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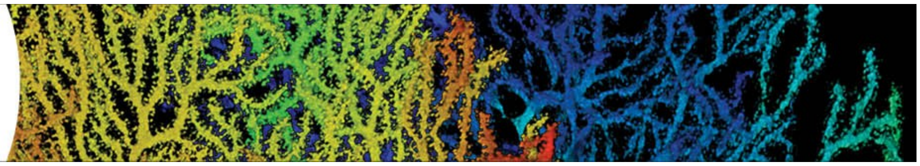

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Rigid Robotic Transformations can approximate the kinematics of soft fingers with ‘bones’

Hand Control and Dexterous Manipulation

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Abstract:

The ability to model and control soft bio-inspired robotic hands would enable a new class of manipulation applications because softness, by passively conforming, decreases the precision required for control (Brock and Valero-Cuevas, Physics of Life Reviews, 2016). Here we tested how well traditional rigid robotic transformations can approximate the kinematics of a semi-soft robotic finger (i.e., rigid `phalanges' embedded in soft material). We made one tendon-driven, semi-soft finger with a length of 13 cm and three 4 cm phalanges (plus a `metacarpal' for mounting) with 0.15 cm of silicone between serving as the `joints'. Then, this semi-soft finger was compared against a ground-truth, rigid 3-link planar hinged finger.

Tendons were routed per the N+1 design (Valero-Cuevas, Fundamentals of Neuromechanics, 2016) where N is 3 degrees of freedom, in which tendons cross, and therefore affect multiple joints. Motors pulled on tendons with seven activation sets to drive the finger to different flexion-extension positions. The resulting finger endpoints were measured at each position using the DeepLabCut motion tracking software (Mathis et al., Nature Neuroscience, 2018). To test the validity of the linear rigid robotic transformations for our semi-soft finger, we calculated a linear regression relating endpoint locations to the seven tendon excursion sets.

The proportion of variance explained by the regression for the semi-soft finger was 69% (R2=0.688), compared to 100% for the rigid-finger. The average discrepancy between the predicted and observed finger endpoints for the 7 positions was 2.1 (± 1.9) mm for the semi-soft finger and 0 (± 0) mm for the rigid finger.

Our results indicate that while kinematic prediction of fingertip endpoints for the semi-soft finger did not follow the linear rigid robotic transformations as closely as that of the rigid finger, they were approximated well with about 69% of the variance explained. These results are encouraging as they show that there may be a way to combine the ability of semi-soft fingers to passively conform to objects grasped, with the numerous effective control methods developed for hinged rigid kinematics chains.

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Poster PDF Link: https://nathan-matharu.github.io/assets/publications/Poster_SFN_Nathan.pdf