Tactile Localization for unknown and known objects

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The lack of tactile reasoning still remains one of the main limitations of dexterous robotic manipulation, and a long-standing challenge in the robotics community. Even after decades of advances in sensing instrumentation and processing power, the basic question remains: How should robots make use of sensed contact information?

To address this question, our work builds from a recent interest in image-based tactile sensors such as GelSlim [1] or GelSight [2] which, by using a soft gel skin and a camera as transducer, achieve very high spatial acuity and pressure sensitivity, yielding highly discriminative tactile signals.

We exploit the discriminative power of tactile sensing by presenting two different approaches to tactile localization that depend on whether the manipulated objects are known or not.

A. *Tactile localization of unknown objects*

Our first approach to tactile localization [3] tackles the case where the geometric model of the object is not available, but we can exert controlled touches at it which allow us to build a tactile model of the object. With this method, we demonstrate that we can combine tactile imprints with robot kinematics to first build a tactile map of an object and then use it for localization. The approach relies on 3 contributions:

1. Local shape estimation: we use *tactile imprints* to estimate the shape of the contact patch using CNNs. This approach can achieve sub-millimeter accuracy.
2. Global tactile mapping: we fuse the tactile imprints and the kinematics of multiple grasps of a fixed object to reconstruct its global *tactile shape*. This includes the object geometric shape as well as a discrete representation of its tactile imprints.
3. Object tactile localization: Fig. 1 illustrates how we combine tactile imprints with an estimation of the shape of the contact patch to localize a grasped object. Our ICP-based algorithm uses tactile imprints for coarse data association, and contact shape for fine refinement.

The main limitation of this approach is that the accuracy is of the localization is highly dependent on the accuracy of the tactile map. Thus higher localization accuracy requires a more exhaustive tactile exploration of the object.

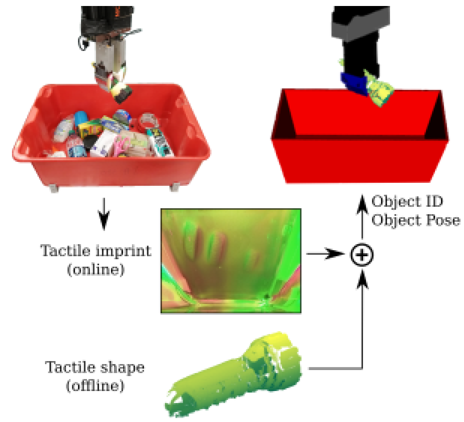

Fig. 1. **Tactile localization for unknown objects.** For unknown objects, in-hand object localization is based on matching the new tactile imprints (online) to a precomputed (offline) tactile map of the object.

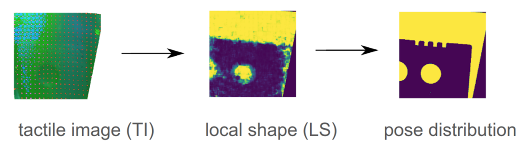

Fig. 2. **Tactile localization for known objects.** For known objects, we can compare the obtained local shape from a tactile imprint to the local shapes given by the geometric model of the object.

B. *Tactile localization of known objects*

Our current work aims to perform tactile localization when the geometric model of the object is available. This allows to bypass the need to build a tactile map for each object which is expensive and requires very precise calibration during the tactile exploration of the object. Moreover, by relying on the geometric model, our approach can do *zero-shot* localization, i.e., estimate the pose of a novel object without having to rely on any tactile information from it.

As depicted in Figure 2, this approach is based on: first, given a new tactile imprint, we compute the local shape of the touched object at contact using the local shape estimator in Section A. Then, by using the geometric model of the object, we compare the obtained local shape to the possible local shapes of the object and select the most similar one to estimate its pose.

Our tactile localization method for known objects can be easily extended to include visual information and multiple contacts by restricting the set of possible local shapes that can be compared to the one coming from the tactile imprint.

References

[1] E. Donlon, S. Dong, M. Liu, J. Li, E. Adelson, and A. Rodriguez, "Gelslim: A high-resolution, compact, robust, and calibrated tactile-sensing finger," *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2018.

[2] W. Yuan, S. Dong, and E. H. Adelson, "Gelsight: High-resolution robot tactile sensors for estimating geometry and force," *Sensors*, vol. 17, no. 12, p. 2762, 2017.

[3] M. Bauza, O. Canal, and A. Rodriguez, "Tactile mapping and localization from high-resolution tactile imprints," *arXiv preprint arXiv:1904.10944*, 2019.