Robot Arm Controlled By Supercoiled Polymer Muscle Fibers

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Introduction

Supercoiled Polymers (SCPs) are artificial manufactured linear actuators that can mimic the contraction and relaxation of organic muscle fibers. They can contract with a strain of more than 20%, and when connected in series, can produce enough force to completely control fingers on a bio-inspired 3D printed hand.

Goals

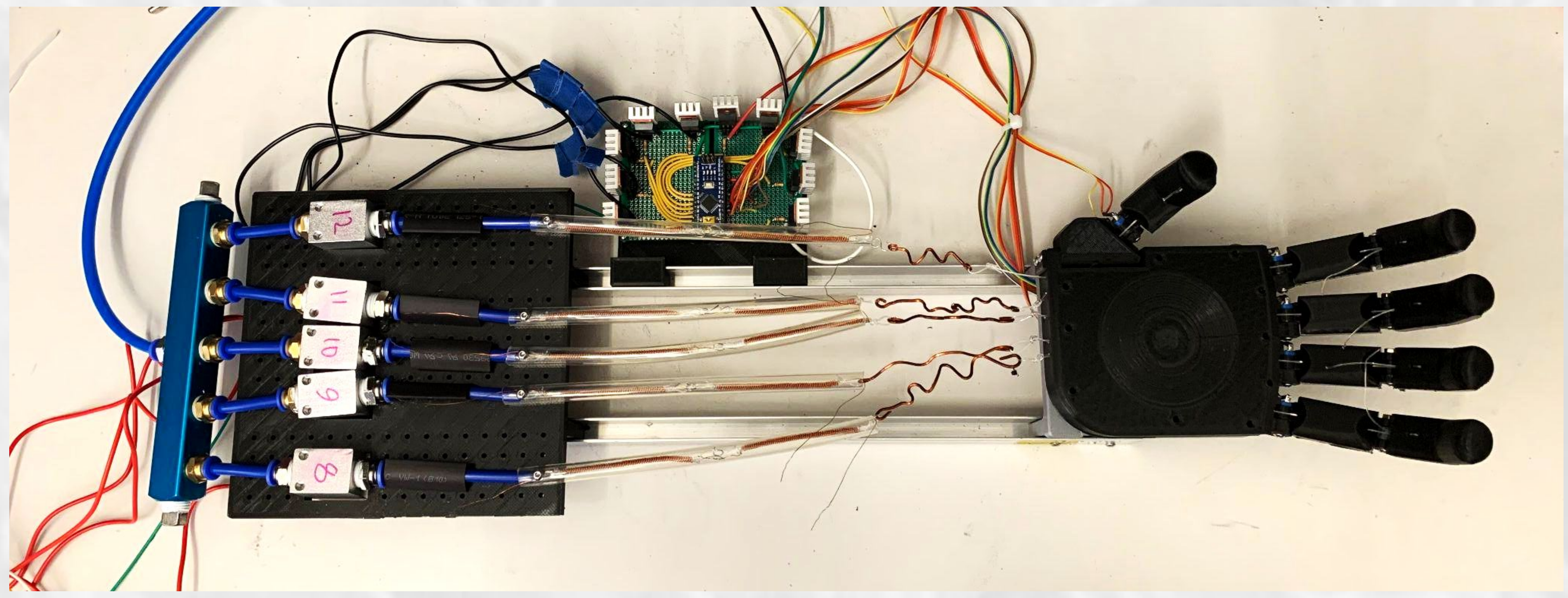
- Showcase the potential of SCPs with subsystems
  - 3D printed hand with five movable fingers comprised of two joints each
  - Electrical heating system to contract the SCPs
  - Compressed air-cooling system operating with low pressure
  - Potentiometers in the finger joints for feedback control

Design of Supercoiled Polymers

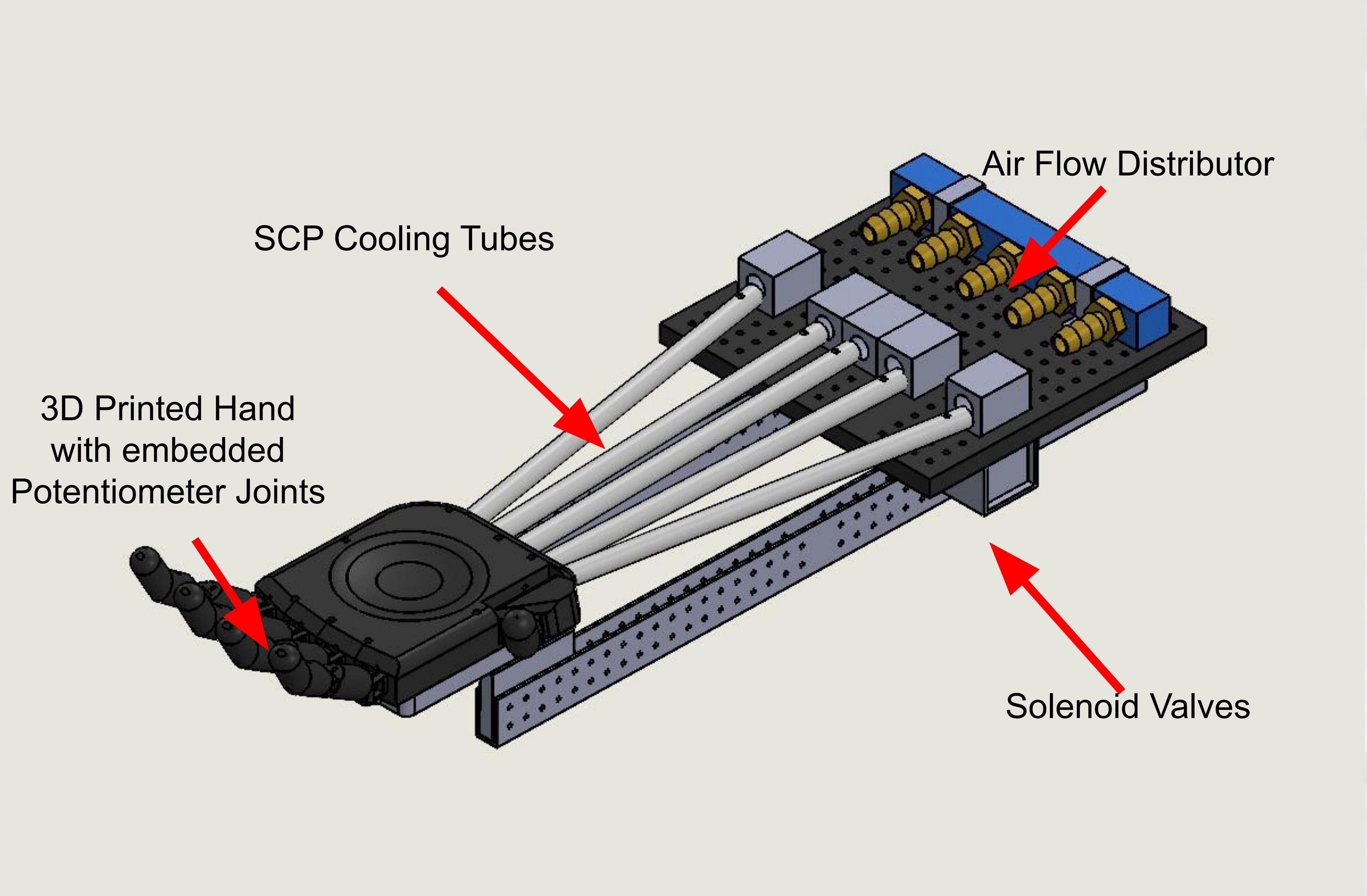
Supercoiled polymers (SCPs) are manufactured through a multi-step process. First, 50lb tensile strength nylon fishing line is wound with 30-gauge copper wire. Once this is complete, the wire is cut and the wound cable is spun in the opposite direction, creating a helical coil. After this, the SCP is heated to set the new natural position. After testing each one for electrical conductivity, the SCPs are ready to be conditioned.

Conditioning of Supercoiled Polymers

The fibers do not achieve high levels of strain immediately after being made. They require conditioning in order to meet or exceed the set goal of at least 13% strain. The SCPs are secured vertically with 300g hanging off the bottom of them, then 10V are applied to the fiber for 1.2 seconds. This is long enough for the SCP to contract fully without being in danger of melting. It is then allowed to cool for 2 minutes to expand fully. This is done 50 times before the SCP strain reaches a plateau and no longer increases after further conditioning. At this point, the strain is recorded and the SCP is tagged so that its maximum strain is known, and the SCP is added to a pool of conditioned fibers to be used in the final hand design.



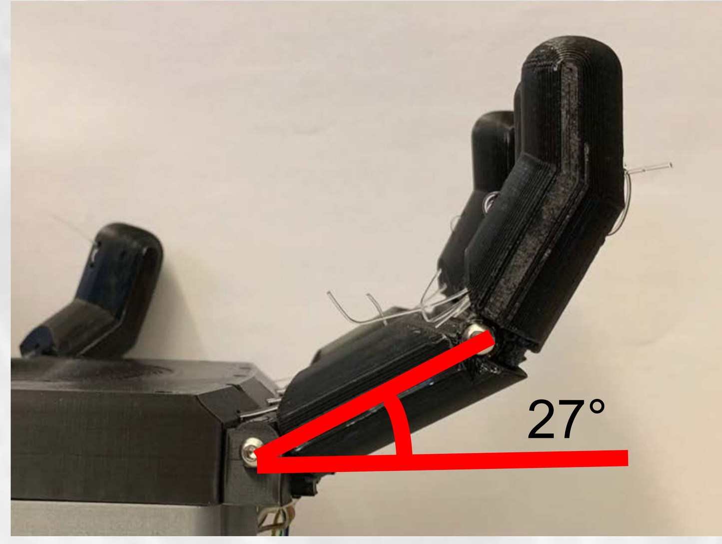
Robot Hand Design

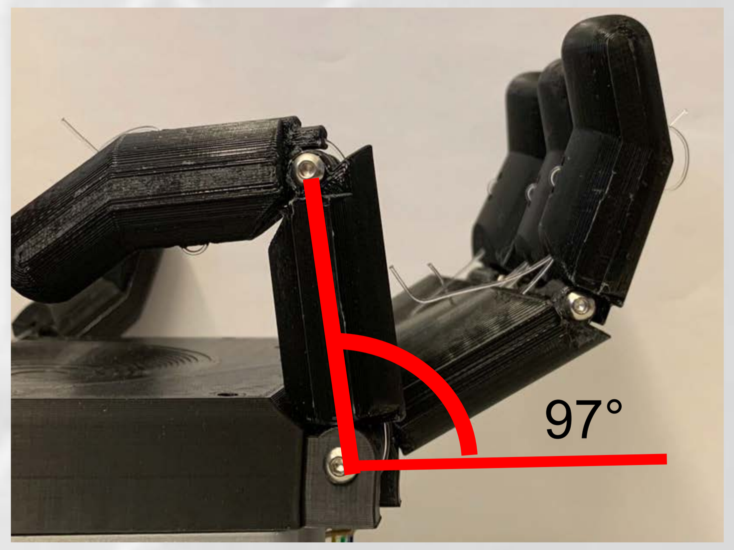


Objective	Metric	Target Value	Achieved Value
Each individual SCP needs to be able to contract with over 10% strain	% Strain	20%	13-20%
Each individual SCP must fully cool and relax	Cooling time (s)	<3 seconds	Average = 3.2
Voltage should allow for easy control of electrically heated SCPs	Voltage (V)	10-15V	10V
Finger needs to actuate with an actuation frequency of 0.2Hz	Actuation frequency (Hz)	0.2 Hz	0.17 Hz
First finger joint needs to go from a neutral position to a fully contracted position	Range of the angles of the first finger joint (deg)	0-90 degrees	27-97 degrees

Control of the Robotic Hand

Rotational potentiometers embedded within the first finger joint allow for angular control and relatable positioning of each finger. The designed hand allows for 70° of motion. Varying voltage and applied time controls the amount of strain.





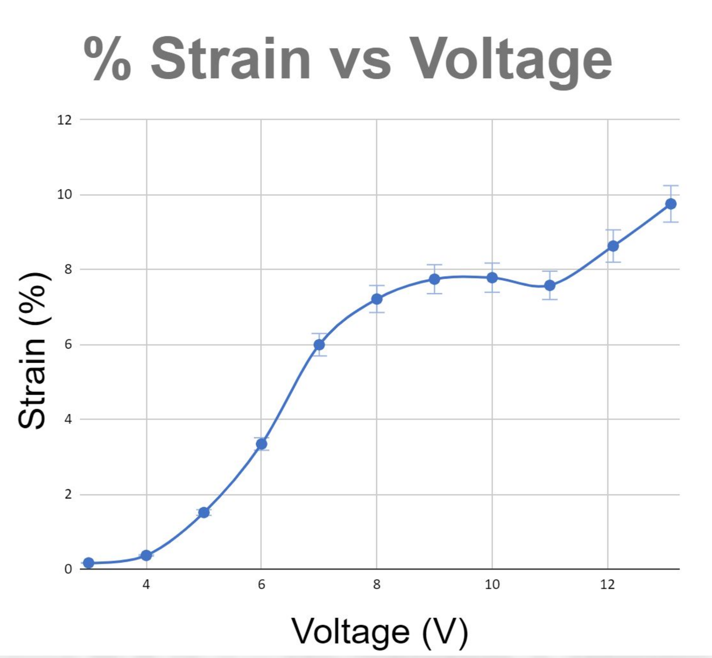


Figure 1: The percent strain the SCP achieves at different voltages while being heated for 1 second

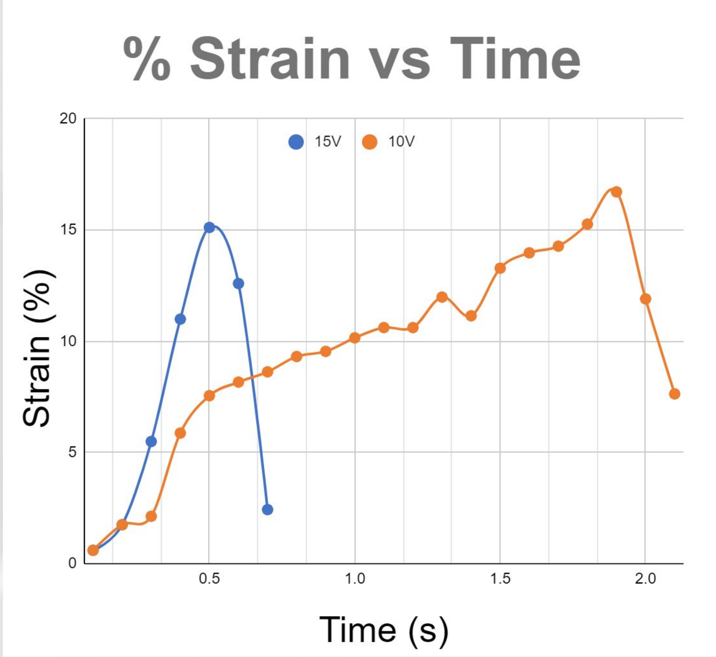


Figure 2: The percent strain that the SCP achieves dependent on time heated at 10V and 15V.

Conclusion and Future Work

SCPs have the ability to produce a large amount of force for being very light weight. Materials to construct SCPs are cheap and the manufacturing process can be fairly simple.
The limitations of SCPs as actuators are largely due to cooling and difficulty of position control. Since SCPs are actuated by heat, rather than electromagnetic forces, they require advanced cooling methods in order to be relaxed quickly. This makes precision of position control more difficult, since the actuation position vs. the voltage applied is not a strictly linear relationship. For SCPs to be successfully used in prosthetics, future work should involve research into advanced cooling methods and systems that are relatively small, so that they can be portable. It may also be helpful to develop a control system that implements temperature feedback as well as potentiometer feedback, to better control position and lessen the risk of melting the SCP.