Morphological optimization of a soft finger mechanism using a black box optimizer

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Abstract

In this work, we present the morphological optimization of the phalanges lengths of a robotic finger, that improves position and torque requirements of grasping tasks. We apply a black box optimizer that uses the kinematic and the dynamic of the fingers as a fitness function, to evaluate the best morphological configuration. The kinematic of the finger is modeled using a hybrid model based on the Denhavit-Hartenberg parameterization modified by Khalil and Kleinfinger and unified with quaternions formulation (DHKK-SQR)[1]. The dynamic model is based on the postulate of virtual displacements and virtual works [2]. Usage of DHKK-SQR model allows us to introduce soft joints and flexible phalanges in our robotic finger. Theoretical and experimental results show that soft links combined with morphological optimization, lead in more precise grasping. The results of the optimization show us an important improvement related to size, torque and consequently energy consumption.

1 Description of the soft robotic finger

Our soft robotic finger has two degrees of freedom (DoF) in the metacarpophalangeal joint, one DoF in the proximal interphalangeal joint and one DoF in the distal interphalangeal joint. The finger is under-actuated, so only one actuator drives the finger. The fingertip is made of silicone with a Shore-A hardness of 32, a tensile strength of 0.8Mpa and a maximal elongation of 150%. Inside the fingertip, a resistive force sensor measures the applied graspling force. Fig. 1a (respect. 1b) shows the kinematic model (respect. the dynamic model) of our soft robotic finger.

2 Morphological optimization

The applied method is confident local optimization (CLOP)[3] for noisy black-box parameters tuning, which was developed to tune parameters of tree search algorithms in computer games. In our case, we follow the methodology proposed in [4] for enhancing the humanoids walking skills through morphogenesis evolution. Therefore, the CLOP is implemented in two stages: evolution and evaluation.

The evolution process consists of several iterations in which a new set of phalanges lengths is calculated and evaluated. The best result is updated when the current solution is better

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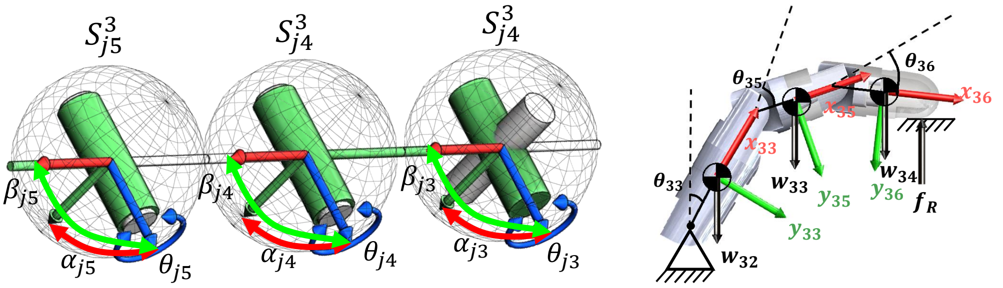

(a) (b)

Figure 1: Equivalent models of the finger. (a) Kinematic Model. (b) Dynamic model

than the stored one. The evaluation uses the results of the kinematics (i.e. fingertip position) and the dynamics (i.e. values of torques) to evaluate the fitness.

3 Conclusion and Outlook

The consideration of an under-actuated mechanisms introduces the necessity of torque control after the contact with the object to grasp, which in our case is the result of the optimal analysis of the morphological parameters. The modelisation of kinematics using DHKK-SQR improves the computational cost, which is very important to reduce the time of the optimization process. The results of the optimization, show us an important improvement related to size, torque and consequently energy consumption.

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