A Shape-Memory Alloy Actuated Hand Exoskeleton

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Many musculoskeletal disabilities restrict motor hand movement to a degree that limits day-to-day function. The purpose of my research was to create a biomechanical glove that aides in finger movement for those with such disabilities. This was achieved by heating and cooling of shape memory alloy (SMA) wire laced into a finger of a glove. SMA wires have a unique ability in which they contract in length under a heated condition, and return to their original length under a cooled condition, producing a "shape memory" effect. The exoskeleton fingers can thus curl from wire contraction with resistive heating of the wires.

Two applications were tested with motion capture: (1) a 3D-printed finger and (2) a custom designed biomechanical glove. Data were also collected from a human finger to serve as an anatomical standard. For each finger, the angle that the mid phalange makes with the proximal phalange was calculated as a function of time. Motion capture data were processed so that the flexion of the 3D-printed finger and the biomechanical glove could be compared to that of the human finger.

The time to reach full flexion for the human finger, the 3D-printed finger, and the glove-assisted finger was approximately 1.2 s, 2.1 s, and 1.85 s, respectively; the change in the mid phalange joint angle over this time was 33.2 degrees, 64.7 degrees, and 29.8 degrees, respectively. Data from the 3D-printed finger and the human finger both show increasing values over time, indicating that the SMA wire in the 3D-printed finger was successful in actuating finger movement in the correct direction. The shape of the human finger flexion curve was different from that of the 3D-printed finger (linear vs exponential). This might be a result of greater joint friction in the printed finger than in the human finger, thus creating irregularity in the rate at which the 3D-printed finger actuates. The glove's flexion curve and the human finger's flexion curve were very similar in shape and range. The glove-assisted finger flexed at a similar rate as did the human finger. The similarity of the human finger flexion and the glove-assisted flexion demonstrates the glove's capability of actuating an impaired user's finger to produce natural, human-like movement.

This study demonstrates the performance of a custom-designed biomechanical glove that assists finger flexion through the controlled heating and cooling of SMA laced into the ring finger. Kinematic data of the 3D printed finger validate use of SMA wires for such finger actuation. The data from the glove-assisted finger and the human finger demonstrates that the glove can produce human-like finger flexion on an immobile hand. Future studies involve increasing actuation speed, load-carrying capabilities, and implementing a feedback control system for position and speed control of the fingers of the glove.

Statement of Research Advisor:

Sean has designed, built, and tested a powered hand exoskeleton that is actuated with shape memory alloy wire laced within a glove. His design has the potential to aid in hand movement rehabilitation and to provide strength augmentation to the user.
—Michael Zabala, *Mechanical Engineering*

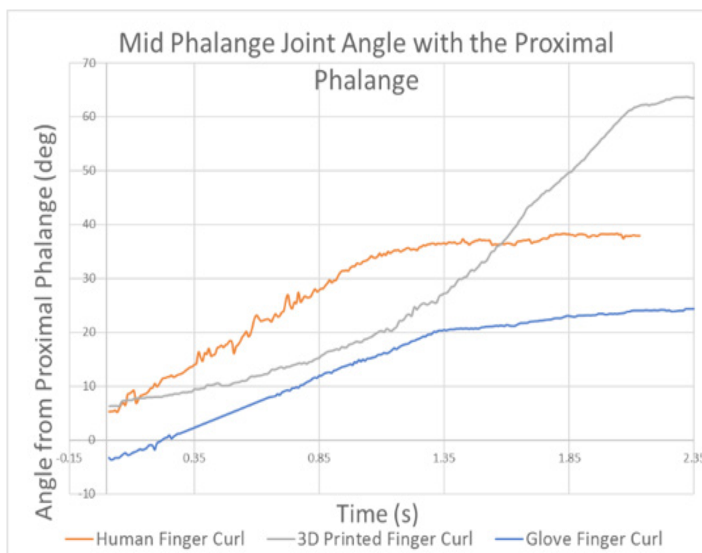

Figure 1. The joint angle that the mid phalange makes with the proximal phalange as a function of time during the flexion process of a human finger, 3D-printed finger, and glove-assisted finger.