Model-free tactile manipulation with a 3d-printed gripper

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Abstract—The use of tactile feedback for precision manipulation in robotics still lags far behind human capabilities. This study has two principal aims: 1) To demonstrate in-hand reorientation of grasped objects through active tactile manipulation. 2) To present the integration of a novel TacTip-GR2 sensor and gripper platform for tactile manipulation. Through the use of Bayesian active perception algorithms, the system successfully achieved in-hand reorientation of cylinders of different diameters (20, 25, 30 and 35 mm) using tactile feedback. Average orientation errors along manipulation trajectories were below 5° for all cylinders. Our model-free methods for active tactile manipulation with the GR2 TacTip gripper can be used to investigate principles of dexterous manipulation and could lead to essential advances in the areas of robotic tactile manipulation and tele-operated robots.

I. INTRODUCTION

In robotics, tactile information is likely essential for any fine manipulation task [2], as it provides clues to the shape, texture, in-hand position and orientation of a grasped object. Complex tactile manipulation is still an area in which humans vastly outperform robots.

Our aims here are two-fold: 1) To demonstrate in-hand tactile reorientation of grasped objects through in-hand manipulation. 2) To present the novel integration of a tactile sensor and gripper system for tactile manipulation.

Tactile reorientation is tested by manipulating cylinders along a trajectory of target orientations. This reorientation is performed on a hardware platform for tactile manipulation consisting of a novel tactile sensor integrated into the GR2 (grasp-reposition-reorient) gripper [4] (Fig. 1).

Overall, we found that accurate reorientation of objects along complex trajectories was successfully achieved through active tactile manipulation (average error in trajectory was below 5° for cylinders of diameters 20, 25, 30 and 35 mm).

Our methods for model-free active tactile manipulation with the GR2 TacTip gripper can be used to investigate principles of dexterous manipulation and could lead to essential advances in robotic tactile manipulation and tele-operated robotics.

II. METHODS

A. Hardware

The TacTip-GR2 is a soft, cheap, robust, 3D-printed optical tactile sensor based on the TacTip [1]. It is straightforward to manufacture and is made up of 3 main parts (Fig. 2):

a) The skin: This soft membrane comes into contact with objects. It has small (1 mm dia.) white-tipped pins on its inside surface, separated from each other by 4 mm. It is 3d-printed (TangoBlack+) and filled with silicone gel (RTV27905, Techsil, UK) which gives the sensor its compliance.

b) The base: This 3D-printed part holds an LED circuit to illuminate the pins, as well as a 1 mm thick acrylic lens to separate the contact area from fragile electronic parts.

c) The camera: We use a Raspberry Pi camera (Adafruit, Spy Camera Module) with a fisheye lens to image the internal pins as the sensor surface deforms.

The TacTip-GR2 integrates with the GR2 gripper [4] (Fig. 1), designed for in-hand reorientation of grasped objects. Experimental stimuli are 3D-printed ABS plastic cylinders of diameters 20, 25, 30 and 35 mm.

B. Data collection and processing

1) Data collection: The full range of motion of the GR2 gripper is separated into 40 discrete positions, with 10 frames collected from both TacTip-GR2s at each position. Captured images are then processed in Matlab to find the x- and y-coordinates of the pin centres in each frame. Object orientation is measured optically and used as a measure of the object’s in-hand location.
A. Validation - Object localization

For initial localization validation, we gather fifteen datasets with the cylinders of 20, 25, 30 and 35 mm diameters over their respective orientation ranges (Table I). Ten are considered training sets, and 10000 data points are sampled randomly from the remaining five test sets with a Monte Carlo procedure to obtain average localization errors $e_{\theta}(\theta)$ at each location.

We achieved accurate localization with all four cylinders over their respective orientation ranges (Table I), with an average localization error below 0.4° for each cylinder (Table I). Accuracy is moderately higher for larger cylinders with a reduced range of orientations (Table I).

TABLE I: Orientation ranges and average localization errors.

<table>
<thead>
<tr>
<th>Cylinder size</th>
<th>20 mm</th>
<th>25 mm</th>
<th>30 mm</th>
<th>35 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$ range (°)</td>
<td>-34.4 to 32.3</td>
<td>-26.9 to 26.0</td>
<td>-23.9 to 22.4</td>
<td>-21.8 to 20.6</td>
</tr>
<tr>
<td>$e_{\theta}$ (°)</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

B. Active manipulation

The manipulation trajectory spans 200 moves of 1 sec. each, and is shaped as a sinusoidal with varying amplitude (Fig 3). Active manipulation is successfully performed with each of the four cylinders of varying diameters. Orientation errors $e_{\theta}$ over the manipulation trajectories are averaged over each cylinder’s five runs and all fall below 5° (Table II). The manipulation trajectory is displayed as an average over 5 runs for the 20 mm cylinder (Fig. 3) as it is actively reoriented across its given range (Table II).

TABLE II: Active manipulation errors.

<table>
<thead>
<tr>
<th>Cylinder size</th>
<th>20 mm</th>
<th>25 mm</th>
<th>30 mm</th>
<th>35 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{\theta}$ (°)</td>
<td>3.9 ± 0.2</td>
<td>4.8 ± 0.2</td>
<td>4.2 ± 0.2</td>
<td>4.3 ± 0.2</td>
</tr>
</tbody>
</table>

IV. DISCUSSION

This study describes the successful implementation of model-free active tactile manipulation on a novel tactile GR2 gripper [4]. We demonstrated this system is capable of precise tactile reorientation of grasped objects of different sizes. Average manipulation errors were kept below 5° for all cylinders.

An extension to this work could involve the addition of object recognition within the perception algorithm. This would allow the gripper to perform simultaneous object localization and identification of objects being manipulated, creating a more versatile and autonomous gripper. It would also be straightforward to investigate the effect of the sensor’s shape and size on manipulation capabilities. This work could further be extended by adapting the TacTip for use on more complex robotic hands.

Our methods for model-free active tactile manipulation on the GR2 TacTip gripper platform can be used to investigate principles of dexterous manipulation and could lead to essential advances in robotic tactile manipulation and tele-operation.

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REFERENCES


