Report for CS 6751, Spring 2017
Grasping and Prehensile Manipulation Project

Vighnesh Vatsal

Sibley School of Mechanical and Aerospace Engineering
Cornell University

1 Introduction

2 Literature Review

Grasping end-effectors are one of the most commonly employed manipulation tools in robotic arms. Most literature on grasping-based manipulation [11] considers the scenario in which the robotic arm firmly grips the object, immobilizing it and making it a part of the arm. To place the object in its desired goal configuration is then considered to be a path-planning problem in the C–space of the robotic arm [3], which has been augmented with the grasped object.

On the contrary, humans tend not to manipulate objects in their environment with only pick-and-place style grasping. For instance, to move a box across a table, one may slide it over the surface by pushing [4]. This form of motion is termed as *prehensile* manipulation. In this class of motion, the object is not assumed to be an extension of the manipulator. Based on the geometry of the object and the robot's end-effector, we can identify configurations that either completely immobilize an object (grasps), or constrain it in such a way that it cannot escape to infinity, but is not completely immobilized (cages). The full geometric framework for these conditions is presented in [12].

Broadly, we can distinguish between control and planning for manipulation tasks. Planning methods take the full plan of action into account, generally simulating the whole process offline to check for conditions of feasibility and optimality [9] of the motion. Control-oriented approaches tend to be real-time, sensor feedback-based methods that aid in the performance of the motion at an implementation level [5], generally ensuring local optimality. Task Frame representational approaches [10], and methods involving friction and physics modeling [4] tend to fall into this category.

This project is aimed at developing a manipulation planner for a robot arm that uses the motion primitives of grasping, caging, and pushing, along with arm translation and rotation. Thus far, most prior work on planning has assumed the grasping primitive to be true, thus reducing the problem to finding a path in C–space of the robot. One such set of algorithms distinguishes between *transit* paths, where the object is not in contact with the robot, and *transfer* paths, where the contact is achieved [1]. In the interim of switching between these two modes, it is assumed that an immobilizing grasp can be found. Work specific to prehensile motions (caging, pushing) includes efforts to geometrically model a pushing motion to facilitate a grasp [8], and caging-specific tree-search based algorithms [6]. There have also been efforts to incorporate object physics, friction and mechanics modeling for highly dynamic motion plans that allow for the object to move as an independent object during the plan [7]. Finally, there are task-space based planners that assume a quasi-static motion of objects, while taking into account the uncertainty in their position, implemented using an RRT-based search [2].

I aim to extend the state of the art by generating a planner that can switch between pushing, caging and grasping based on the environment and goal for a particular prismatic object. At present, tree-search and probabilistic roadmap [9] based approaches are being explored where the switching condition emerges as a consequence of a suitable search heuristic cost function.

3 Technical Contribution

Kinect gives position, orientation of pipe. Then specify end goal position and orientation. Then run three parallel PRM* trees with motion primitives, apply motion with lowest cost based on heuristic. Switch between motions when one cost becomes lower than others, or other two become intractable, like pushing or caging when lifting up. Testing remains to be done.

References

1. Alami, R., Laumond, J.P., Siméon, T.: Two manipulation planning algorithms. In: WAFR Proceedings of the workshop on Algorithmic foundations of robotics. pp. 109–125. AK Peters, Ltd. Natick, MA, USA (1994)
2. Berenson, D., Srinivasa, S.S., Kuffner, J.J.: Addressing pose uncertainty in manipulation planning using task space regions. In: Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on. pp. 1419–1425. IEEE (2009)
3. Brock, O., Kuffner, J., Xiao, J.: Motion for manipulation tasks. In: Springer Handbook of Robotics, pp. 615–645. Springer (2008)
4. Chavan-Dafle, N., Rodriguez, A.: Prehensile pushing: In-hand manipulation with push-primitives. In: Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on. pp. 6215–6222. IEEE (2015)
5. Dafle, N.C., Rodriguez, A., Paolini, R., Tang, B., Srinivasa, S.S., Erdmann, M., Mason, M.T., Lundberg, I., Staab, H., Fuhlbrigge, T.: Extrinsic dexterity: In-hand manipulation with external forces. In: Robotics and Automation (ICRA), 2014 IEEE International Conference on. pp. 1578–1585. IEEE (2014)
6. Diankov, R., Srinivasa, S.S., Ferguson, D., Kuffner, J.: Manipulation planning with caging grasps. In: Humanoid Robots, 2008. Humanoids 2008. 8th IEEE-RAS International Conference on. pp. 285–292. IEEE (2008)
7. Dogar, M., Hsiao, K., Ciocarlie, M., Srinivasa, S.: Physics-based grasp planning through clutter (2012)

8. Dogar, M.R., Srinivasa, S.S.: Push-grasping with dexterous hands: Mechanics and a method. In: Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on. pp. 2123–2130. IEEE (2010)
9. Kavraki, L.E., LaValle, S.M.: Motion planning. In: Springer handbook of robotics, pp. 139–162. Springer (2016)
10. Prats, M., Sanz, P.J., Del Pobil, A.P.: A framework for compliant physical interaction. Autonomous Robots 28(1), 89–111 (2010)
11. Prattichizzo, D., Trinkle, J.C.: Grasping. In: Springer handbook of robotics, pp. 955–988. Springer (2016)
12. Rodriguez, A., Mason, M.T., Ferry, S.: From caging to grasping. The International Journal of Robotics Research 31(7), 886–900 (2012)