Design of a Configurable Anthropomorphic Underactuated Hand

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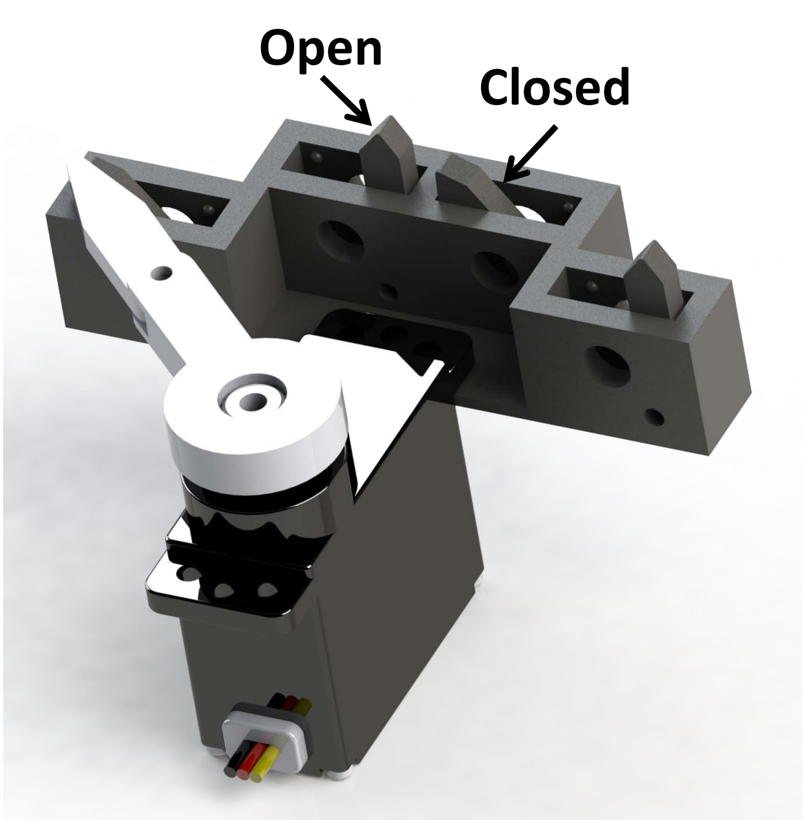
Abstract

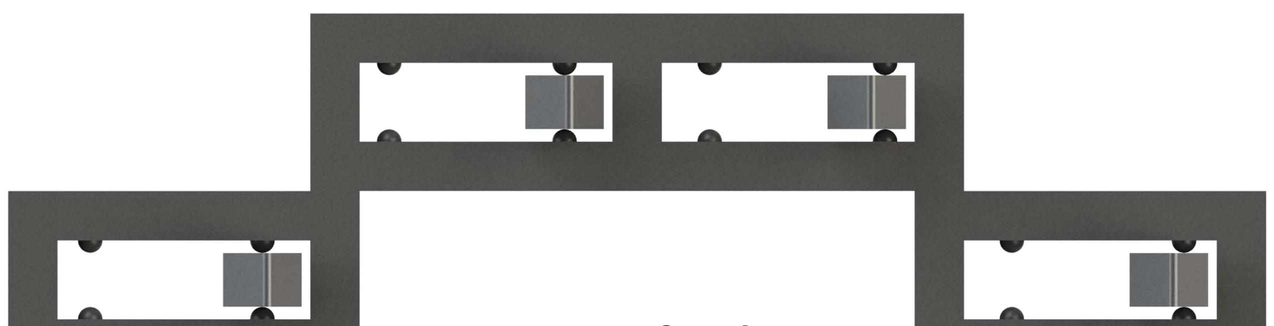
We present the design and fabrication of a configurable anthropomorphic underactuated hand for multipurpose manipulation tasks. In order to increase the versatility of an underactuated hand, a mechanical selector was introduced to individually control the actuation for each of the four tendon-driven fingers. The selector is controlled by a servo motor and the grasping motion is controlled by a DC motor. The body of the hand and fingers are 3D-printed from a rigid plastic while the antagonistic passive elastic members for the fingers are a silicone elastomer. Lastly, the hand uses a differential pulley system for an adaptive grasp.

Mechanical Selector



Setup of the Mechanical Gate

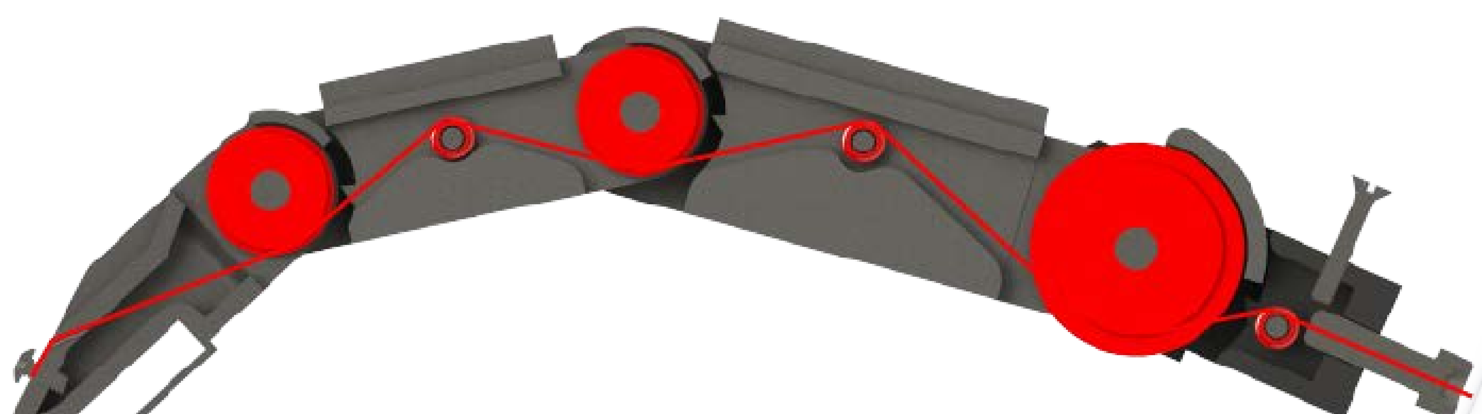
The mechanical selector is the key component which controls the actuation of each finger. If the gate is closed, then the finger tendon is physically blocked and thus the finger cannot actuate. Each gate is opened and closed by a servo motor, where a clockwise motion opens the gates and a counter-clockwise closes the gates. It is possible to choose which gates are opened and closed by either bypassing the gate by continuously rotating clockwise until it reaches the next gate or rotating counter-clockwise to close the gate and to continue to the next gate.



Top-View of Selector

Friction bumps keep each gate in position, so dynamically moving the entire hand will have no effect on the mechanical selector. The servo arm is hinged, allowing it to bypass gates that physically cannot move (the gate is against the wall). The servo arm can return to its original straight configuration due to passive elastic bands.

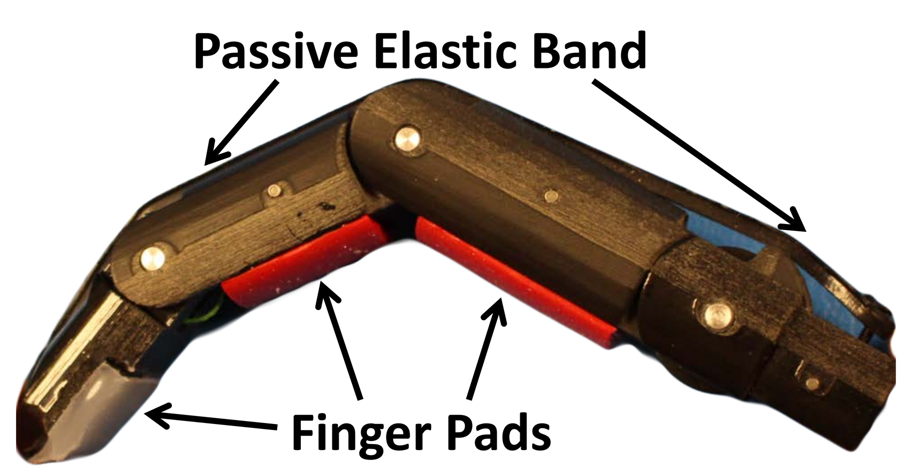
Finger Design



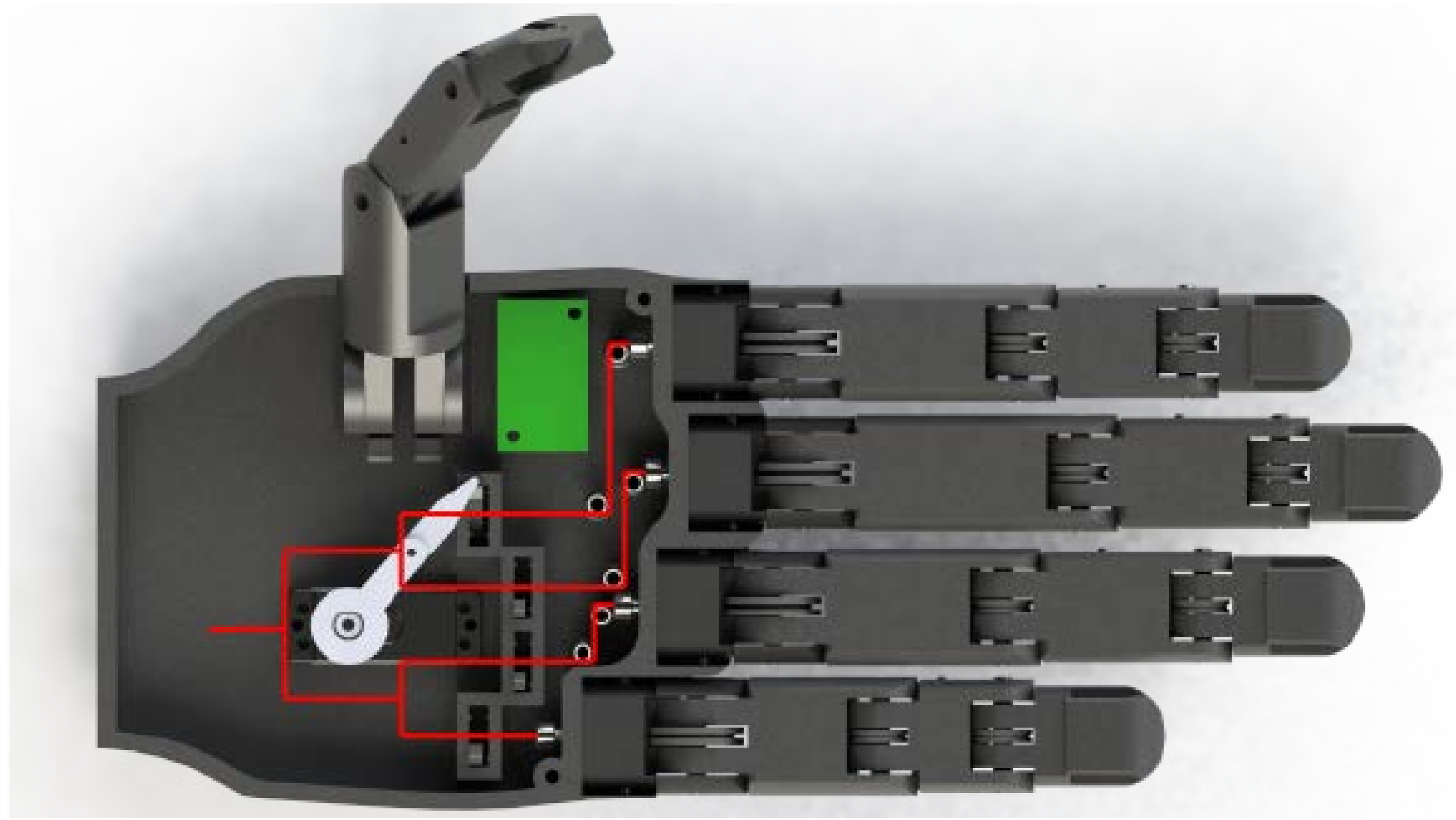
Cross-Section View of Finger

Tendon-driven fingers were chosen because they allow for a simple differential underactuated system. An antagonistic passive elastic band composed of a silicone elastomer pulls the finger back into its straight position. The trade-off with using the passive elastic band is making the system simpler at the cost of increasing the force needed to actuate the finger. However, the force can be reduced by lowering the minimal stiffness of the passive elastic band, which was done by incorporating idler pulleys decrease the friction between the tendon and the finger.

The fingers are 3D-printed from a rigid engineering plastic. 3D-printing allowed the fingers to have complex interiors and an anthropomorphic shape. The finger pads were molded from a silicone elastomer and glued onto the base of each phalange. Having a finger pad with a high friction coefficient greatly reduces the force needed to grip an object.

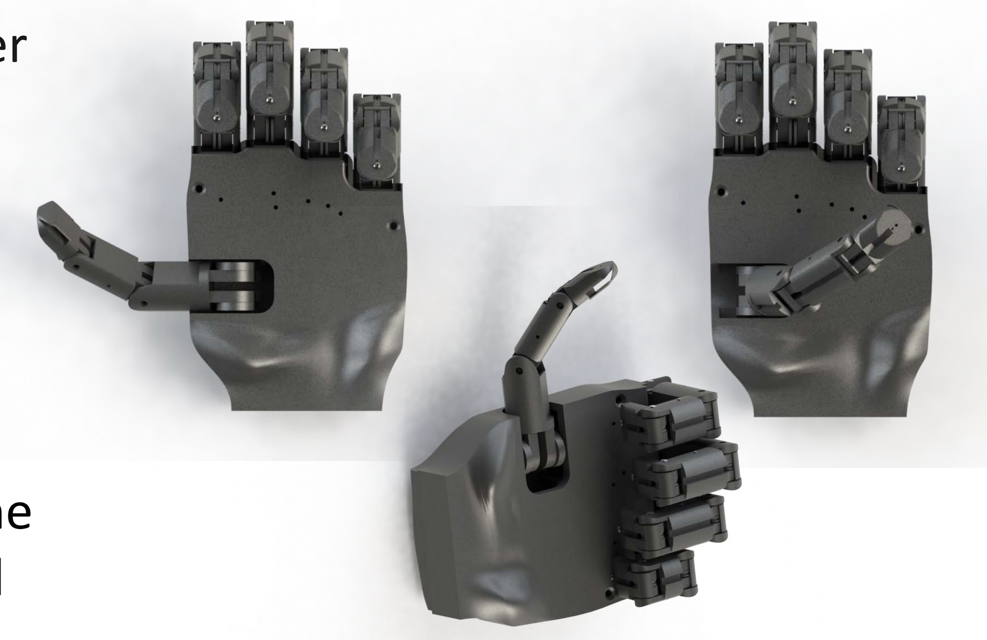


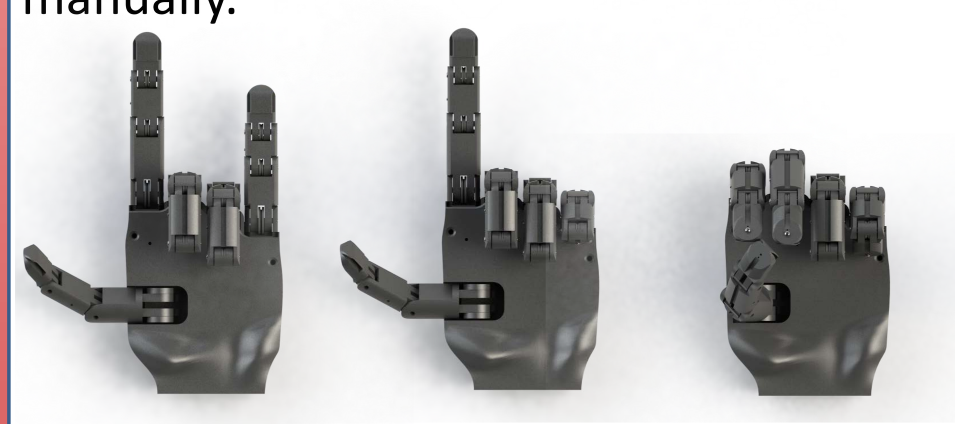
Hand Design



The anthropomorphic hand closely followed the geometry of an average human hand size, which required the internal components of the hand to be compact. The fingers are part of a underactuated differential pulley mechanism which allows for an adaptive grasp. The finger and thumb positions require the tendons to be re-routed, which are represented by red lines in the figure above. The structure of the hand is 3D-printed from the same rigid plastic as the fingers. However, since the structure is not complex, it is possible to minimally modify it to be CNC machined from aluminum, giving it the potential to be lighter and stronger.

The thumb is made similarly to the other fingers, with the exception that the thumb must manually be positioned to accomplish various grasping configurations. However, it is still actuated by the same motor that actuates the grasping motion of the fingers. The figures on the right show the range of the thumb, which is positioned manually.





In total, there will be 4^2, or 16 automatically adjusted configurations, in addition to 16 multiplied by many manually adjustable thumb positions.

Conclusion and Future Work

The configurable anthropomorphic underactuated hand is only be controlled by two motors yet it can achieve 16 automated configurations. By incorporating the mechanical selector, we were able to increase the versatility of a typical underactuated hand, all conveniently packaged into an average-sized human hand. Utilizing a tendon-based differential pulley system, the hand can also achieve adaptive grasping.

We plan to have the thumb be automatically adjusted, which will multiply the number of automated configurations the hand can produce. It will also be unique to be able to control the stiffness of the antagonistic passive elastic bands.

Acknowledgements

I would like to thank the Soft Robotics and Bionics Lab members and Dr. Yong-Lae Park for the advice and resources to work on this project, as well as the RISS Program for the opportunity to work here over the summer.

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