NailTact: Vision-based Tactile Sensing in Both Fingerpad and Nail

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***Abstract*— When human pick up a relatively small object placed on a flat surface with two fingers, they may not only use the pads of their fingers depending on the size of the object, but may also use their fingernails for small or thin objects. It has been shown that fingertips with a nail structure are effective for picking up objects like this in robot hands as well. Moreover, in actual work, accidental contact between sensors and surrounding objects such as tables often occurs. Sensors with fingernails can avoid this situation in advance by having the fingernails touch the object before the fingertips touch the object. In this work, we present the NailTact, which can detect the force applied to both the fingertip part and the nail part from the same camera image by single-camera. Using the prototype robot finger, we verified the sensor response characteristics to the load on the nail and the sensor response when grasping an object with the nail and the situation when finger makes contact with a table. We also show the angle change of the sensor to use both the nail part and fingertip part to grab objects of different sizes.**

BACKGROUND

Tactile sensors play a pivotal role in modern robotics and human-machine interaction systems. To improve the performance of tactile sensors while reducing costs, a vision-based tactile sensors employing camera have been developed [1], [2]. It can aquire tactile information as image sequence with high spatial resolution, and can measure the force applied to the grasped object while getting the information about the position and posture, and applied to manipulation [3] and inspection tasks [4]. The most of these vision-based tactile sensors have flat or hemispherical sensing surface and are implemented as a finger pad. For some small and thin objects such as cards, chips and so on, it will be difficult to pick them up from the desktop. In human daily life, when encountering this situation, we can use our fingernails to take grasping operations. Even in robotics, robotic finger with nail have been proposed and its effectivity for expanding the range of object to be grasped was shown [5], [6]. However, in such a robotic finger, both or one of the finger pad and nail lack sensing function and can not detect the contact with that. By giving the perception abilities to both the finger pad and the nail, it can be used more effectively similar to that in human. In this work, we propose a robotic finger with nail which has perception abilities both in finger pad and nail, called NailTact. As shown in Fig.1, this robotic finger grasps object with various size using its finger pad and nail, and acquires tactile information in finger pad and nail as an image with single camera embedded in the finger.

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CURRENT RESULTS

In the proposed NailTact, the main idea is to simultaneously acquire tactile information on the pad of the finger and detect the force applied to the nail using a single camera. Fig.2 shows sensing principle for these information. For the pad of the finger, we used a tactile image sensing with reflective membrane method, which has similar structure of sensing surface in [4]. For the nail of the finger, we used a tactile image sensing with marker displacement method. When the force is applied to the finger nail, the nail that attached on the elastomer slightly moves and visual markers (A and B in the figure) also move. By capturing these movement by using a camera placed inside the finger, we can know the force applied to the nail as shown in Fig.4. These tactile images in the finger pad and nail are acquired by the single camera as shown in Fig.3.

We conducted the experiment with marker pen grasping as shown in Fig.5. In the first picture in (a), in the initial state without grasping. When the gripper begins to descend and the nail part touches the table, the marker displacement of the nail part begins to change. In the third picture, after contact with the marker pen and grasping, the displacement of the marker in the nail part changes again. Simultaneously, in the fingertip image, the elastomer on the surface deforms due to contact with the marker pen. By analyzing these changes in the images, we can determine the center of gravity of the clamping position and the marker direction. Finally, as shown in the fourth picture, when the gripper rises, the marker displacement of the nail part changes with a larger displacement.

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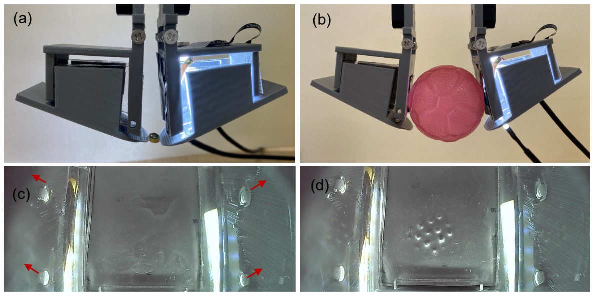

Fig. 1: NailTact grasping capabilities(e.g. small objects like an M3 nut in (a); big objects like clear soccer ball with uneven surface in (b). (c) and (d) are the images from camera by (a) and (b).

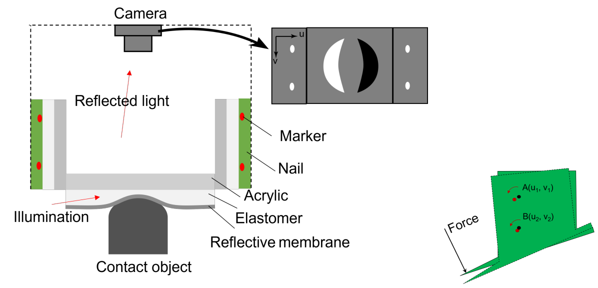

Fig. 2: Sensing principle in finger pad (a) and nail (b).

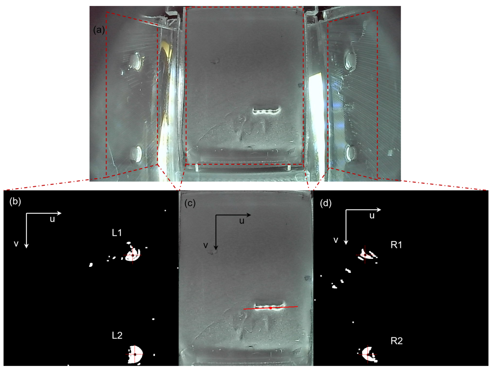

Fig. 3: (a): The image captured by the camera. (b): Binarization and perspective transform of the left side of (a). (c): Calculate the center of gravity and slope for the middle of (a). (d): Binarization and perspective transform of the right side of (a).

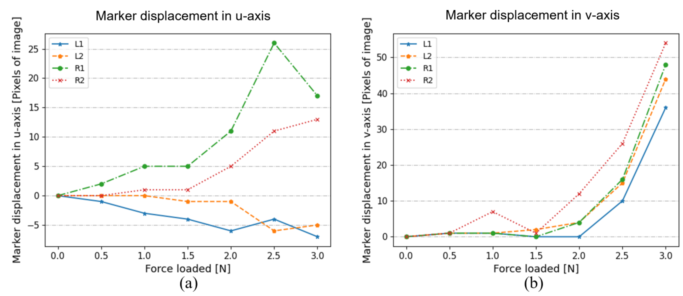

Fig. 4: Relationship between the displacement of the markers and applied force. Displacement of the markers in u-axis (a) and v-axis (b), respectively, when the force in Fig. 2 (b) is applied.

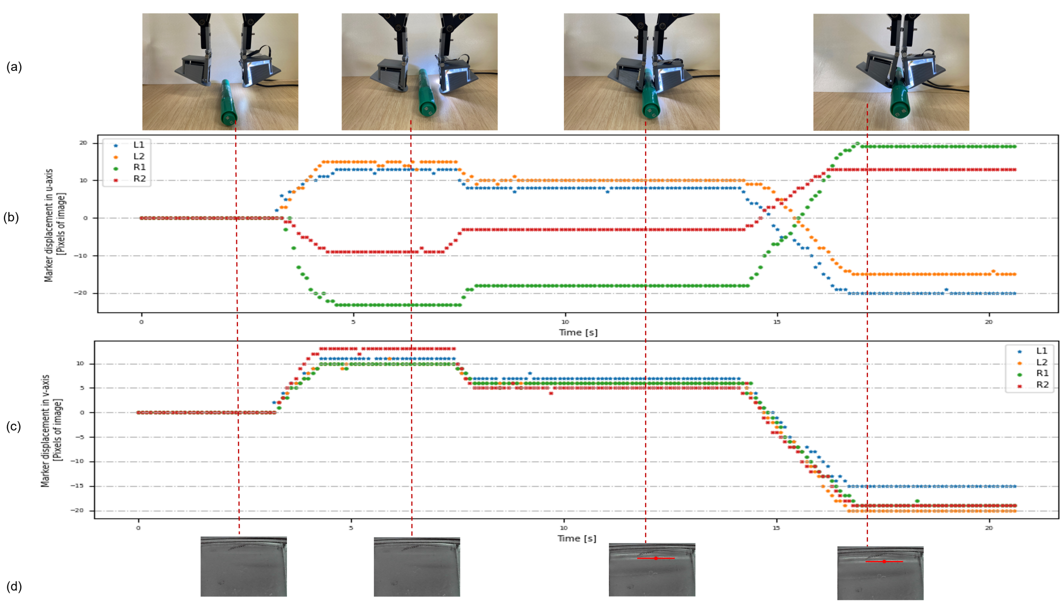

Fig. 5: Time course of displacement of the markers in pickup of the marker pen using the nail. Pictures during the pickup task (a), and marker displacement in u-axis (b) and v-axis (c), respectively. (d) Output images from the finger pad sensor.