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# Push Planning for Object Placement in Clutter Using the PR-2

Victor Emeli Charles C. Kemp Mike Stilman

## I. INTRODUCTION

The goal of this project is to investigate the implementation of a planning algorithm for the problem of placing objects on a cluttered surface with a PR-2 mobile manipulator. The original push planning algorithm [1] was initially developed as a simulation. We modified the simulator for execution in real-world cluttered environments. This paper discusses the challenges of implementation and presents empirical results that determine how well the simulator models the real world as clutter is pushed and collides with other objects.

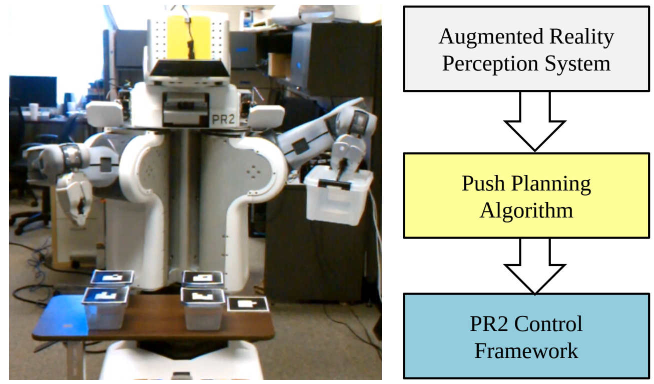
Within recent years, there has been more attention directed towards picking up and placing objects on surface with increased levels of natural clutter [1], [2], [3]. The presence of clutter is very prevalent in real-world environments. Algorithms that work well at grasping and placing objects in controlled environments, often fail once applied to a real-world scenario. The classical motion planners that work well in the laboratory either require sparsely populated tables in order to perform reliable picking and placing tasks or assume that other objects (clutter) are off limits and cannot be manipulated in order to accomplish a task. This does not scale well in the real-world, and does not resemble how humans interact with their environment on a daily basis.

The push planning algorithm [1] implemented on the PR-2 in this paper addresses the problem of placing objects on a cluttered surface, where non prehensile push actions may be able to create space for the object. These actions may also result in collisions between objects that make up the clutter, which are modelled using a 2D physics engine. The algorithm has two main components. The first is a planner that selects a sequence of pushing actions to clear a space large enough to place the target object. The second is a heuristic that guides search by finding candidate placements that are likely to yield simpler manipulation plans. We investigated the implementation of this push planning algorithm on the Willow Garage PR-2 (Fig. 1a).

## II. TECHNICAL APPROACH

The implementation uses an augmented reality based perception system, a modification of the original push planning algorithm, and a framework to control the pushing and placement actions of the PR-2. The flowchart (Fig. 1b) illustrates the interaction between each system component. We describe each of these components in the following subsections:

The authors are affiliated with the Center for Robotics and Intelligent Machines (RIM) at the Georgia Institute of Technology, Atlanta, Georgia 30332, USA. Emails: ve7@gatech.edu, charlie.kemp@bme.gatech.edu, mstilman@cc.gatech.edu




(a) PR2 Near Cluttered Table. (b) System Components.

Fig. 1. PR2 Implementation of Autonomous Clutter Clearing.

### A. Augmented Reality (AR) Perception System

The clutter objects are plastic Tupperware containers with circular and square shapes. We affixed the top of the containers with physical markers (AR tags) which enabled convenient identification, location, and pose information. Specifically, the system uses the ROS wrapper of the artoolkit provided as open source from the ccny-ros-pkg repository. This feature is used to overlay the virtual coordinate frame of each clutter object, which is visible through a ROS visualization application (rviz). A 6D marker tracking system provides all the positional and quaternion parameters.

We used the Kinect sensor from Microsoft to capture the AR tags in the environment. The Kinect captures the location of the AR tags, which can be represented relative to any frame that is tracked by the robot. Figure 3 shows an example of a table with AR tag enhanced clutter objects. The AR tag

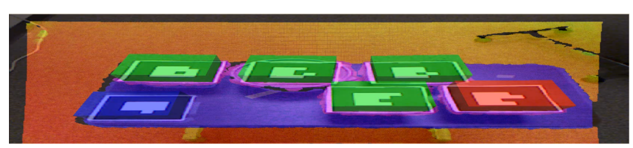


Fig. 2. AR visualization

in the lower left corner of the table (Figure 3) represents the coordinate location that all clutter objects will use as an offset. The clutter and table pose will be provided as input to the push planning simulator in order to model the table and objects.

### B. Push Planning Algorithm

We also modified the push planning simulator[1] to read in parameters from the AR system in order to create a 2D representation of the table and clutter objects. Modifications to how the simulator represents the coordinates for gripper placement, object placement, push distance and angles were performed to scale the system for execution on the PR-2. We compiled these parameters into a series of step-by-step end-effector motions that result in a series of push and place actions. This constitutes the plan that is supplied to the PR-2 Control Framework.

Figure 4 shows our simulated model of the table environment autonomously generated by the AR system (Fig. 3):

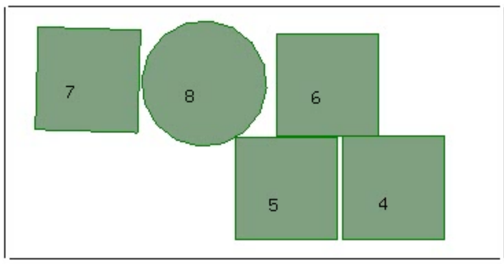



Fig. 3. Push planner simulator.

### C. PR-2 Control Framework

The PR-2 utilizes its right arm to perform the linear push actions on the clutter objects. These actions are executed with the gripper fingertips perpendicular to the surface of the table and with a push angle ranging from 0 to 360 degrees. The PR-2 uses the left arm to position the designated placement object onto a cleared area on the table surface and is the last action that is executed in a given plan. The software used to control the arms is based on the move_arm package available in ROS.

A successful push action requires an orientation constraint on the right arm. The pitch of the gripper is constrained to 90 degrees at all times. This enables the gripper to easily position itself between various objects on the table and replicates the modeled environment of the world in the simulator. A second constraint on the elbow position of the right arm is also required. To prevent the elbow from making contact with the table or other objects on the table, a position constraint is set to keep the elbow as high above the gripper as possible.

The move_arm package uses collision avoidance to enable collision-free motion planning. Since this project entails performing push actions that require the gripper to make contact with objects, we modified the motion planner's parameters to only allow collisions between the right gripper and the rest of the world. The PR-2 uses the left arm to place objects in the cleared space. So in order to achieve proper placement, the motion planner's parameters were also modified to allow the left arm and gripper to collide with the rest of the world.

## III. Experimental Design

This project investigates the real world implementation of a push planner for object placement in a cluttered environment. Given a gripper position, orientation, and push distance, the PR-2 will attempt linear pushes in a direction that is always normal to the plane of the table. This motion reflects the push motions performed in the simulation that produces the plans for the PR-2. The PR-2's left arm is used to set down objects designated for placement.

Ten randomly positioned clutter configurations consisting of Tupperware were presented to the PR-2 in succession. We measured how many successful placement runs were achieved during these trials. We define failure to be when the gripper either makes contact with a clutter object or the table before attempting a pushing motion or the said motion drives an object off of the table.

An example of the different configurations are illustrated in Figure 5. The AR tag in the lower left hand corner is used to track the table. The same placement object was used on

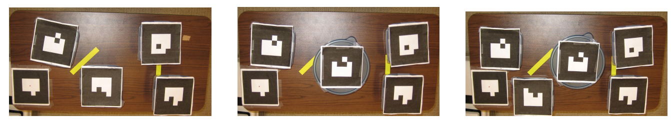


Fig. 4. Clutter configurations.

every trial run. It was a large rectangular container with a graspable handle. In order to compensate for variance in the grip, the placement object dimensions were grown by 10 % in the push planning simulation.

## IV. Results

There were 10 out of 10 successfully executed push and placement plans. The collisions between two objects were modelled well within the simulator. The collisions between three objects varied slightly from what was modelled in the simulator but did not affect the success of the plan. Modifying the parameters that dictate the density of the objects, friction between the object and surface, and the linear and angular damping may allow the simulator to better model the real world. The PR-2 did not execute push motions of 1 cm or less. It just lowers its end-effector and then lifts it back up. During the execution of one of the plans, the right elbow of the PR-2 came into contact with one of the clutter objects, but it did not alter the outcome of the plan.

## V. Conclusion and Future Works

This project investigated the implementation of a push planning algorithm in the real-world using the PR-2. We demonstrated a high success rate for plan execution using simple objects and AR-tag based perception. The PR2 successfully pushed clutter out of the way and placed the container on the table. Future work will include using point cloud segmentation and object recognition to increase the autonomy of the system.

## References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