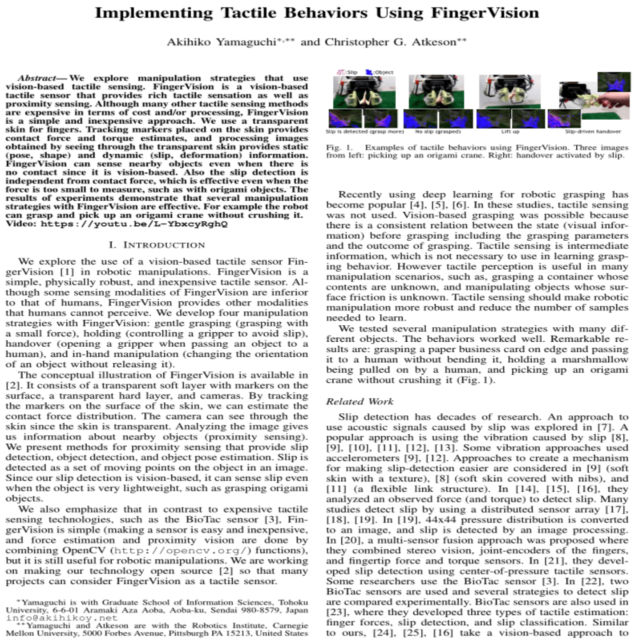
The Visual Neuroscience of Robotic Grasping: Achieving Sensorimotor Skills through Dorsal-Ventral St



Implementing Tactile Behaviors Using FingerVision

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Abstract— **We explore manipulation strategies that use vision-based tactile sensing. FingerVision is a vision-based tactile sensor that provides rich tactile sensation as well as proximity sensing. Although many other tactile sensing methods are expensive in terms of cost and/or processing, FingerVision is a simple and inexpensive approach. We use a transparent skin for fingers. Tracking markers placed on the skin provides contact force and torque estimates, and processing images obtained by seeing through the transparent skin provides static (pose, shape) and dynamic (slip, deformation) information. FingerVision can sense nearby objects even when there is no contact since it is vision-based. Also the slip detection is independent from contact force, which is effective even when the force is too small to measure, such as with origami objects. The results of experiments demonstrate that several manipulation strategies with FingerVision are effective. For example the robot can grasp and pick up an origami crane without crushing it. Video: `https://youtu.be/L-YbxcyRghQ`**

I. INTRODUCTION

We explore the use of a vision-based tactile sensor FingerVision [1] in robotic manipulations. FingerVision is a simple, physically robust, and inexpensive tactile sensor. Although some sensing modalities of FingerVision are inferior to that of humans, FingerVision provides other modalities that humans cannot perceive. We develop four manipulation strategies with FingerVision: gentle grasping (grasping with a small force), holding (controlling a gripper to avoid slip), handover (opening a gripper when passing an object to a human), and in-hand manipulation (changing the orientation of an object without releasing it).

The conceptual illustration of FingerVision is available in [2]. It consists of a transparent soft layer with markers on the surface, a transparent hard layer, and cameras. By tracking the markers on the surface of the skin, we can estimate the contact force distribution. The camera can see through the skin since the skin is transparent. Analyzing the image gives us information about nearby objects (proximity sensing). We present methods for proximity sensing that provide slip detection, object detection, and object pose estimation. Slip is detected as a set of moving points on the object in an image. Since our slip detection is vision-based, it can sense slip even when the object is very lightweight, such as grasping origami objects.

We also emphasize that in contrast to expensive tactile sensing technologies, such as the BioTac sensor [3], FingerVision is simple (making a sensor is easy and inexpensive, and force estimation and proximity vision are done by combining OpenCV (`http://opencv.org/`) functions), but it is still useful for robotic manipulations. We are working on making our technology open source [2] so that many projects can consider FingerVision as a tactile sensor.

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:Slip :Object

Slip is detected (grasp more) No slip (grasped) Lift up Slip-driven handover

Fig. 1. Examples of tactile behaviors using FingerVision. Three images from left: picking up an origami crane. Right: handover activated by slip.

Recently using deep learning for robotic grasping has become popular [4], [5], [6]. In these studies, tactile sensing was not used. Vision-based grasping was possible because there is a consistent relation between the state (visual information) before grasping including the grasping parameters and the outcome of grasping. Tactile sensing is intermediate information, which is not necessary to use in learning grasping behavior. However tactile perception is useful in many manipulation scenarios, such as, grasping a container whose contents are unknown, and manipulating objects whose surface friction is unknown. Tactile sensing should make robotic manipulation more robust and reduce the number of samples needed to learn.

We tested several manipulation strategies with many different objects. The behaviors worked well. Remarkable results are: grasping a paper business card on edge and passing it to a human without bending it, holding a marshmallow being pulled on by a human, and picking up an origami crane without crushing it (Fig. 1).

Related Work

Slip detection has decades of research. An approach to use acoustic signals caused by slip was explored in [7]. A popular approach is using the vibration caused by slip [8], [9], [10], [11], [12], [13]. Some vibration approaches used accelerometers [9], [12]. Approaches to create a mechanism for making slip-detection easier are considered in [9] (soft skin with a texture), [8] (soft skin covered with nibs), and [11] (a flexible link structure). In [14], [15], [16], they analyzed an observed force (and torque) to detect slip. Many studies detect slip by using a distributed sensor array [17], [18], [19]. In [19], 44x44 pressure distribution is converted to an image, and slip is detected by an image processing. In [20], a multi-sensor fusion approach was proposed where they combined stereo vision, joint-encoders of the fingers, and fingertip force and torque sensors. In [21], they developed slip detection using center-of-pressure tactile sensors. Some researchers use the BioTac sensor [3]. In [22], two BioTac sensors are used and several strategies to detect slip are compared experimentally. BioTac sensors are also used in [23], where they developed three types of tactile estimation: finger forces, slip detection, and slip classification. Similar to ours, [24], [25], [16] take a vision-based approach to

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