Grasping on Contact Primitives by Fingertip Surface Optimization

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I. Problem Statement

Grasping is an essential ability that enables the robot to physically interact with the world. Contact-based grasping, which explicitly considers the contacts made by a grasp, has been widely studied to address various aspects of grasping. Contact modeling is one of the basic building blocks for the research of contact-based grasping. Depending on the friction and softness at contacts, form or force closure based grasp quality can be calculated in the grasp wrench space. However, it is commonly identified that the analytic contact modeling has two major issues: 1) the point contact model does not precisely reflect the real physics, and 2) it is vulnerable to uncertainties in positioning errors. This line of work has indicated that the modeling of contact geometries for fingertip design can significantly improve grasp stability, as well as improving the robustness against uncertainties. However, it is worthwhile noting that the existing work is infeasible to address novel or a large number of objects.

II. Methodology and Contribution

Although daily objects possess a large variety of global shapes, we identify the fact that most of grasp contacts on daily objects share only a few classes of local geometries, such as edges, corners and curved surfaces etc. To this end, we define the concept of Contact Primitive to represent a set of similar contact local geometries, and optimize the corresponding fingertip surface to maximally mimic each geometry within the Contact Primitive. Given a set of training objects with desired grasp contacts, we provide a uniform cost algorithm to first classify the contacts into a finite set of Contact Primitives, and then design a fingertip for each Contact Primitive. The designed fingertips are 3D printed using soft materials, in order to compensate for the optimization residuals to further maximize contact areas.

Moreover, based on our previous work, we provide a hierarchical algorithm for grasp planning on novel objects to find grasp contacts that match the designed fingertip geometries, while providing stable and reachable grasps. Figure 1 exemplifies our designs on a Baxter gripper, as well as the generated grasp contacts at corresponding Contact Primitives on a novel object. For evaluation, we install the designed fingertips on a Baxter robot and show that it is able to grasp a large set of novel objects. The experiment results indicate that the optimized fingertips significantly improve grasp stability, and that it is more robust against uncertainties.

REFERENCES