ECE testbed - A hardware tool to benchmark fingers and hands on their capability to use environment constraints exploration

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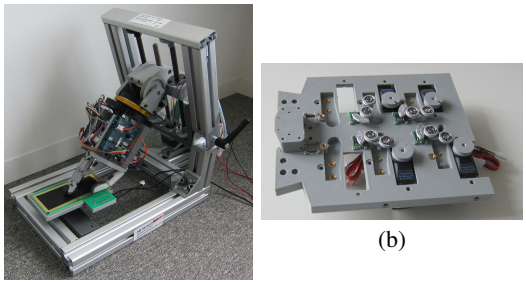
I. Rationale

The use of environmental constraints in manipulation helps the human to compensate for uncertainties in his world model. Recently, the same principle has started to be applied to robotics, so that soft underactuated hands improve their grasping capability by using environmental constraints exploitation (ECE) [1]. With the aim of having a standard method to compare the ability of soft robotic fingers or hands to use ECE, we have constructed the ECE testbed. The testbed can provide information about the correct stiffness of the finger actuation and the necessary wrist motion to fulfill the ECE task. Thanks to the use of rapid prototyping technology and standard components, the testbed is a robust and cheap platform for grasping experimentation. ECE tasks that can be performed on the testbed include: Slide finger over a surface to an object, slide an object to good grasp position and flip object. Also, the testbed allows lifting a grasped object, which helps in the evaluation of grasp stability. The testbed has embedded sensor equipment that helps to measure accuracy and reaction forces on the fingers/hands.



(a) (b)

Fig. 1: ECE testbed: a) Testbed configurations; b) ECE actuator box.

II. Design

The testbed offers two active degrees of freedom (DOF) for positioning the finger or hand with respect to the object or sensor surface (EC: slip finger over table to reach object). Both axis are actuated by stepper motors, controlled by Beckhoff Ethercat clamps. A passive DOF can bring the testbed into its second configuration (Fig. 1a) to slide the object over the sensor surface, for simulating the case where the object is too far to be directly grasped. To compare different finger architectures, the testbed is endowed with the following sensors: a low cost 17 x 6 tactile sensor array for measuring the position and contact force, a force sensor that provides information on the normal force, and an encoder to measure the rotation position of the wrist. For testing different finger designs, an actuator box can be mounted on the ECE testbed. It is equipped with eight FAS servo actuators with changeable stiffness behavior. This allows testing a large variety of fingers, from one tendon underactuated fingers as in the Prensilia hand [2], to 2n designs like the DLR Awiwi hand [3]. Furthermore, differential finger designs can be tested by using control to mimic the behavior of underactuated fingers.

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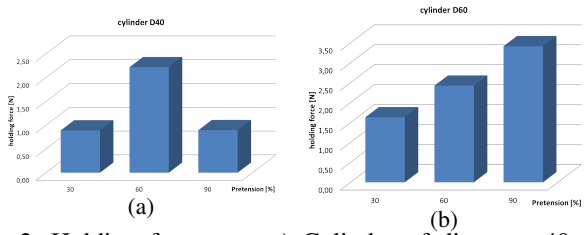
III. Initial experiments

To illustrate the capabilities of the ECE testbed, a prototypical experiment uses the DLR WHISG hand (a modular variable impedance hand) for grasping cylinders of different diameter. The goal of the experiment is to retrieve information on the overall grasping force and decide the right stiffness behavior for the spring elements required to grasp different objects. During the test, the hand automatically grasps the object with a preset stiffness. Afterward, the hand is lifted by the ECE testbed and the holding grasp force is measured. For the highest stiffness and the cylinder of 40mm, the lifting process fails because the two underactuated fingers cannot hold a stiff position in this configuration. More detailed experiments are an ongoing work.



(a) (b)

Fig. 2: Holding force test: a) Cylinder of diameter 40mm; b) Cylinder of diameter 60mm.

References

[1] C. Eppner and O. Brock, "Planning grasp strategies that exploit environmental constraints," in *IEEE Int. Conf. Robotics and Automation - ICRA*, 2015, pp. 4947–4952.

[2] C. Cipriani, F. Zaccone, G. Stellin, L. Beccai, G. Cappiello, M. C. Carrozza, and P. Dario, "Closed-loop controller for a bio-inspired multi-fingered underactuated prosthesis," in *IEEE Int. Conf. Robotics and Automation - ICRA*, 2006, pp. 2111–2116.

[3] M. Grebenstein, *Approaching Human Performance: The Functionality-Driven Awiwi Robot Hand*. Springer, 2014.

The ECE finger-testbed

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Introduction

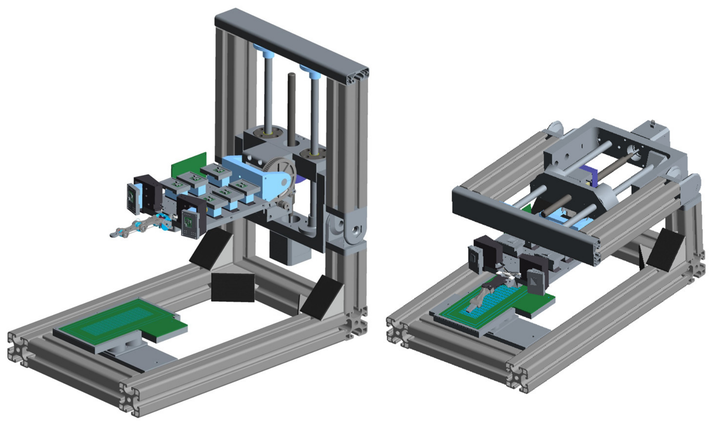
The idea of the ECE finger-testbed is to benchmark our soft-fingers and soft hands to EC's in general on a uniform platform.

Design

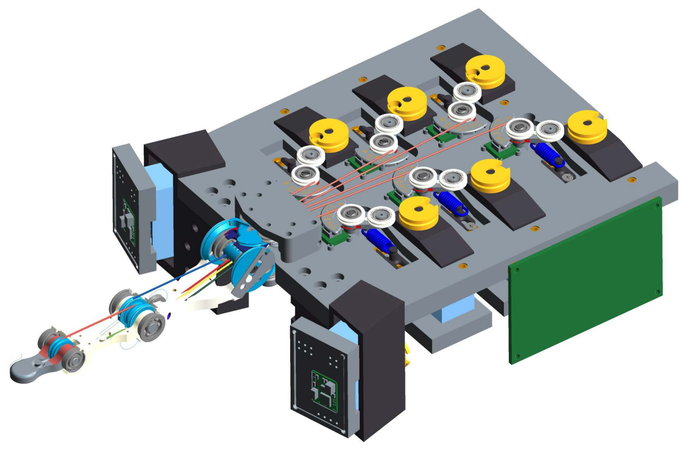
- Two active DOFs for position the finger to object or sensor surface (EC slip finger over table to reach object)
- Passive DOF to bring the testbed in second configuration to slide object over sensor surface
- 17 x 6 taxel array
- Low cost actuators and mostly printed parts

DLR will use the platform also to compare between 2N- and N+1-tendon design in order to reduce the complexity of our variable-stiffness soft-hand. We will also investigate which influence the reduced number of passive stiffness degree has on the use of ECs. For this we can mount the EC actuator box with eight motors and eight FAS with integrated tendon force sensors.
A further interesting point is the right number of sensor in the hand, this will we explored on the ECE testbed too, because it is much easy to test sensor on one finger than to integrate them on a whole hand.

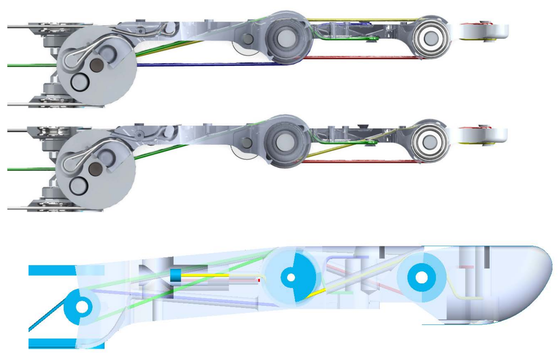
Design



ECE testbed in both configurations

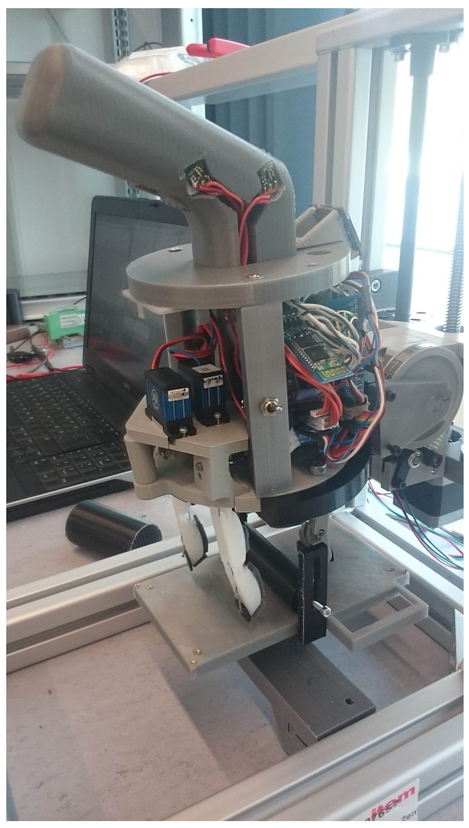


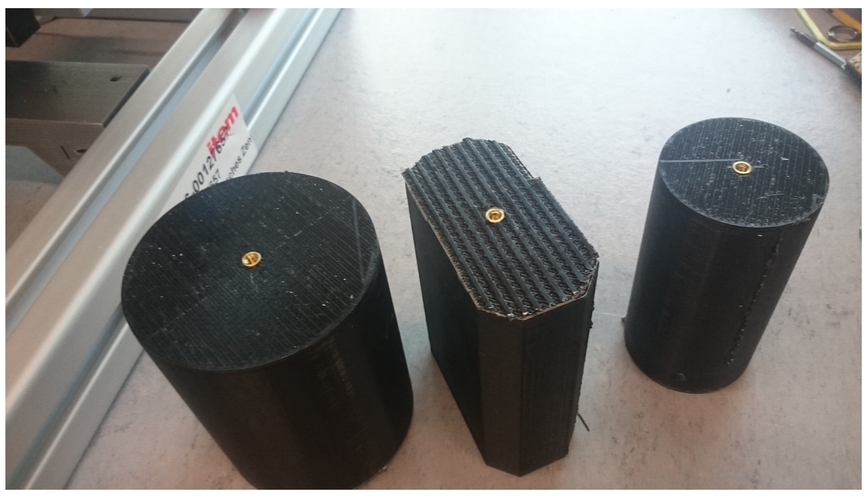
Actuator box



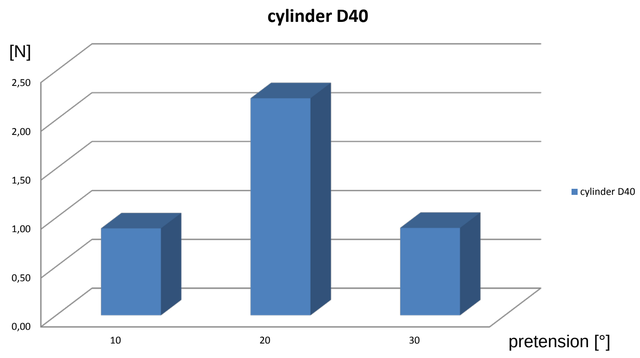
Top: 2N, middle N+2; bottom: N+1

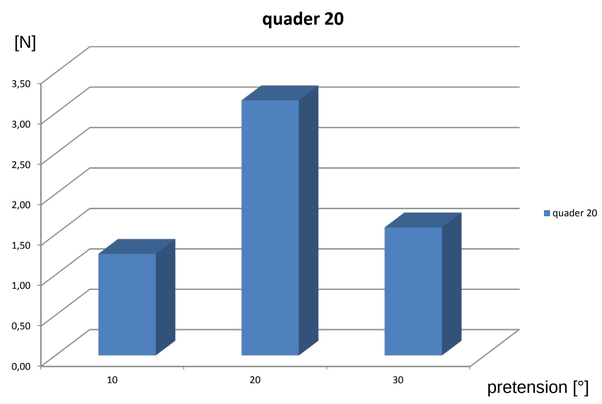
First results with WHISH hand

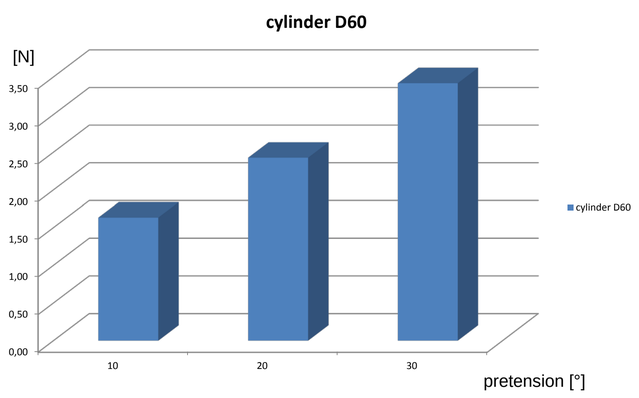




Different objects to test grasping with different stiffness







<u>WHISG on ECE Testboard:</u>
Gripper grasp unkown object, set stiffness and then linear axis lift hand.
Applied holding force is measured by force gauge.