Vision-Based Flexure Gripper Configuration Estimation for Visuo-Tactile Sensing

Marissa Jonker[⋆,†], Jan de Jong[⋆], Wesley Roozing[†], and Wouter Hakvoort[⋆]

[⋆] Precision Engineering, University of Twente, Enschede, The Netherlands
[†] Robotics and Mechatronics, University of Twente, Enschede, The Netherlands
email: {l.m.jonker, j.j.dejong, w.roozing, w.b.j.hakvoort}@utwente.nl

1 Introduction

As the need for automation in agriculture is rising, the demand for suitable grippers to grasp delicate crops grows. Sensing the grasping forces is needed to carefully manipulate crops. However, sensing without contact sensors is desired to upkeep cleanability, thus we aim to do this remotely via vision. For this, we need to know the configuration of the gripper and contact points first.

Current research on visually obtaining mechanism configuration do not account for occlusions [1], or do so by adding an additional camera [2]. We propose a method to visually estimate the configuration of an underactuated gripper, while accounting for occlusions due to e.g. leaves, by tracking a redundant set of markers on the gripper, as shown in Figure 1.

2 Configuration estimation

We use an Extended Kalman Filter to estimate the pose of the base marker relative to the camera (position p and rotation as quaternion q), and the three internal degrees of freedom of the gripper (two rotations ϕ and one translation a):

$$x_k = \begin{bmatrix} \left(p_2^C\right)^\top & \left(q_2^C\right)^\top & \phi_7 & \phi_{15} & a \end{bmatrix}^\top. \tag{1}$$

The measurements contain the positions of all markers, and the rotation of the base marker:

$$y_k = \begin{bmatrix} \left(p_2^C\right)^\top & \left(p_1^C\right)^\top & \left(p_3^C\right)^\top & \dots & \left(p_{42}^C\right)^\top & \left(q_2^C\right)^\top \end{bmatrix}^\top. \tag{2}$$



Figure 1: Gripper 3D model grasping object.

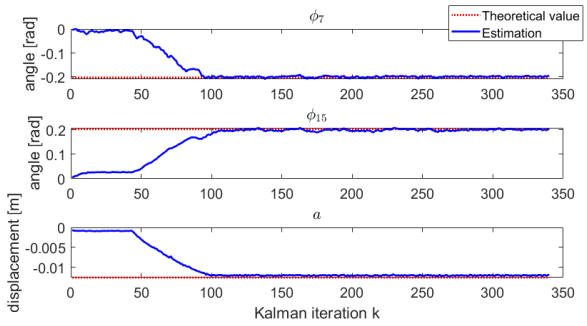


Figure 2: Estimated gripper DoFs: grasping object with radius 39 mm

The measurement function $\hat{y}_k = h(x_k)$ contains the known gripper kinematics and loop-closure equations.

3 Results

We validate our method on the flexure-based gripper from Okken et al. [3] (Figure 1), by grasping ideal circular objects, as these make contact with the gripper at the same five locations, irrespective of object radius. Thus we calculate the theoretic gripper configuration and compare this to our estimates x_k. An example estimation with corresponding theoretical values is shown in Figure 2.

References

[1] J. Fu, Z. Yu, Q. Guo, L. Zheng, and D. Gan, "A variable stiffness robotic gripper based on parallel beam with vision-based force sensing for flexible grasping," *Robotica*, pp. 1–19, Dec. 2023, ISSN: 0263-5747. DOI: 10.1017/S026357472300156X.

[2] V. Ortenzi, N. Marturi, M. Mistry, J. Kuo, and R. Stolkin, "Vision-Based Framework to Estimate Robot Configuration and Kinematic Constraints," *IEEE/ASME Transactions on Mechatronics*, vol. 23, no. 5, pp. 2402–2412, Oct. 2018, ISSN: 1083-4435. DOI: 10.1109/TMECH.2018.2865758.

[3] B. Okken, J. P. Dekker, J. J. de Jong, and D. M. Brouwer, "Numerical Optimization of Underactuated Flexure-Based Grippers," in *Volume 8: 47th Mechanisms and Robotics Conference (MR)*, American Society of Mechanical Engineers, Aug. 2023, ISBN: 978-0-7918-8736-3. DOI: 10.1115/DETC2023-116752.

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