Two-fingered, tactile-based manipulation of unknown objects

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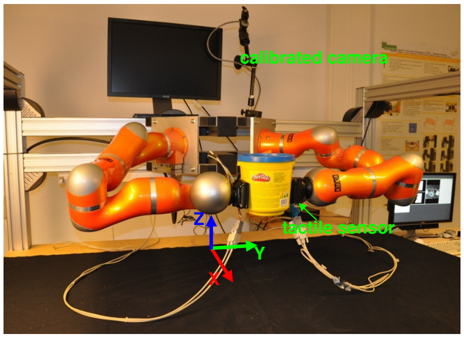

Fig. 1: Experimental setup with tactile sensor arrays mounted as fingertips to Kuka LWRs.

Modern sensor arrays providing tactile feedback with high spatial and temporal resolution allow for new control strategies to exploit this valuable sensory channel for grasping and manipulation tasks.

We present our recent efforts to transfer a control approach specifically developed to exploit tactile information for in-hand manipulation of objects [3] from simulation to the real world. Aiming to handle unknown objects, the control strategy makes as parsimonious assumptions about available prior knowledge as possible: Neither the object properties (shape, weight) nor contact properties (friction coefficients, softness) are assumed to be available.

Rather, we assume that the contact position, normal direction and contact force is known from a tactile sensor array providing sufficient spatial and temporal resolution. Because an appropriate tactile fingertip sensor so far only exists as a prototype [1] and needs to be integrated into our robot hand, we employ a previously developed, tactile sensor array [6] mounted as large fingertips on two Kuka LWR arms (see Fig. 1) to demonstrate the feasibility of the approach in the real world.

The tactile sensor array of 16×16 tactile elements, sized 5×5mm each, provides a frame rate of 1.9kHz and a linear measurement range between 4-17kPa rendering its use for real-time robot control feasible. Employing image processing methods, we compute the contact location on the sensor as the weighted center of forces within the largest connected contact region. Exploiting the known kinematics of the robot we can transform these sensor-local coordinates into the robot's reference frame. From the known shape of the tactile sensor we extract the contact normal direction thus providing all necessary information for the control strategy [3].

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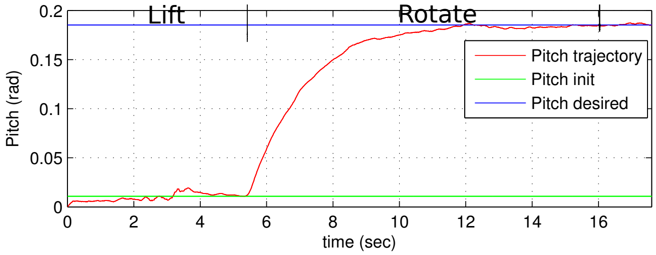

Fig. 2: Pitch rotation manipulation

The control strategy is based on the fundamental assumption, that contact points do not move (slide or roll) during manipulation. Naturally, this assumption will not hold true during real manipulation motions, especially because the contact and shape properties are not modeled. However, employing tactile servoing controllers [4], we can efficiently compensate for unexpected slipping and rolling. To this end, the desired contact/finger motion – obtained from the desired object displacement and inverse hand kinematics – is superimposed to the corrective finger motion from the tactile servoing controller employing a hybrid force/position control scheme. The object's pose is tracked in real time using a marker-based vision system.

Results: object rotation about y-axis

The accompanying video [5] demonstrates some basic visual servoing primitives and the rotation of an unknown object about the three coordinate axes of the global reference frame (as depicted in Fig. 1). To this end, the object is picked, lifted, and finally displaced w.r.t. its initial pose. The evolution of the pitch angle of the object resulting from the rotation about the y-axis is shown Fig. 2. Our previous attempt to realize this manipulation task was limited to linear displacements of the fingertips resp. contact points [2].

References

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