Enabling Semi-Autonomous Manipulation on iRobot's PackBot

Jessica Gwozdz (CS/RBE), Alexander Henning (RBE),
Nicholas Morin (CS/RBE), Ransom Mowris (PW/RBE)
Advisor: Professor Dmitry Berenson (CS/RBE)

Motivation

- PackBot is the most successful security and defense robot in the world
- Using a PackBot's arm and gripper requires a skilled operator's full attention
- The operator's safety and situational awareness might be compromised while commanding the robot
- If PackBots could perform some tasks with minimal user input, operators could direct more of their attention to the situation around them and their robot

A PackBot prepares to grasp a suspicious object

Desired Outcomes

- Simulate PackBot in the OpenRAVE motion planner
- Implement trajectory planning and execution
- Use a 3D sensor to recognize obstacles and cylinders
- Enable users to command the robot to grasp recognized objects

Background

Tools Used:

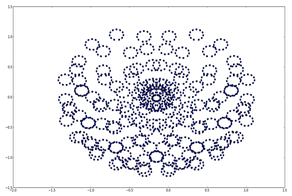
iRobot PackBot with EOD Arm

Open Robotics Automation Virtual Environment

PrimeSense 3D Sensor + Point Cloud Library

Inverse Kinematics for a 5DOF Arm:

- Because PackBot's arm is 5DOF, solving inverse kinematics (IK) for a desired pose is not always straightforward
- Our IK Solver searches a database of 3 million arm Jacobians for the closest possible pose
- Searches with Fast Library for Approximate Nearest Neighbor
- Optimizes using gradient descent

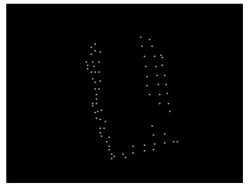


A partial visualization of our IK database

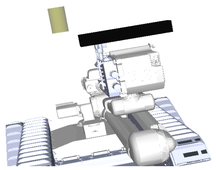
Sensing

Cylinders

Camera view of our sensor and a grasp target

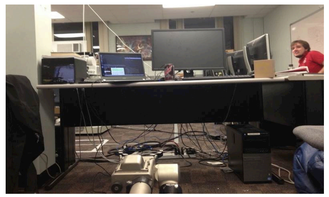


Segmented point cloud representation of the target

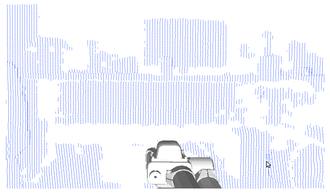


OpenRAVE simulator after importing the target

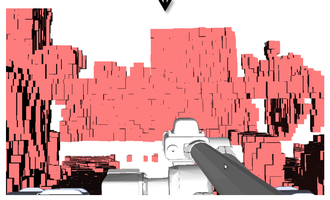
Obstacles



Camera view of a crowded environment

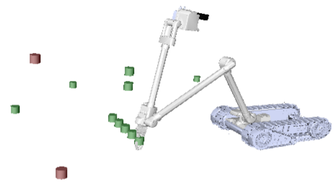


The same environment represented as a point cloud

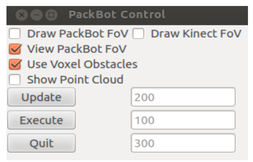


OpenRAVE simulator with the same view, now represented as voxels

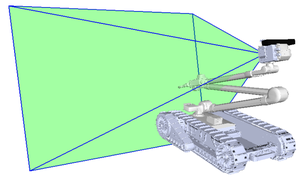
User Interface



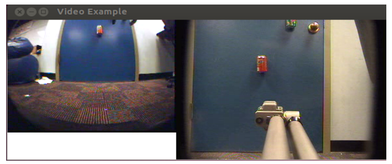
Cylinders are colored green if OpenRAVE can find at least one grasp. The user can click on an object to command the robot to grasp it



PyQt user interface which contains options for our additions to the OpenRAVE environment

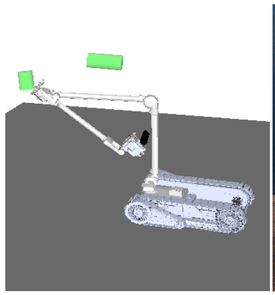


Within OpenRAVE, users can see the field of view of the PackBot camera or the additional 3D sensor



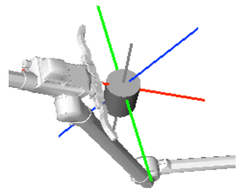
A separate window displays the video stream from two cameras on the robot

Grasping



OpenRAVE plans a grasp

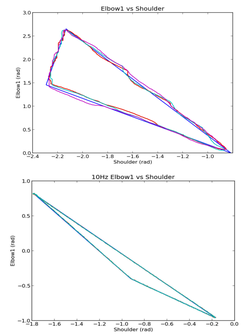
PackBot executes the same grasp



A visualization of our grasp optimization strategy

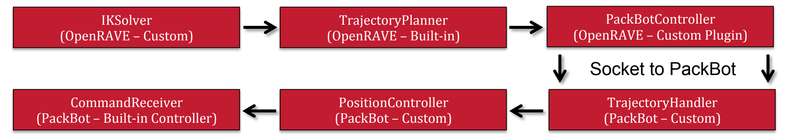
Database Size	Lambda	Jacobian	Success Rate
2,000	.95	Multi	3%
2,000,000	.90	Single	16%
2,000,000	.95	Single	27%
2,000,000	.95	Multi	34%
2,000,000	.99	Single	50%
3,000,000	.95	Multi with optimization	84%
3,000,000	.99	Multi with optimization	97%

Results from testing several iterations of our IK Solver in simulation



Trajectory-following accuracy before and after we implemented a controller

Trajectory Planning & Execution



Results

- Generated trajectories in simulation and precisely executed them on the PackBot
- Recognized cylinders and obstacles and imported them into OpenRAVE
- Successfully grasped cylinders and avoided obstacles
- Demonstrated how OpenRAVE can be used to develop autonomous or semi-autonomous manipulation functionality

ARC LAB
Autonomous Robotic Collaboration