, a user provides only the start and end pose of a robot’s arm instead of providing intermediate poses to avoid possible obstacles. Three interfaces on the ‘rviz’ tool of Robot Operating System (ROS) are depicted in Fig. 1.

Approach

In this paper, we aim to develop a goal-directed robot programming tool that human operators do not need to provide specific trajectories to perform a given task. The proposed interface also aims to consecutively perform such actions by either providing a sequence of actions to be taken or a goal state of an object.

To achieve this, we bring humans in the loop to provide perceptions of the world, especially where the objects are and how to grasp them. Operators are asked put bounding boxes, an object template, around segments in a point cloud to specify objects’ location and size and their grasp locations. The actions such as ‘pick’, ‘place’, ‘go to’, and ‘pour’ are given by the system which can be parameterized and such parameters can be modified by human operators during the programming phase. Human operators can sequentially place each actions or specify goal states of objects depending on contexts of a given task. When goal states are given, a generalized planner inside the system calculates a sequence of primitive actions. When actions are given, prerequisites can be checked and perform a necessary action given by a planner.

A generalized planner can plan such high level actions via affordance based object templates. Object templates define an affordance of an object, here it is ‘grasp’. Object tem-

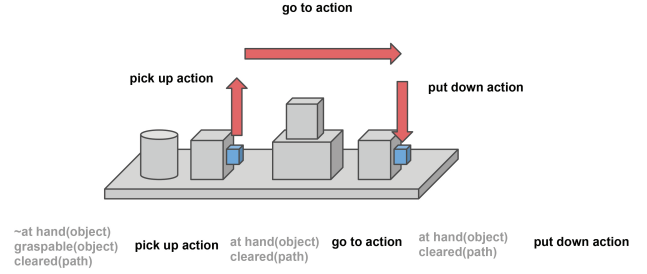


Figure 2: Planning of the pick-and-place task

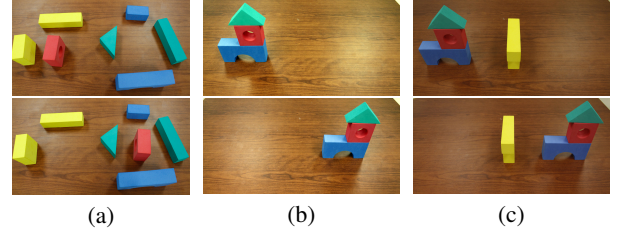


Figure 3: (a) Basic pick-and-place task with obstacles (b) Moving a configuration of blocks to another spot (c) Moving a configuration of blocks to another spot with obstacles

plates are directly placed upon a point cloud scene not upon a category of an object. This makes the system bypass the vision system which is used to register an object’s position and pose and its class in a RGB-D scene. We assume that when the object is fully grasped by a robot’s end effector, it will not change its pose while moving. Otherwise, the system will need to consistently detect an object’s pose in a RGB-D scene when an action is being executed. Each action template contain a sequence of action to be taken to achieve a single goal state. For example, ‘pick’ action will need an object and a robot’s arm as prerequisites, and will perform an approach action to go to the grasp location of an object and perform gripper close action. Then it will playback a joint trajectory that directly lift up the end effector to a certain distance. A motion planning algorithm with obstacle avoidance mechanism will be used for an approach action. Other actions can also be played back in simulation and can be checked if an action make a robot collide with any existing objects in the world. ‘Go-to’ action will be just a motion planned action to move an end effector’s pose from one to the other.

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