Design Criteria of the Passive Joints in Underactuated Modular Soft Hands

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Introduction: The problem that we want to solve was: how can we design finger joint stiffness in robotic soft hands so that, when applying a certain force to the tendons, the joint configuration vector q assumes a desired shape qr and thus the fingertip follows a desired trajectory?

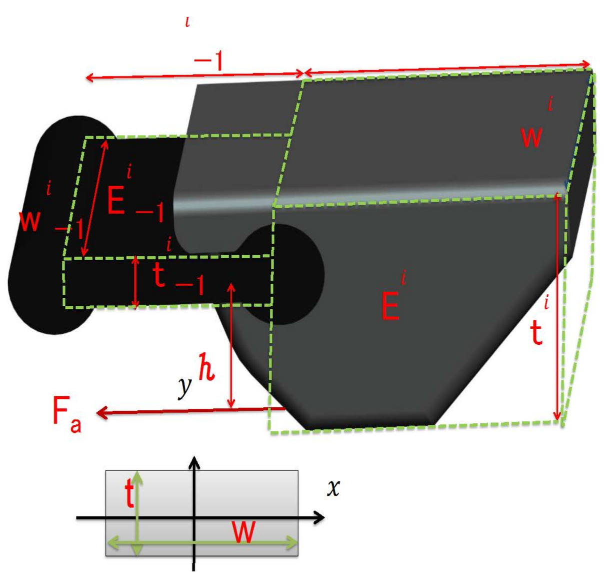

Figure 1: modular element. **Figure 2**: different trajectories.

Methods: We propose a method to compute the stiffness given a certain kinematics of the robotic hand. We exploited the main results on beam theory to find the stiffness for a particular geometry of the soft parts. We adopted a simple serial kinematic chain, in which we can choose the number of elements, and we focus on trajectories more common on power grasp executed by robotic hands.

The overall passive joint stiffness k depends mainly on joint geometry and material structural properties, (e.g. Young's modulus):

$$k = k(\mathbf{d}, E),$$

where **d** defines joint geometry. Young's modulus E depends on material parameters and fabrication methods, i.e.

$$E = E(p1, p2, \ldots, pn),$$

We investigated the dependency numerically to infill density percentage and printing pattern.

Results: We have analytically and numerically analysed how the different infill density percentage affects the overall joint stiffness. To consider the role of other parameters, as for instance the printing pattern, we set up some experimental tests. In particular in the tests we investigated different combinations of infill density percentage and printing patterns. Results show that the mechanical behavior of the joint depends on both

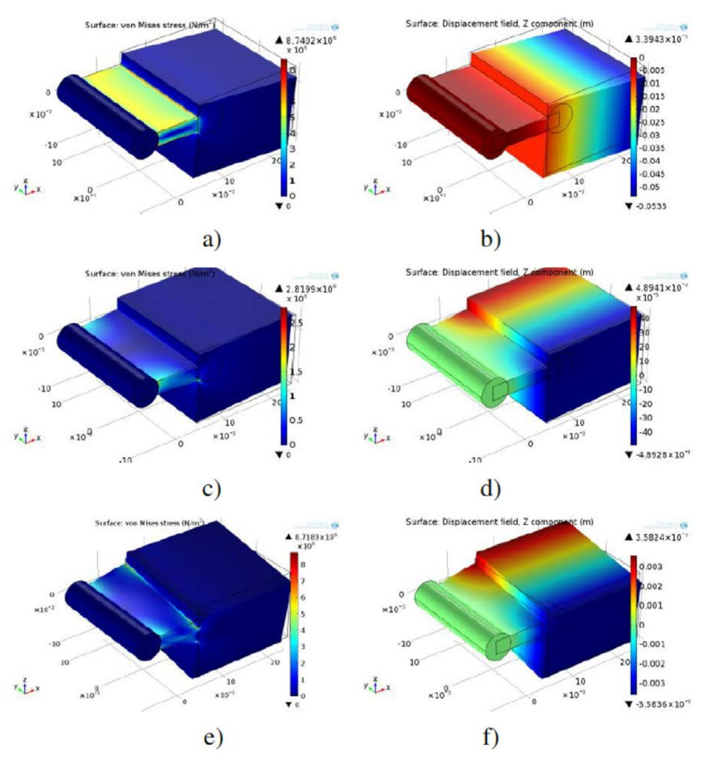

Figure 3: FEM simulations.

Infill density $\rho\%$	E (MPa)
10	1.07
30	1.38
50	2.07
70	6.53
90	9.45
100	10.50

Table 1: properties of TPU material.

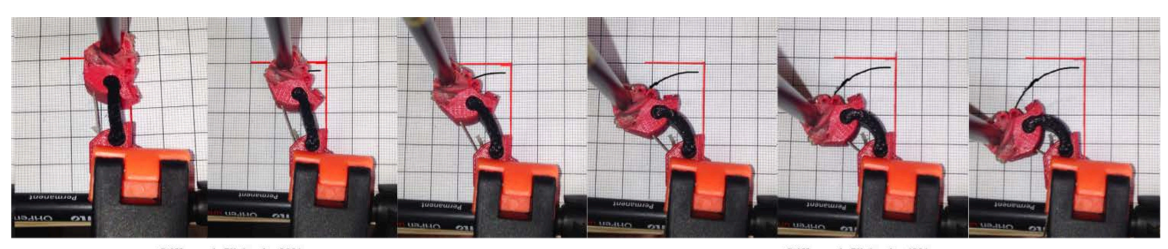

Figure 4: experimental tests.

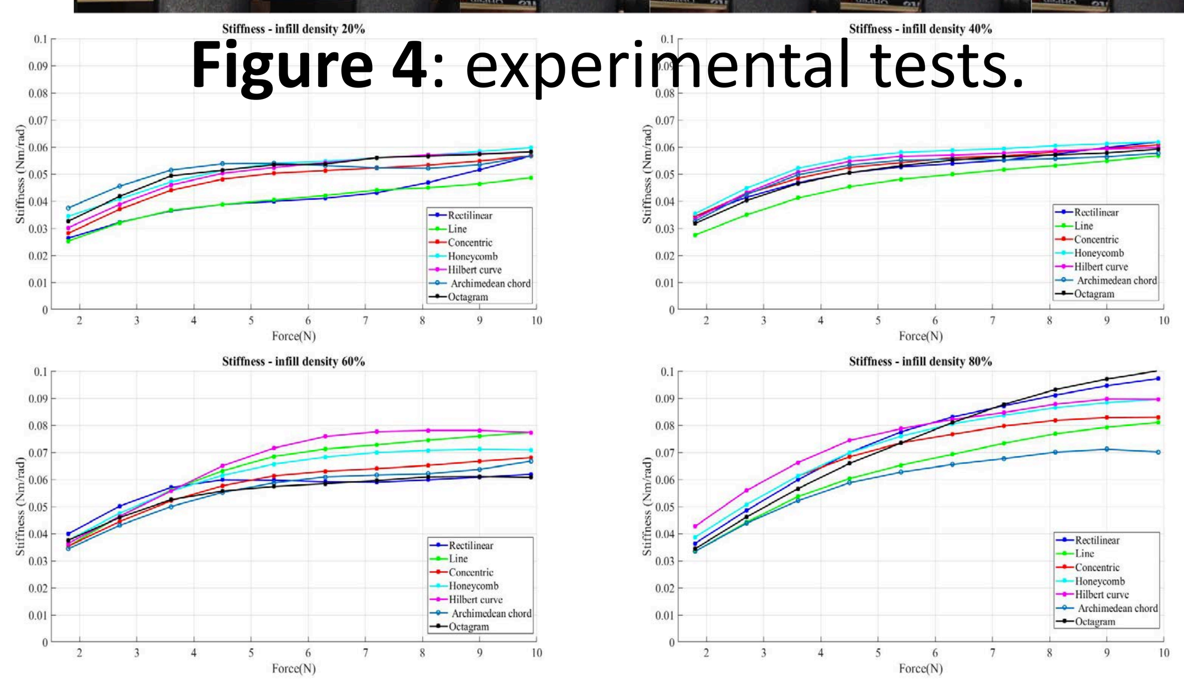

Figure 5: joint stiffness vs applied force.

Conclusions: we present a preliminary study aimed at defining a systematic tool for the design of passive joints in underactuated modular hands. Methods for simulating different printing patterns through FEM simulation will be one of the topic of our future studies.