Contact detection and location from robot and object tracking on RGB-D images

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I. Introduction

In this work, we address the problem of detecting contacts between a robot hand and an object during the approach and execution phases of manipulation tasks in the absence of touch perception. In order to detect contact in such conditions, we implemented a method which uses the visual tracking of objects using ICP (Iterative Closest Point) to detect small movements of the object's RGB-D point-cloud which has been previously segmented. Once a movement has been detected, a combination of a 3D occupancy grid of the object and an sphere-based model of the robot is used to probabilistically estimate the locations of contacts.

II. Approach Description and underlying assumptions

We propose a novel virtual contact sensor which uses exclusively RGB-D images, without the help of any touch sensors. The whole process is divided in several steps:

1) On the first step the object point cloud is segmented from the whole scene using a spherical geometric modelling of the robot, once object point cloud is segmented we create a occupancy grid map (OGM) with the camera occluded area.
2) On the second step, the object point cloud is tracked using an ICP approach in order to detect any relevant movement, if there is no contact the cells of OGM that intersect with the hand model are labelled as free cells. As soon as a movement is detected a probability estimator is used to update the occupancy grid of the object and to detect the most likely locations where the contact has happened.

Our approach assumes that a single rigid object lying on a planar surface. No previous model of the object is available and no assumptions about its shape or aspect are made.

The only sensor modality that our approach is going to use is a *Kinect* sensor which delivers RGB-D images and point clouds describing the scene. Assumptions are made that the kinematics of the arm and hand are known and the correspondence between coordinates of the scene point-cloud and the frame of the robot arm are calibrated accurately.

III. Experimental Results

Our robot platform is an upper body humanoid composed of two 7 DOF robot arms, a Schunk Dextrous Hand with 7 DOF, equipped with a JR3 Force-Torque sensor on the wrist. The hand has three fingers, each with 2 DOF and two Weiss tactile sensors. The vision system is composed of a pan-tilt head with a *Kinect* sensor. For our experiments, the force-torque sensor has not been used and the tactile sensors have been only used to provide ground truth validation data.

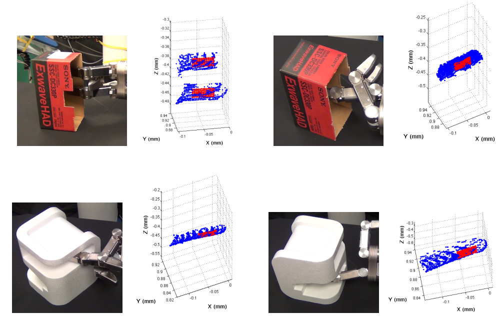

Fig. 1. Contact Estimation Validation

Two validation experiments have been implemented. The first one seeks to demonstrate that our approach is more sensitive than the real tactile sensors. The second one evaluates our approach for estimating contacts with occluded parts of non convex objects. The objects used for validation are: a very light object with a non-trivial shape and an empty light cardboard box.

Figure 1 shows the results of the second experiment (to see both experimetns visit http://youtu.be/CdTDnyKb5P8). The graphs in the right of each figure show the estimated contact locations (in blue) and real contact tactile readings (in red). The 3D positions of the tactile readings are reconstructed using the known kinematics and configuration of the robot. As it can be seen, the proposed estimator is able to detect accurately the contact locations.

IV. Discussion

We present a first implementation of a contact sensor based exclusively on visual information. This has never been demonstrated to the knowledge of the authors. The experiments have shown that the visual sensors can provide information that touch sensors are unable, i.e.: contacts with light objects, or on not-sensorized surfaces. An important improvement is to design schemes to integrate visual and touch modalities of contact detections, in order to design more robust manipulation controllers. Also we can use the OGM to obtain a rough model.