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Design and Implementation of an Underactuated and Sensor-rich Gripper

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Abstract—**We report on the design of an underactuated and sensor-rich gripper, which is capable of grasping the shape-unknown objects randomly placed within the workspace.**

I. Introduction

Intelligent manipulation is an interdisciplinary field in between robotics and haptics which has recently received significant attention. Despite computer vision can provide important spatial position and orientation of the object, to robustly manipulate the object still heavily relies on tactile information of the gripper [1]. The Gripper in general is designed in two different approaches: the sophisticated gripper which mimics high degree-of-freedom (DOF) morphology of human, and the underactuated gripper which tries to achieve reliable grasping with simple mechanical structure. The shape and force adaptiveness of fingers allows the gripper to grasp various objects [2]. In addition, this type of gripper is relatively cheap, lightweight, and easy to control in comparison with the fully actuated graspers.

II. Gripper Design

Aiming at designing a gripper with simple mechanical structure yet with robust grasping behavior, the developed gripper has several characteristics: (i) each finger only has one active DOF, but it also has passive compliance which is generated by a torsional spring mounted within the linkage mechanism of the finger. Thus, the finger can smoothly adapt itself to objects with different shapes [3]. (ii) The special mechanism of the fingers allows the gripper to have two grasping modes: "Parallel grasp" where the lower side of the distal phalanx touches the object, and "envelope grasp" where distal phalanx rotates inward and envelopes the objects. The gripper in the former mode can access the object in tight space and that in the latter mode can sustain the object with heavier weight. (iii) The gripper can change two out of three fingers' relative configuration (i.e., separate or close to each other) and operates in either "two-finger" mode or "three-finger" mode (Fig. 1). When the gripper operates in the two-finger mode, it can access the object in tight space or grasp long objects. In contrast, the gripper operating in the latter mode can effectively secure the objects.

On the control side, several sensors are implemented to provide valuable information of gripper status for feedback control. The inner surface of the distal phalanx of the finger is covered with pressure sensors array, and the outer surface and

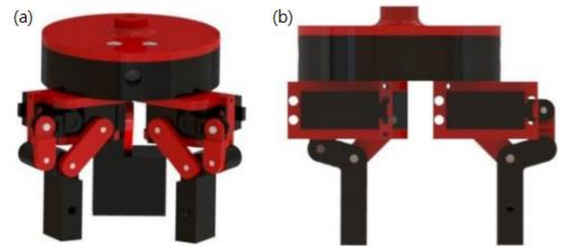

Fig. 1. Two modes of the gripper: (a) Three-finger mode and (b) two-finger mode.

the tip of that is installed with pressure sensors. The accelerometer is embedded inside the distal phalanx of the finger, providing sensitive touch and un-touch information. In addition, several potentiometers are installed to yield the configuration of the gripper.

III. Grasping Strategy

With adequate grasping strategy, the gripper is capable of grasping shape-unknown objects randomly placed within the workspace. In order to experimentally evaluate performance of the system, the gripper is mounted on a 4-DOF SCARA manipulator, and a cylinder is utilized as the object.

The grasping strategy includes three stages: search, move, and grasp. In the search stage, the gripper follows a designed trajectory, and it stops when the contact is detected by either the accelerometer or the pressure sensor. Then, the gripper shifts to the move stage where it moves toward the estimated position of the object. Next, the gripper starts the grasp mode, where the gripper gradually closes to hold the objects until the pressure sensor array senses enough normal forces. Finally, the gripper with the held object is moved to the destination.

IV. Conclusion

The presented gripper has adequate balance of form and function for grasping task. The compliant, underactuated, and shape-changeable fingers allows the gripper to adequately adopt its configuration to the objects with unknown shape. The rich sensory information together with control strategy endows the gripper to adequately hold the unknown objects. We are in the process of implementing the object identification function, which allows us to optimize the grasping configuration to the objects.

References

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