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# The Schulich Hand

## Underactuated Robot Hand Capable of In-Hand Manipulation

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ROBOTARIUM

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## Introduction

Bio-inspired robotics are required to bridge the gap between autonomous mechanical design and intricate biological systems.

**The purpose of this project is to design an underactuated robot hand capable of in-hand object manipulation.**

Underactuation and in-hand object manipulation have generally been independent to one another [1].

- Underactuated systems have less actuators than degrees of freedom (DoF).
- In-hand manipulation is significant motion without losing grip or regrasping of an object.

Combining these two concepts will increase the dexterity and efficiency of underactuated hands and the simplicity and cost-effectiveness of hands with in-hand manipulation.

Applications of this design:

- Autonomous search and rescue after disasters.
- Limb replacement in biomedical prosthetics.
- Exploration of inaccessible or dangerous locations.

## Objectives

Design requirements:

- Size of an average human hand
- Have at least 3 phalanges
- Materials suitable for harsh environments
- Support objects up to 10kg
- Weight less than 600g
- Bilaterial configuration
- Maximum of 1 motor per finger
- Have a universal wrist mounting system

Objective Motions:

| | | | |
|---|---|---|---|
| Pen | Longitudinal Translation >5° | Long-axis Rotation >180° | Short-axis Rotation >5° |
| Ball | Palm-to-Fingertip Translation >2cm | In-Palm Rotation >5° | |

Legend: Objective Grips | Tip Pinch | Key Pinch | Tripod Pinch

*Figure 1: Objective Grips (left to right) Tip, Key and Tripod Pinches*

## The Schulich Hand – Design and Specifications

Torsional Springs

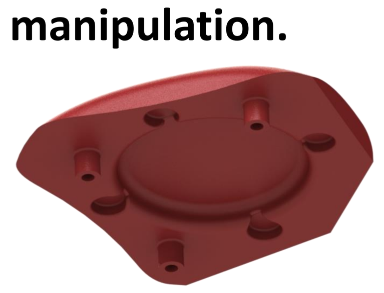
- Allows passive extension, the key to under actuation.
- Located on all flexion joints.

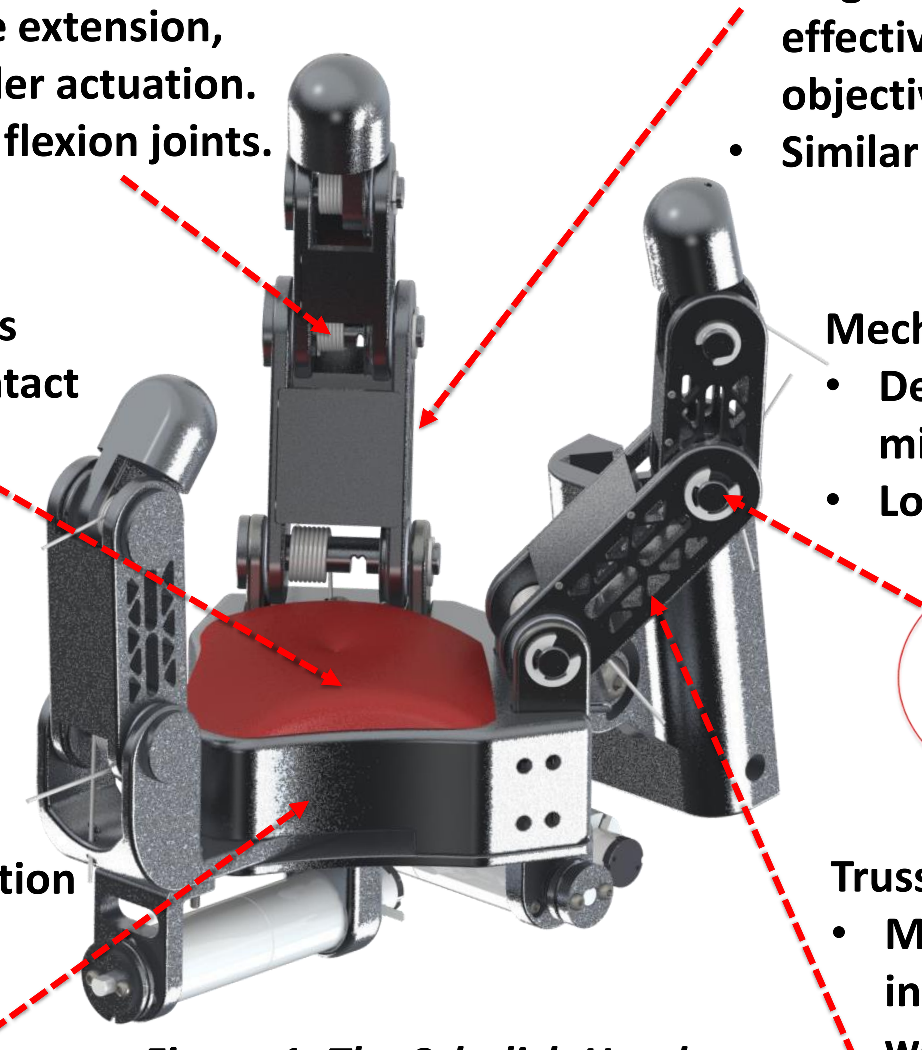
Dimensions and Geometry

- Fingers and thumb can effectively produce objective grips.
- Similar size to human hand.

Palm Surface

- Interchangeable surfaces define an additional contact surface for object manipulation.





Mechanical Limiters

- Defines maximum and minimum joint angles.
- Located at every joint.

Stepper Motor

- Thumb adduction/abduction
- Max Torque: 0.18 Nm
- Step Angle: 1.8°

Truss Pattern

- Maintains structural integrity while reducing weight.

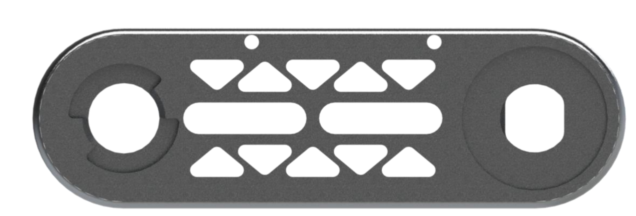


*Figure 1: The Schulich Hand*

Wrist Mount

- Universal mounting system.
- 3 locations maximize configurability.

Tendon Routing:

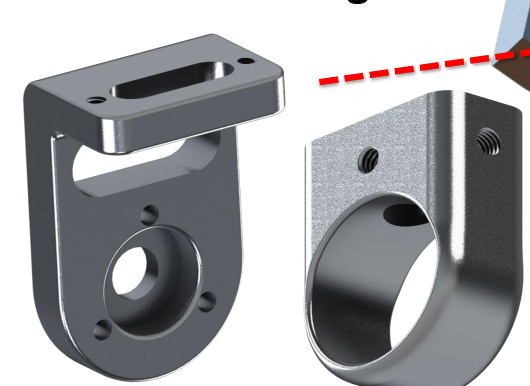
- Converts motor rotation into joint rotation.
- Responsible for fingertip path of motion.

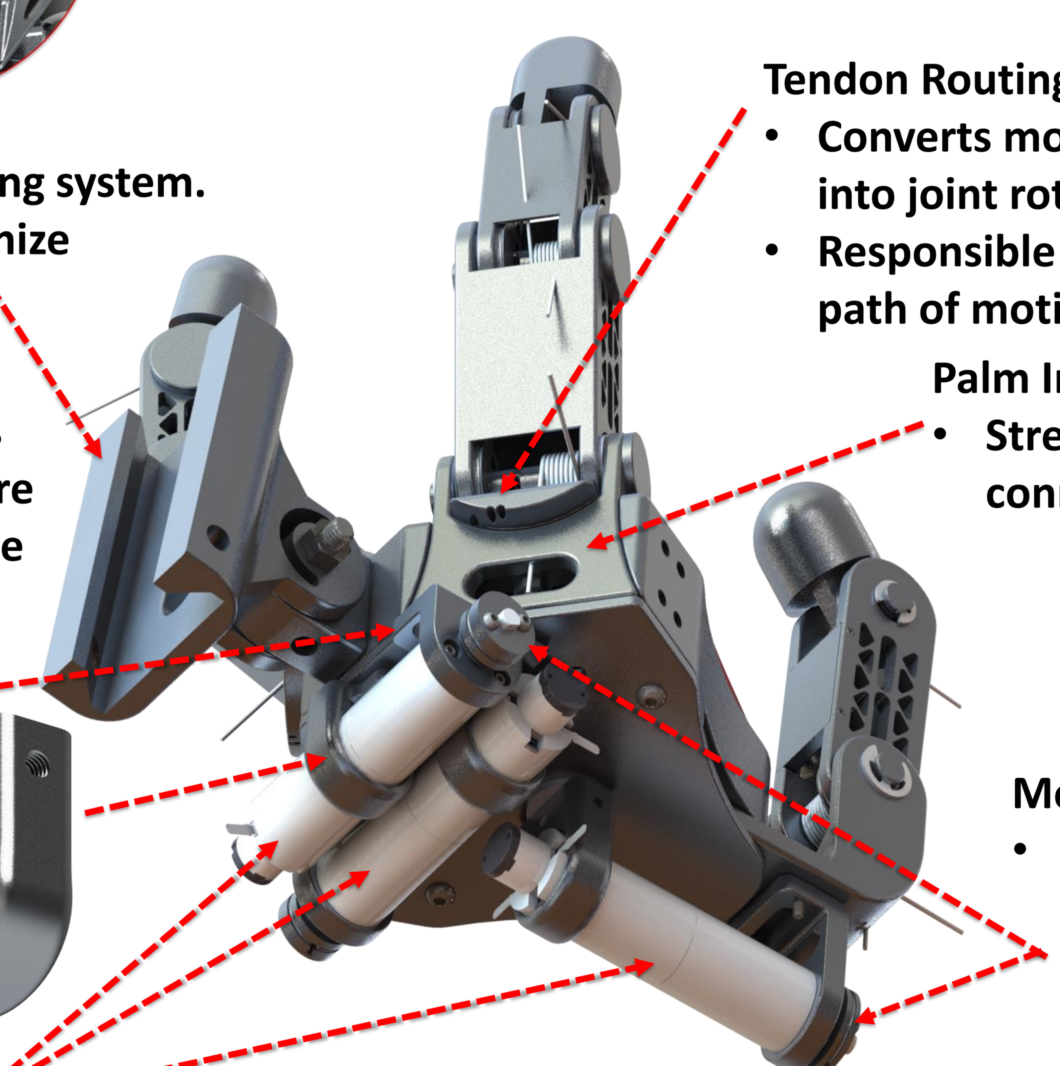
Motor Mounting:

- Secures the motors and ensures they are in place for effective tendon routing

Palm Inserts

- Strengthens the finger's connection to the palm.





Motor Pulleys

- Transfer torque from the motor output shaft to the joints.

DC Motors

- Finger and thumb flexion
- Max Torque: 0.7 Nm
- Weight: 26g

*Figure 2: The Schulich Hand - Underhand View*

## Engineering Analysis

Motion and power analysis was performed to design/select the components of the hand such as springs, motors, pulleys, etc.

$$T_{stepper} = m_{object} g\mu \sin(\emptyset) + m_{thumb} g r_{o,c}$$

$$T_{joint} = mg\sin(\emptyset) + k\theta_{max}$$

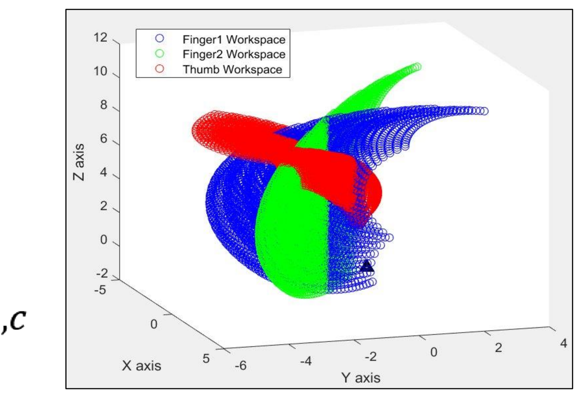


*Figure 3: Manipulative Workspace*

Torque, pulley diameter, rotational position and velocity are dependent on pulley ratios between the motor and joints. (*Equation 3*). Path planning for each grip depends on pulley ratios (Fig. 4)

$$\frac{T_2}{T_1} = \frac{d_2}{d_1} = \frac{\theta_1}{\theta_2} = \frac{\omega_1}{\omega_2}$$

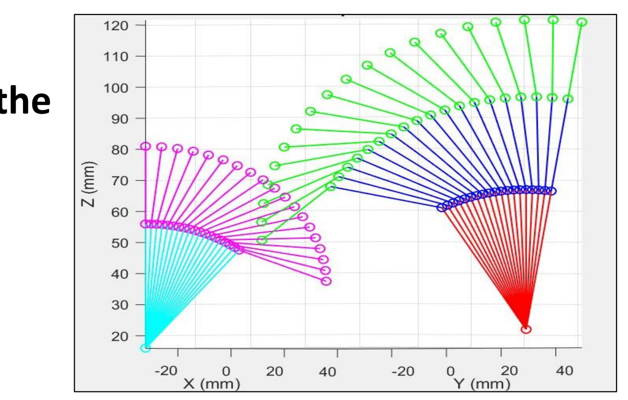


*Figure 4: Tip Pinch Trajectory Planning*

## Simulation Results

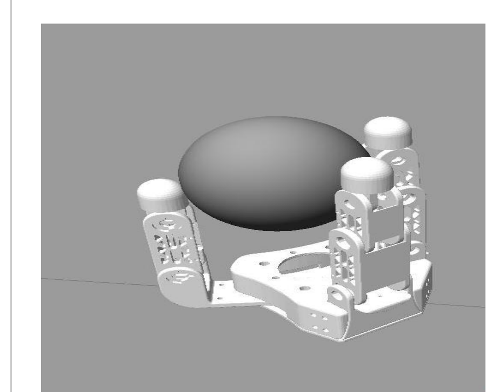


*Figure 5: Max tripod.*

MoveIt software and derived engineering equations were used for theoretical and simulation work.

| Grip | Max. Object Size | Min. Object Size |
|---|---|---|
| Tip | 121.38 mm | 0 mm |
| Key | 39.92 mm | 17.61 mm |
| Tripod | 117.12 mm | 38.70 mm |

*Table 1: Object sizes for each grip*

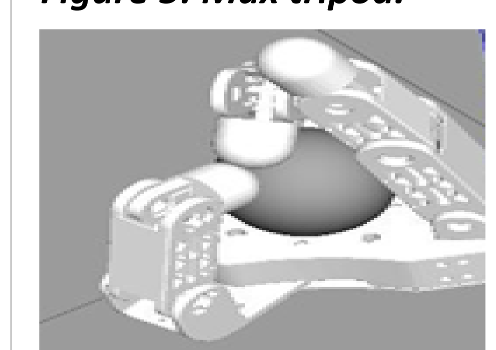


*Figure 6: Secure object grip*

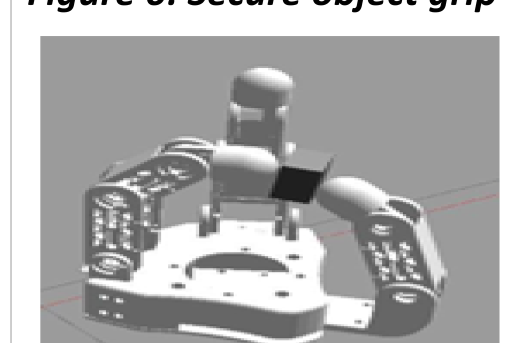


*Figure 7: Sample Tip pinch*

- Figure 5: Displays our simulation results while iterating for defining maximum object sizes.
- Figure 6: Demonstrates how our hand can be used to securely grip an object, which is useful in search and rescue operations.
- Figure 7: Illustrates the Schulich Hand's precise tip pinch grip capability, which corresponds to our MATLAB-modeled trajectory planning (Figure 4), which is critical for handling delicate tasks.

## Conclusions

Conclusion Statement: We successfully achieved our primary project objective of designing an underactuated robot hand with a final mass of 530g capable of in-hand object manipulation and fulfilled all design criteria.

Next Steps:

- Verification of simulation results. Physical hand testing under a variety of operating conditions with a variety of objects.
- Implementation into The Robotarium Lab's Humanoid Project for autonomous search and rescue operations.

## References

1. A. Ramirez-Serrano, "Humanoid Robot," *UVS Robotics Lab*, 2018. https://www.uvs-robotarium-lab.ca/humanoid-robot (accessed Mar. 22, 2024).
2. Team 11, "Tendon and Actuation System for High Speed Three-Fingered Robot Hand," *Department of Mechanical Engineering, University of Calgary, 2012 (accessed Mar. 22, 2024)*

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