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Using Analytical Modeling to Design Customized Fiber-Reinforced Soft Actuators

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As the field of soft robotics continues to grow, there is increasing need for efficient methods of designing soft actuators. Despite recent advances in the modeling of soft actuators, solving their inverse kinematics remains problematic. This problem has been studied in detail for rigid robots, but developing an analog for soft robots is challenging, due to their highly nonlinear response. To address this issue, we present a design tool which, when given the kinematics of a particular motion as an input, outputs the optimal design parameters for a soft actuator which will replicate this motion.

Here we study fiber-reinforced soft pneumatic actuators, as it has previously been shown that these actuators can be tuned to achieve many different motions, including extension, twisting, and bending. We present experimentally-verified analytical models for (1) extending, expanding, twisting actuators and (2) bending actuators, and use the models to explore the actuator design space.

Furthermore, we use these analytical models in a simple optimization algorithm to design actuators customized for a particular function. The algorithm takes the desired motion as its input, and outputs the design parameters for the actuator. The resulting actuator may consist of multiple segments with different geometries, but requires just a single pressure input. We use the algorithm to design actuators which mimic the motion of the index finger and the thumb.