An in-finger sliding skill for cable routing and manipulation

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1 Introduction

Higher wages and increased product variation in the production of electric commodities and machines have lead to an increased automation in manufacturing plants and therefore also an increased number of tasks that involve cable automation. However, cable manipulation is still a challenging task for robotic automation. The complexity arises because cables have infinite degrees of freedom by nature, they can deform in unexpected ways and their kinematics are hard to model. One possible way to deal with the complexity of manipulating cables is to keep the cable in tension during the task. This because while in tension, the cable behaves as a rigid object in the direction stretching. Enabling robots to slide through cables while mantaining the tension is then an interesting topic.

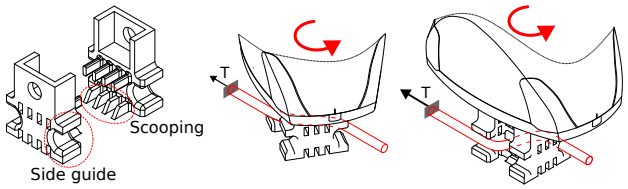
2 Methodology

In [1] a robotic sliding skill was proposed, tactile sensing was used to estimate the cable in-hand state, then a control action is generated by a reinforcement learning based policy. This work designs gripper fingers and a controller for cable sliding. The design (Fig. 1a) exploits the relationship between deformation of the cable and friction with the fingers. They can (i) scoop the cables from a planar table, (ii) guide the cable so that it remains inside the gripper during manipulation, and (iii) guide the cable's orientation when it is twisted. When mounted on a position controlled parallel gripper three modes are available: (i) Open, (ii) Slide, (iii) Grip. In slide mode the distance between the fingers is defined as the cable diameter plus a constant gap for the cable to freely move. This enables the gripper to handle different sized cables. The deformation of the cable is controlled by the twisting angle of gripper fingers (Fig. 1b). When sliding the cable through the fingers, this deformation causes a friction monotonically related to the twisting angle.

Similar to an admittance controller [2], an angular velocity proportional to the error between the cable tension and the tension setpoint was implemented. The force error is scaled with a constant to match the units of the angular velocity.

3 Results

Experiments were performed with cables with different physical properties (size, thickness, bending and friction),



(a) (b)

Figure 1: (a) Gripper finger design, and (b) interaction between the fingers and the cable



Figure 2: Robot execution of cable sliding skill for different cables

and with the same cable tension setpoint and control gains. The control performance was robust over the whole range of these cable properties. The cable tension is measured with a force sensor at the end-effector of the robot.

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References

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[2] G. Borghesan and J. De Schutter, "Constraint-based specification of hybrid position-impedance-force tasks," 2014 IEEE International Conference on Robotics and Automation (ICRA), Hong Kong, China, 2014, pp. 2290-2296.