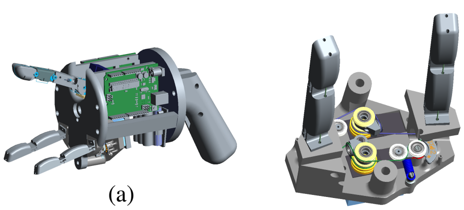
WHISG - A wearable hand to investigate passive stiffness in grasping

Werner Friedl, Hannes Höppner, Máximo A. Roa and Markus Grebenstein

I. Introduction

Wearable robotic hands [1], [2] allow the partial recovery of hand functionality in amputees, and also allow users to investigate the capabilities of the hands [3]. In fact, the human can use his intuition to locate the hand in an optimal position in order to reliably grasp any object. The influence of variable passive stiffness on grasping is rarely explored in the design of hands, since the DLR Awiwi is the only existing hand that provides variable stiffness actuation [4]. However, this hand is not portable due to its weight, and consumes too much energy to be driven by battery only. This work introduces the WHISG hand, a three-finger hand that uses the same variable stiffness concept as the Awiwi hand [5], combined with low cost servo actuators and rapid prototyping parts, leading to a light, cheap, and robust platform for grasping experimentation. The user can place the portable hand in a convenient position with respect to the object, and can choose the grip stiffness using an adjustment wheel. A trigger is used to initiate the grasp, and fingers are closed while allowing their adaptation to the object shape. Then, the hand sets the chosen stiffness for a reliable grasp.



(a) (b)

Fig. 1: Underactuated WHISG Hand: a) Hand structure; b) Finger setup, with one stiffness degree.

II. Design

The hand is composed by one finger with 4-DoF and two underactuated, 3D-printed nylon fingers with 2-DoF each (Fig. 1a). The main finger is actuated by four servos and can be used as an opposing finger ("thumb"); it has a *n+1* tendon design with one under-actuated DoF between the distal (DIP) and proximal (PIP) joints. Therefore, the two DoF in the metacarpal (MCP) joint can be independently moved, while the PIP and DIP joints are always coupled. The four tendons run over a flexible antagonistic spring element (FAS) [5] that measures the tendon force and makes the fingers robust against external perturbations. A change in the stiffness always affects all four joints. The FAS used in the Awiwi hand is simplified here by using a rotatory spring instead of a linear spring. Four Bluebird BMS 385 servos actuate the main finger. With its maximum servo torque of 0.45 Nm, the finger can reach about 10 N of fingertip force. The two other fingers are driven by two antagonistic servos; the difference in their actuation defines if either position or stiffness of the two fingers is changed (Fig. 1b). In contrast to the Pisa/IIT SoftHand [2], the differential tendon mechanism is integrated here in the servo winder. The benefit of this solution is that a normal servo can be used, without changing its range of motion or electronics.

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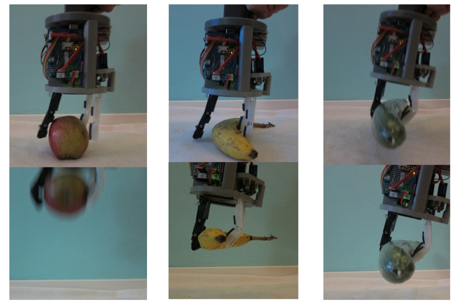

Fig. 2: WHISG Hand grasping fruits and vegetables.

III. Experiments

One of the use-cases within the EU-project SoMa is to pick up fruits out of a box. In this pilot study, the hand grasps different groceries (Fig. 2); it is able to grasp apples, bananas and cucumbers up to a weight of 400 g. However, the two 3D-printed fingers opposing the main finger are too weak for heavier objects. The results of this study provide evidence of the clear relation between the weight of the objects and an optimal stiffness-preset.

References

[1] R. Deimel and O. Brock, "A novel type of compliant and underactuated robotic hand for dexterous grasping," *Int. J. Robotics Research*, pp. 1–25, 2015.

[2] M. Tavakoli and A. de Almeida, "Adaptive under-actuated anthropomorphic hand: ISR-SoftHand," in *IEEE/RSJ Int. Conf. Intelligent Robots and Systems*, 2014, pp. 1629–1634.

[3] M. Bonilla, E. Farnioli, C. Piazza, M. Catalano, G. Grioli, M. Garabini, M. Gabiccini, and A. Bicchi, "Grasping with soft hands," in *IEEE-RAS Int. Conf. Humanoid Robots*, 2014, pp. 581–587.

[4] M. Grebenstein, "The Awiwi hand: An artificial hand for the DLR hand arm system," in *Approaching Human Performance*. Springer, 2014, pp. 65–130.

[5] W. Friedl, M. Chalon, J. Reinecke, and M. Grebenstein, "FAS— A flexible antagonistic spring element for a high performance over actuated hand," in *IEEE/RSJ Int. Conf. Intelligent Robots and Systems*, 2011, pp. 1366–1372.

WHISG - A wearable hand to investigate passive stiffness while grasping

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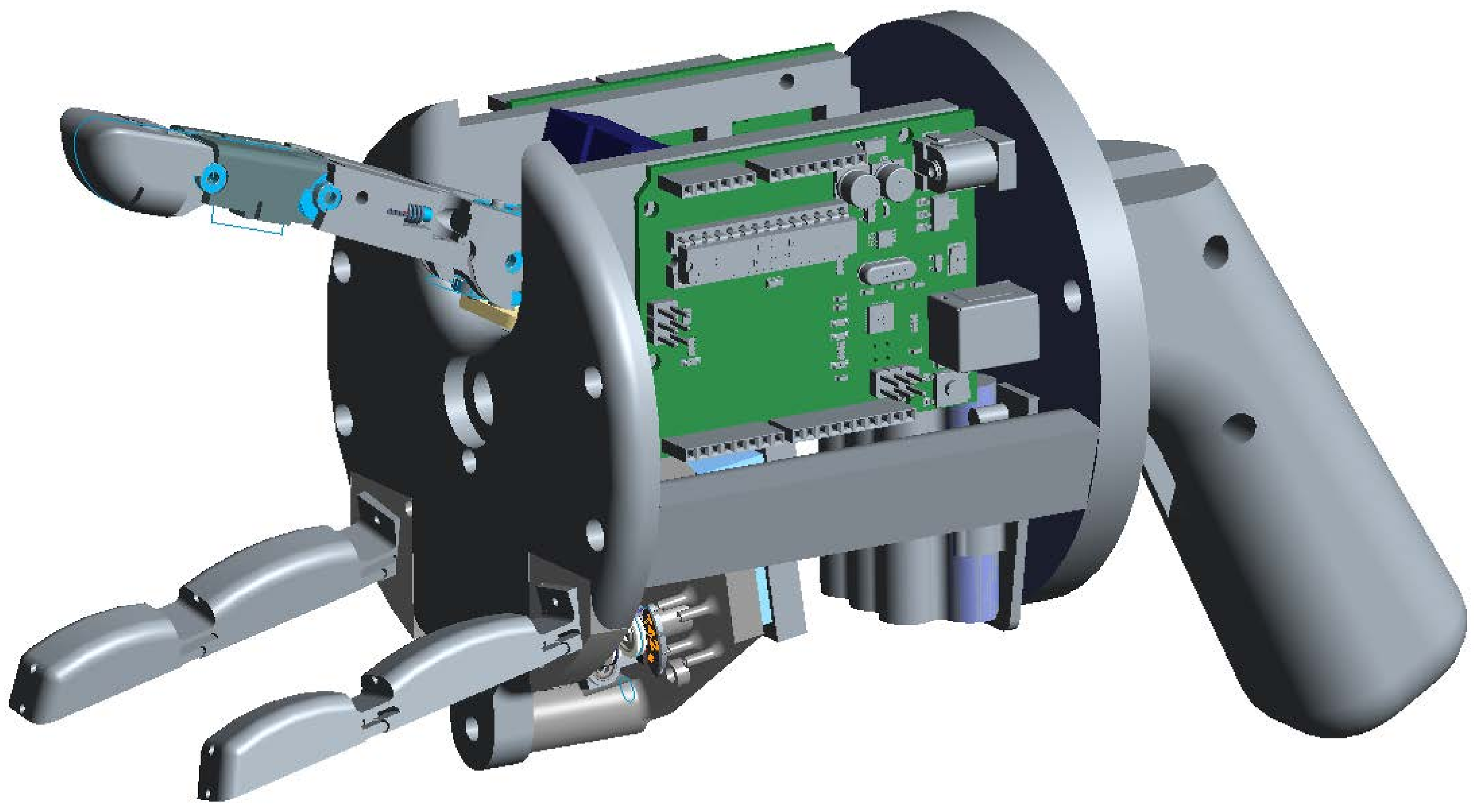
Abstract: Wearable robot hands [1, 2, 3] allow the partial recovery of hand functionality in amputees, and also allow users to investigate the capabilities of the hands[4,5]. In fact, the human can use his intuition to locate the hand in an optimal position in order to reliably grasp any object. The influence of variable passive stiffness on grasping is rarely explored in the design of hands, since the DLR Awiwi is the only existing hand that provides variable stiffness actuation[6]. However, this hand is not portable due to its weight, and consumes too much energy to be driven by battery only. This work introduces the WHISG hand, a three-finger hand that uses the same variable stiffness concept as the Awiwi hand[7] combined with low cost servo actuators and rapid prototyping parts, leading to a light, cheap, and robust platform for grasping experimentation. The user can place the portable hand in a convenient position with respect to the object, and can choose the grip stiffness using an adjustment wheel. A trigger is used to initiate the grasp, and fingers are closed while allowing their adaptation to the object shape. Then, the hand sets the chosen stiffness for a reliable grasp.



Design

- Three finger hand with pistol grip
- Main finger with N+1 design and 10 N finger tip force
- Printed nylon fingers with differential coupling
- Two degree of stiffness for hole hand
- Low cost architecture based on servos and Arduino hardware
- Main frame and fingers 3D printed
- Telemetric data by Bluetooth

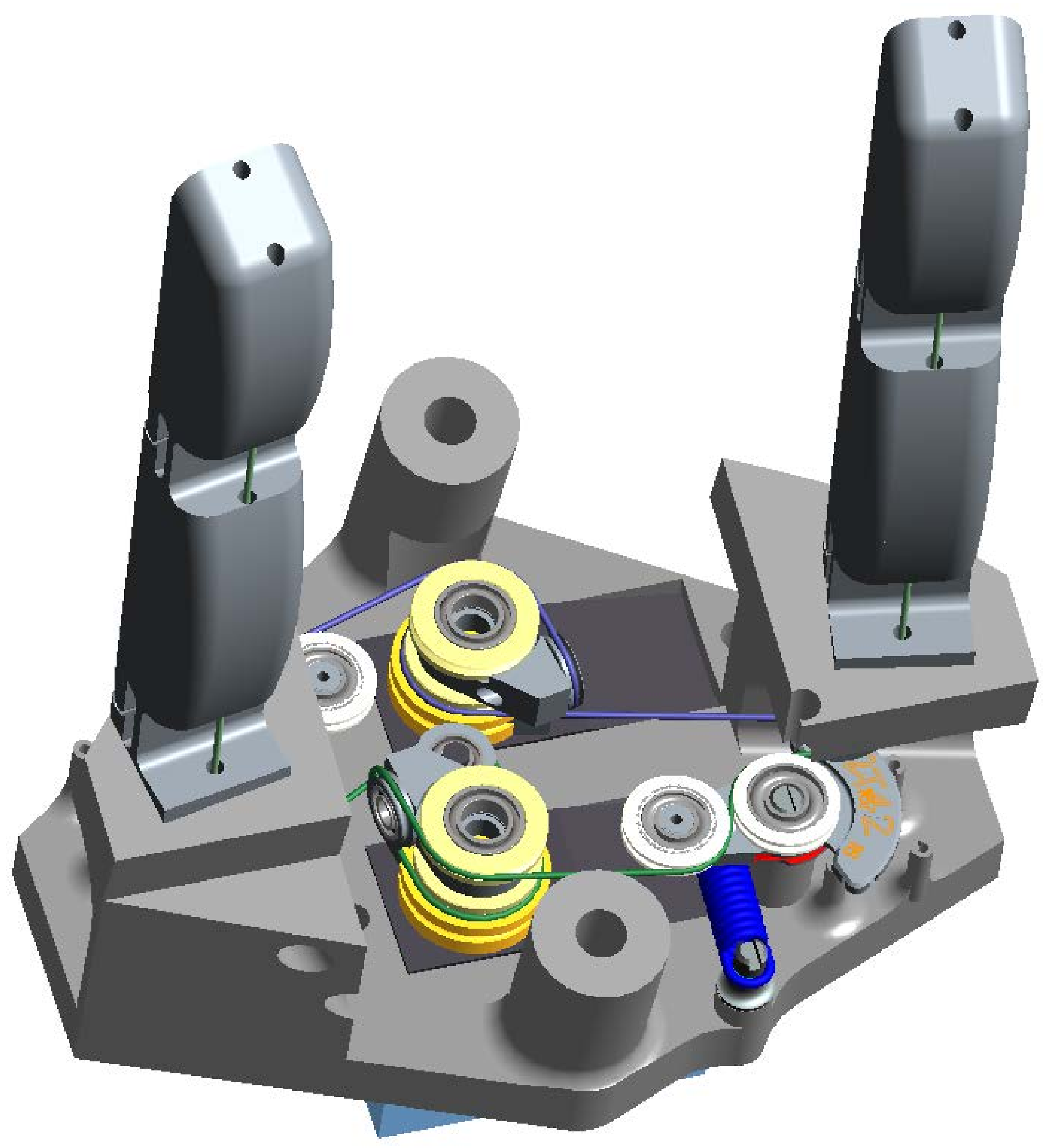
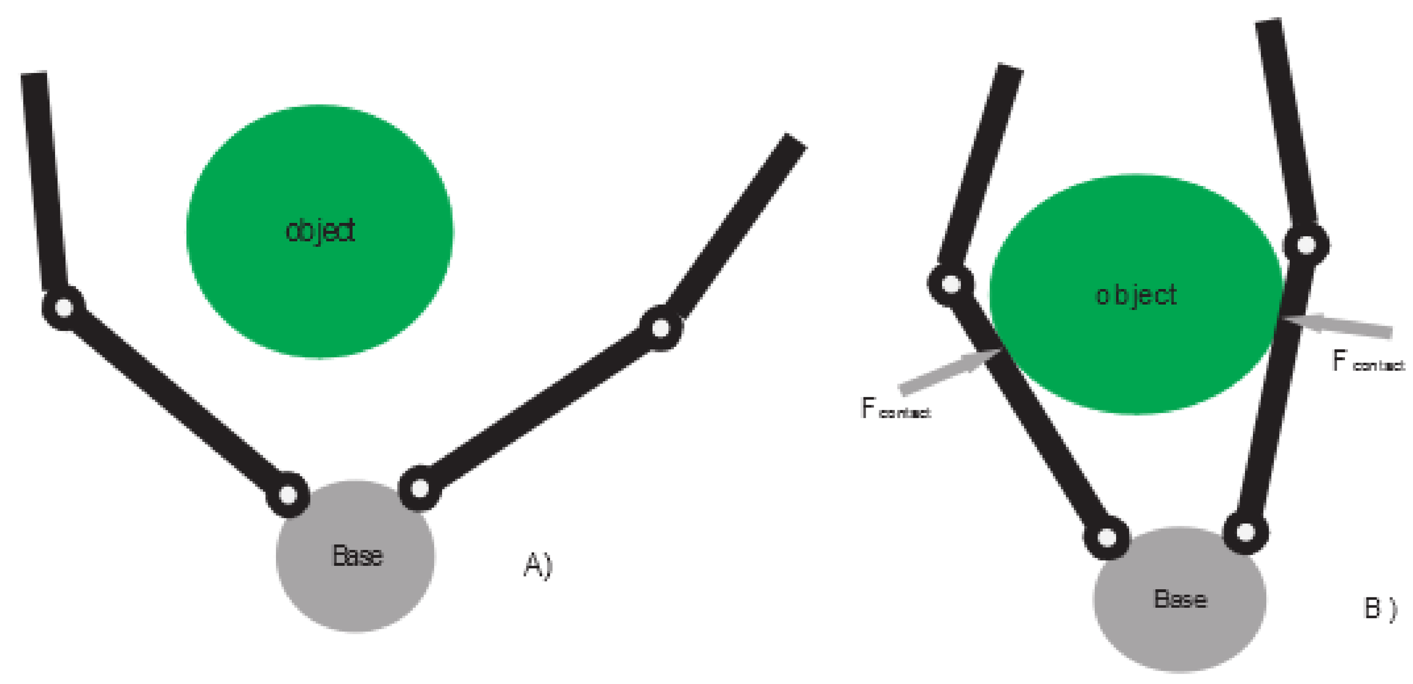
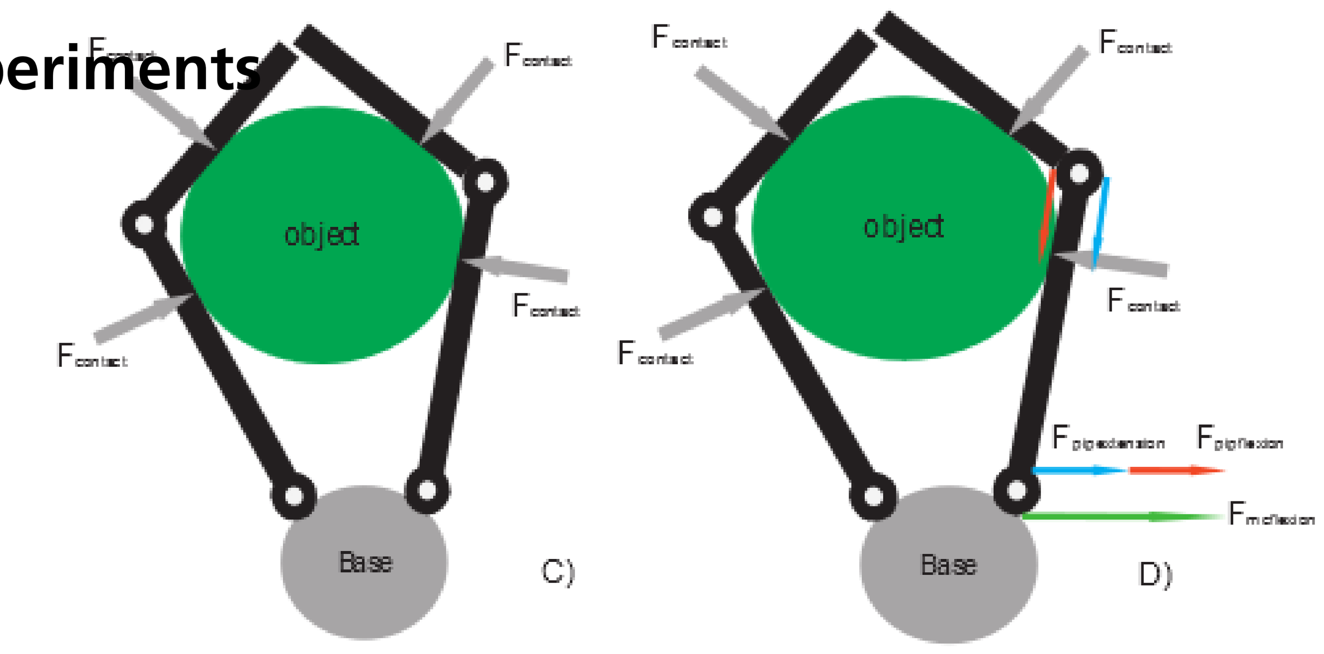


Fig. 1.: underact finger setup with one stiffness degree

software underact modus with stiffness adaption

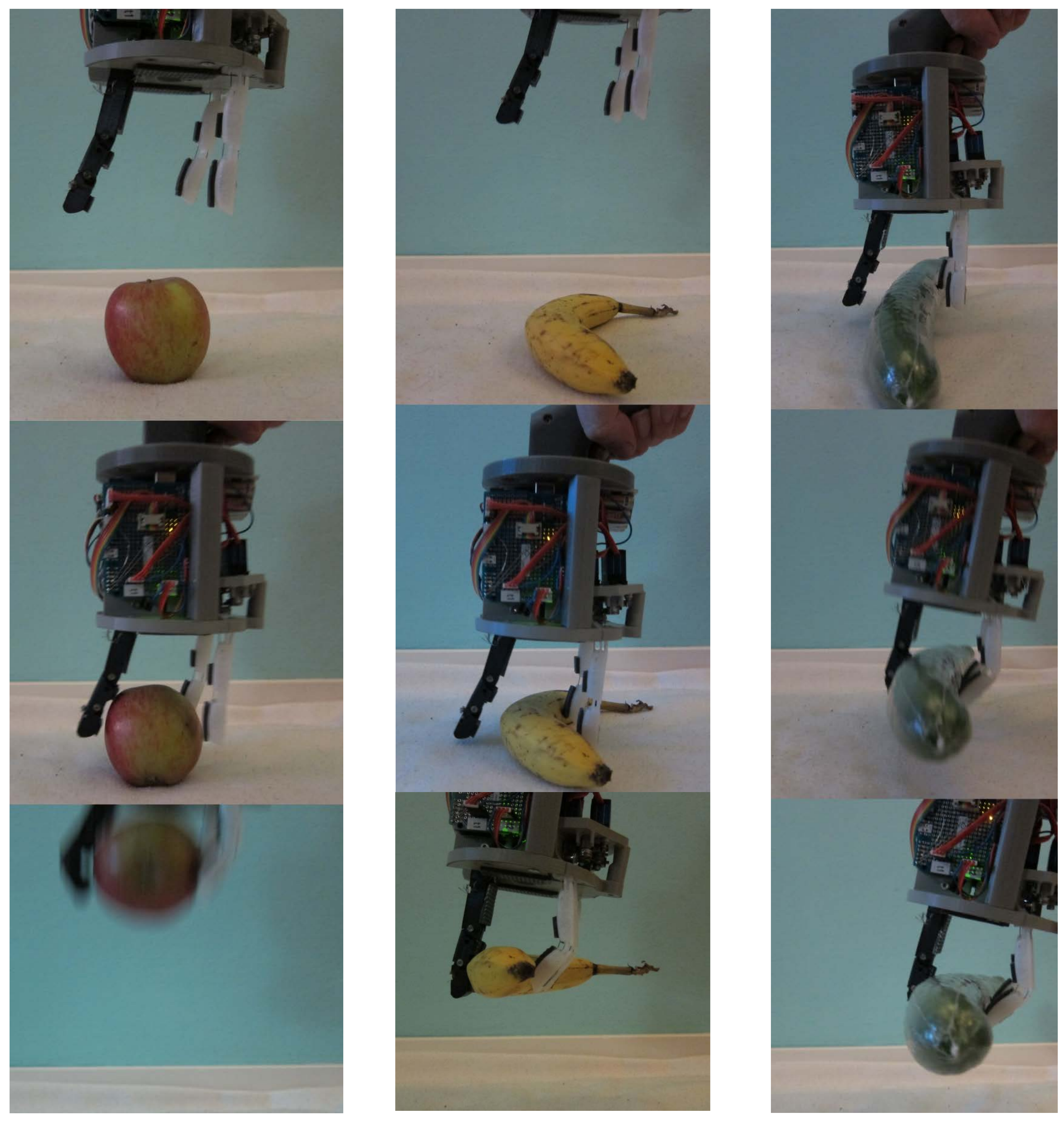


Experiments



A) Hand position before grasp; B) The hand close proximal joint until force higher the threshold; C) closing distal joint until contact; D) Controller increase bias forces for higher stiffness

Experiments:



The hand is able to grasp apple, bananas and cucumber up to a weight of 400g, for more the printed nylon fingers are to weak. Naturally, the results of this pre-study provides evidence of a clear relation between the weight of the objects and an optimal stiffness-preset.

References:

[1] R. Deimel and O. Brock, “A novel type of compliant and underactuated robotic hand for dexterous grasping,”The International Journal of Robotics.
[2] M. Tavakoli and A. T. de Almeida, “Adaptive underactuated anthropomorphic hand: Isr-softhand,” in Intelligent Robots and Systems (IROS 2014)
[3] M. Bonilla, E. Farnioli, C. Piazza, M. Catalano, G. Grioli,
M. Garabini, M. Gabiccini, and A. Bicchi, “Grasping with soft hands,” in Humanoid Robots (Humanoids),
[4] M. Grebenstein, “The awiwi hand: An artificial hand for the DLR hand arm system,” in Approaching Human Performance. Springer, 2014, pp. 65–130.
[5] W. Friedl, M. Chalon, J. Reinecke, and M. Grebenstein, “FAS—A flexible antagonistic spring element for a high performance over actuated hand.” in Intelligent Robots and Systems (IROS), 2011

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SOFT MANIPULATION

DLR