Using Contacts During Robot Manipulation to Map and Reconstruct a Scene

Joao Bimbo
Universidade Lusofona de Humanidades e Tecnologias
Lisboa, Portugal
Email: joao.bimbo@ulusofona.pt

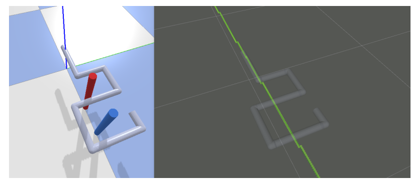
Andrew S. Morgan and Aaron M. Dollar
Yale University
New Haven (CT) USA
Email: {andrew.morgan;aaron.dollar}@yale.edu

***Abstract*—Robot grasping and manipulation in real world scenarios typically imply *i)* objects of unknown shape, *ii)* cluttered, unstructured settings with a high degree of uncertainty, and *iii)* contacts between the grasped object and obstacles in the environment. In this paper we present an approach to reconstruct the shape of a grasped object and map the environment by measuring the contact forces while a robot tries to retrieve an object from a scene. We use a probabilistic approach that computes the probability of occupancy of two 3 dimensional maps (one for the grasped object and one for the environment), where the update on each map informs the construction of the other. Our method relies only on the force and torque measurements from the robot end-effector to find the line of action of the interaction forces, compute the possible contact locations and populate the two occupancy maps. Here we present our method, that we named SMORE (Simultaneous Mapping and Object Reconstruction), and discuss some future developments of this approach.**

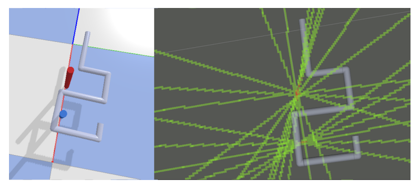
I. Introduction

When robots operate outside laboratories and factories, in scenarios such as our homes or the outdoors, there is an inherent uncertainty that comes with being in these unstructured environments. This uncertainty brings about a number of difficulties and challenges when a robot has to grasp and manipulate objects. In these tasks, there is typically limited *a priori* knowledge on object properties, such as its friction, mass, and even its shape, as well as the shape of the environment (map). Then, as the robot interacts with the world, there is a high chance of unexpected collisions between robot and environment or between the grasped object and the environment. It is also important to note that in some scenarios the usage of computer vision may be limited, particularly when there is a significant amount of clutter and disarray. In these situations, other sensing modalities such as tactile and force sensing can be useful to obtain information relevant to the task.

Here we detail a method that uses the force measurements when a grasped object collides with obstacles in the environment while trying to retrieve it, to simultaneously reconstruct the shape of the object and the obstacles in the environment. This method populates two 3D maps with the probability that the voxels are occupied and, as we learn more about one of the maps (object or environment), so it becomes easier to construct the other. We devised two probability laws to update the maps: one is applied when a contact is detected, the possible contact locations are computed and the voxels along that line are updated; the second probability law is applied when there is no force detected, and so the object is not in contact with an obstacle. We consider an application of our method, where an object of unknown, complex shape, is "tangled" with obstacles in the environment. The system repeatedly attempts to retrieve the object by planning a collision-free path with its current knowledge of the object and map geometries. As it fails to retrieve the object and hits the obstacles, the maps are constructed and refined until enough of the object and obstacles is known to achieve a successful retrieval. This method was previously presented in [1], and here we discuss some of the limitations and future possibilities of this work.



(a) Discretization along the force line-of-action $\mathcal{L}$



(b) Obstacles are detected after a number of contacts

Fig. 1. Simulated environment: S-shaped object and two vertical peg obstacles. (a) Collisions between the object and an obstacle generate a force, and its line-of-action can be computed. (b) As multiple collisions occur along different line-of-actions, we can probabilistically determine the occupancy probability.

II. Methods

The proposed method builds and populates two 3D maps: $\mathcal{M}_w$ maps the environment and is attached to a fixed frame, and $\mathcal{M}_o$ moves with the robot end-effector describes the shape of the grasped object. The occupancy of each voxel is updated sequentially and taking into account the current probabilities. When a collision is detected, the occupancy probabilities increase for the possible contact locations, while the opposite occurs when the robot is moving in free space without hitting an obstacle.