POOP SCOOP: Perception Of Offensive Products and Sensorized Control Of Object Pickup

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I. Introduction

Thus far, the most compelling applications for robotics are for "dirty, dangerous, dull, or inaccessible tasks." These robotic applications are traditionally thought of as being limited to settings that are exotic for most people, e.g. nuclear plants, battle fields, factory floors, space. However, the decreasing cost of robotic systems and their increasing capability allows for robotics to find applications in more common settings, such as our homes. One application that seems particularly promising for mobile manipulators, such as Willow Garage's PR2, is the common household task of clearing areas of Potentially Offensive Objects for Pickup (POOP). This task is well known for being "dirty, dull, and occasionally dangerous," and it certainly can make areas of our home "inaccessible."

The problem we are targeting is a scenario commonly found in our own backyards. More specifically, we are all well aware of fields covered in POOP that are in need of clearing before we can walk through them comfortably again. Our goal is to develop a routine for the PR2 in which it can autonomously clear a fenced off area of all POOPs. The routine describes a three stage process. The procedure includes an *identification* stage in which the POOPs are identified and indexed, then an *approach* stage, when the robot approaches the POOP and finally a *removal* stage in which it scoops the POOP to be discarded later. In the future we plan on preceding this three stage method with an *exploration* phase. Also, POOP can take a variety of forms. While the perceptual solution proposed in this paper is limited to POOP of a specific nature, the routine can easily be adapted to include other forms of POOP such as, litter and toys.

II. System Architecture

A. Detection & Localization

To identify POOPs we rely on a simple color blob detection algorithm. We use the high-resolution Prosilica camera in the PR2's sensor head because of the quality of colors it captures when compared to the stereo pairs. The perception system runs at camera rate (we are limited by the Prosilica frames being delivered at 2.5 Hz). We convert the rectified image to the HSV color space, then we mask out specular reflections, adaptively threshold the grass, and recursively threshold POOP colored pixels. We then find connected components of POOP and filter them based on their size in the image. Finally, we assume the POOP is on the ground, compute how far away it is using the robot pose, and filter based on approximate actual size. Refer to Figure 2 for results.

To localize the POOPs, we do a simple transformation from the image frame of the camera to the *base link* frame of the robot. We experienced some trouble achieving precise localization this way. We suspect that the Prosilica camera has not yet been calibrated and a simple recalibration can fix this problem.

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Fig. 1. Graspy is saddened as he realizes he has to cancel the weekly PR2 soccer game because there are too many POOPs on the field.

B. Navigation

For navigation we used the *Navigation Stack* that was written by Eitan Marder-Epstein at Willow Garage. After all of the POOPs that are in the robot's field of view are localized on the map, they are sorted based on their distance from the robot. A goal position is then computed for the robot, that would put it within arm's reach of the nearest POOP. The goal position is then sent off to *move base* and it subsequently plans a path and steers the robot along it.

We found the interface to *move base* to be very simple and convenient, however we experienced bizarre behavior by the robot after it achieved the xy portion of the goal pose and before it snapped to the desired yaw angle, θ_{goal}. In such a case, the PR2 would spin in place for a while before settling at the goal. Oddly enough, the PR2 would usually initiate the spinning in a direction leading it away from the θ_{goal}.

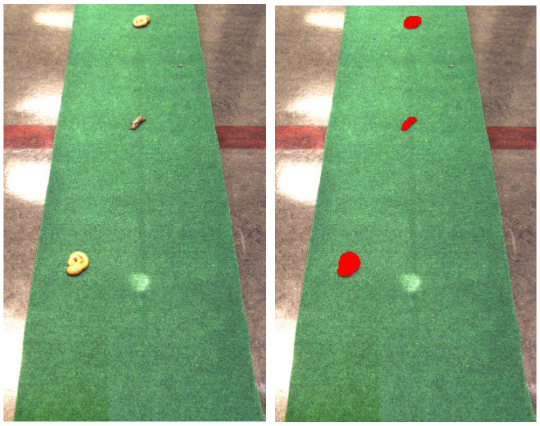

Fig. 2. On the left is a simulated grassy environment. The right image shows the identified POOPs in red.

C. Scooping

The arms begin in tucked positions to the side of the robot. The right arm wields a large commercial scooper, which was modified to have flat surfaces to facilitate stable grasping by the robot's grippers (See Figure 3). The left arm holds a bucket into which the POOPs are deposited after pickup. The arm scooping motion is defined as a set of recorded joint configurations which are fed into the joint trajectory action server. This motion is designed to scoop a POOP that is in a given location relative to the robot. However, if the base is unable to accurately position itself, the arm motions are automatically adapted to compensate for error in base positioning. The scooping motion begins by moving the right arm out of it's tucked position to a position in front of the robot. The scooper is then opened and lowered to the ground around the POOP. The gripper's accelerometer signal and the position error of the arm controller are monitored to detect when the scooper has hit the ground. The scooper is then closed, and raised up. The left arm moves the bucket out of it's tucked position and the scooper is opened to drop the POOP into the bucket. The left gripper acceleration signal is monitored to determine whether or not the POOP was successfully dropped into the bucket. If the expected acceleration signal does not occur, the PR2 realizes that it failed to achieve it's goal and tries again. The fingertip pressure sensors are used to force control the grippers so that the robot maintains a stable grasp on the scooper throughout the motion.

Fig. 3. The modified scooper.

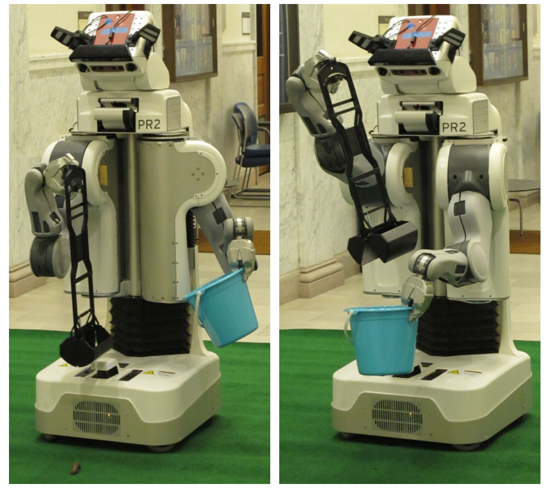

Fig. 4. The PR2 begins the scooping motion on the left. On the right, the final stage of the motion is shown.

III. Experimental Results

The work presented here was performed over a "weekend hack-a-thon." In the attached video you can see our preliminary results. The video shows that we were successful in scooping four POOPs, however the robot was aware of their locations a priori due to problems with the POOP localization. Given the predetermined locations within a 12ft by 12ft area, we found that the PR2 was able to scoop up the POOPs at an average rate of 1.6 POOPs per minute (ppm). The main bottleneck in achieving our original goal of 1ppm, is odd behavior by the Navigation Stack in which the PR2 would spin in place after approaching the POOP. We feel that with some tweaking, we can reduce the amount of spinning.

Despite not having met all of our goals over the weekend, we are hopeful that with a couple of days work we can complete the project as planned. We are planning on completing this work in time for a live demonstration at the workshop.