Flexible Robotic Origami Gripper (FROG)

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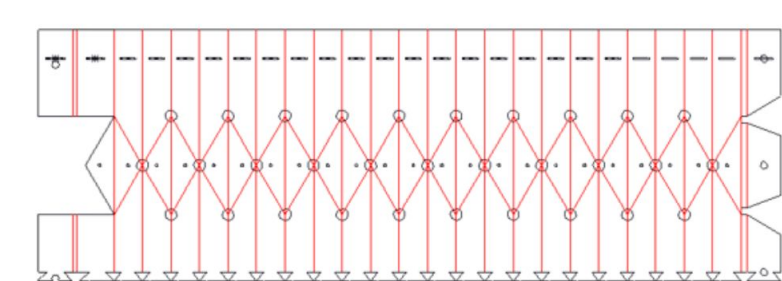
Abstract

Origami robots have been introduced as a new soft robotic technology that can be easily constructed from planar sheets of material to create **rigid or deformable linkages**. With this Major Qualifying Project, the team investigated the capabilities of a modular soft robotic gripper with **triangular beam** and **Yoshimura** origami finger designs folded from PET plastic. Due to its origami design, the gripper is **lightweight, flexible, and durable.** A vision system working in conjunction with an impedance controller aided the gripper to determine and provide **three stable grasp patterns** to pick up an assortment of objects. The implementation of a switching control system has demonstrated the need for more adaptive control for this compliant gripper. This project provides a foundation for future research into origami grippers.
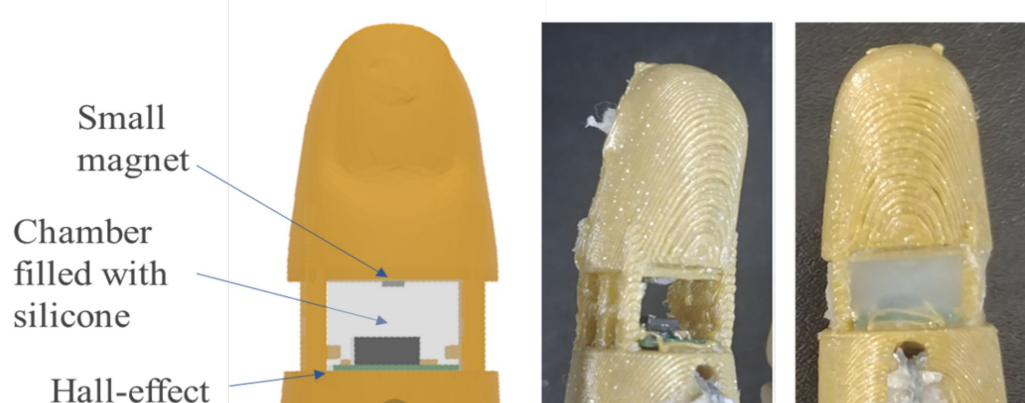
Background
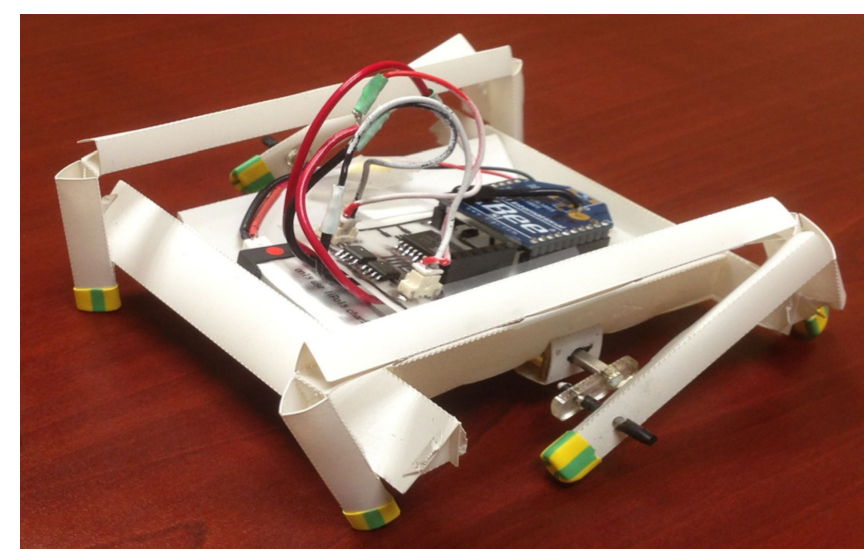
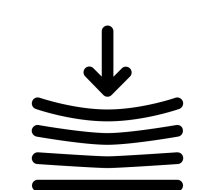Foldable Hexapod Robot Triangular Beams [1]

Small magnet
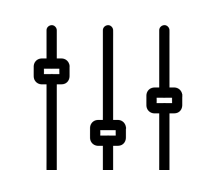Chamber filled with silicone
Hall-effect PCB

Force Sensing Fingertip [2]

Origami Yoshimura Module [3]

Goals and Objectives

Create a flexible robotic origami gripper that can recognize and grasp objects.

- Analyze benefits of origami folded soft materials as components of the gripper
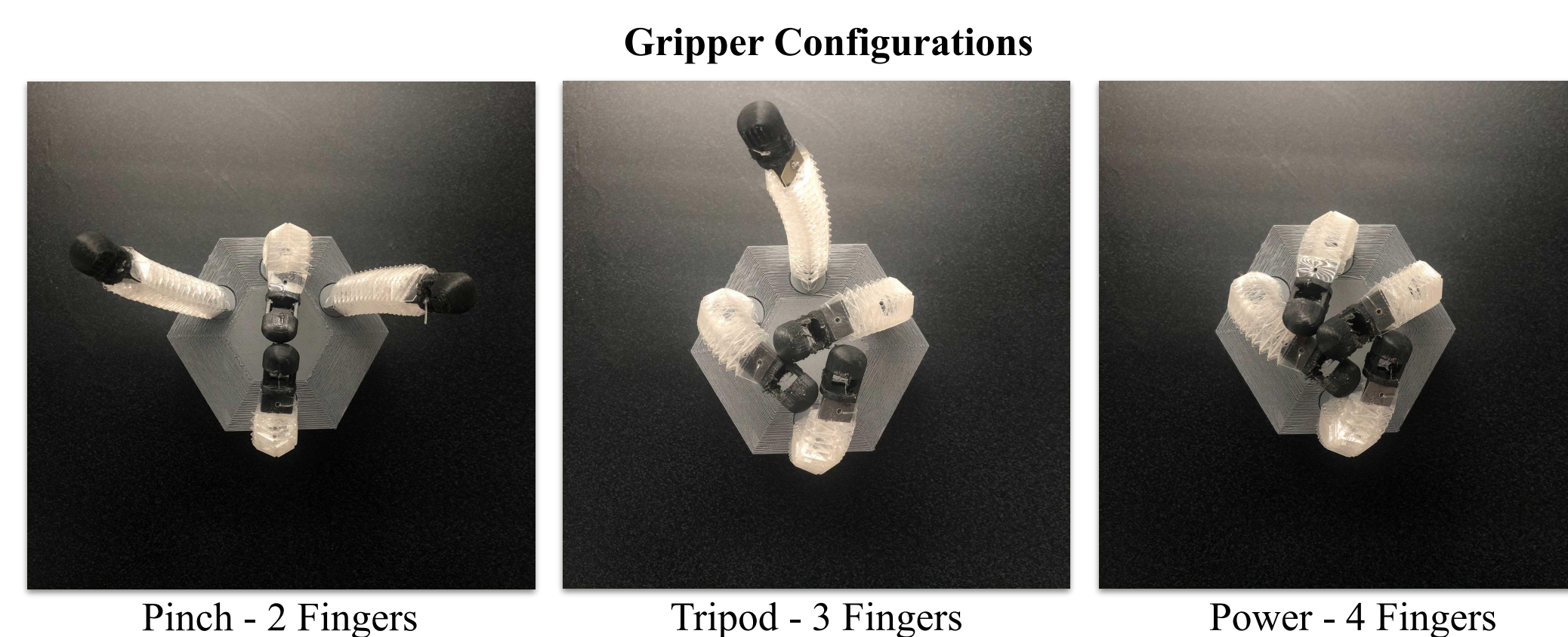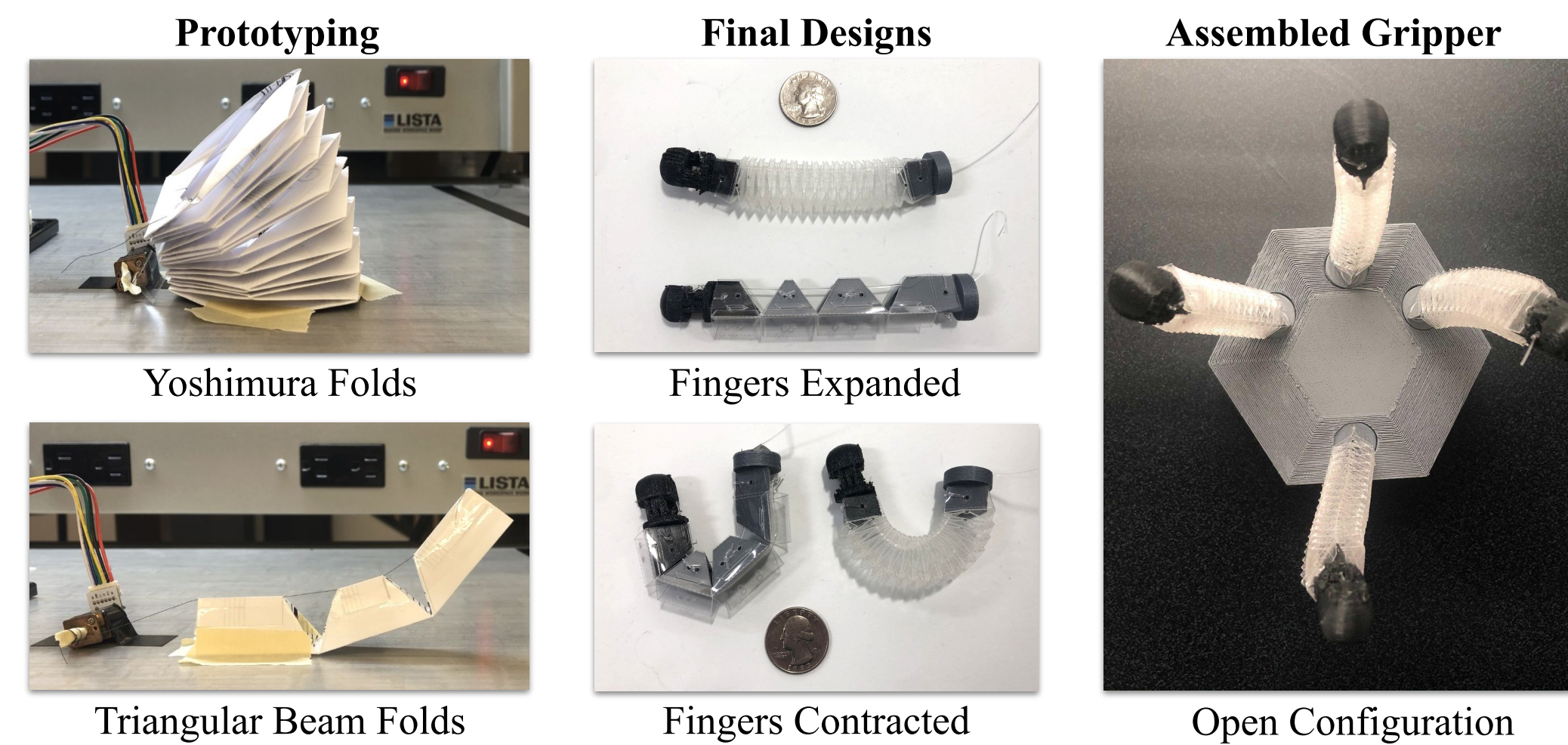- Control the movement and strength of the robotic gripper using switching control
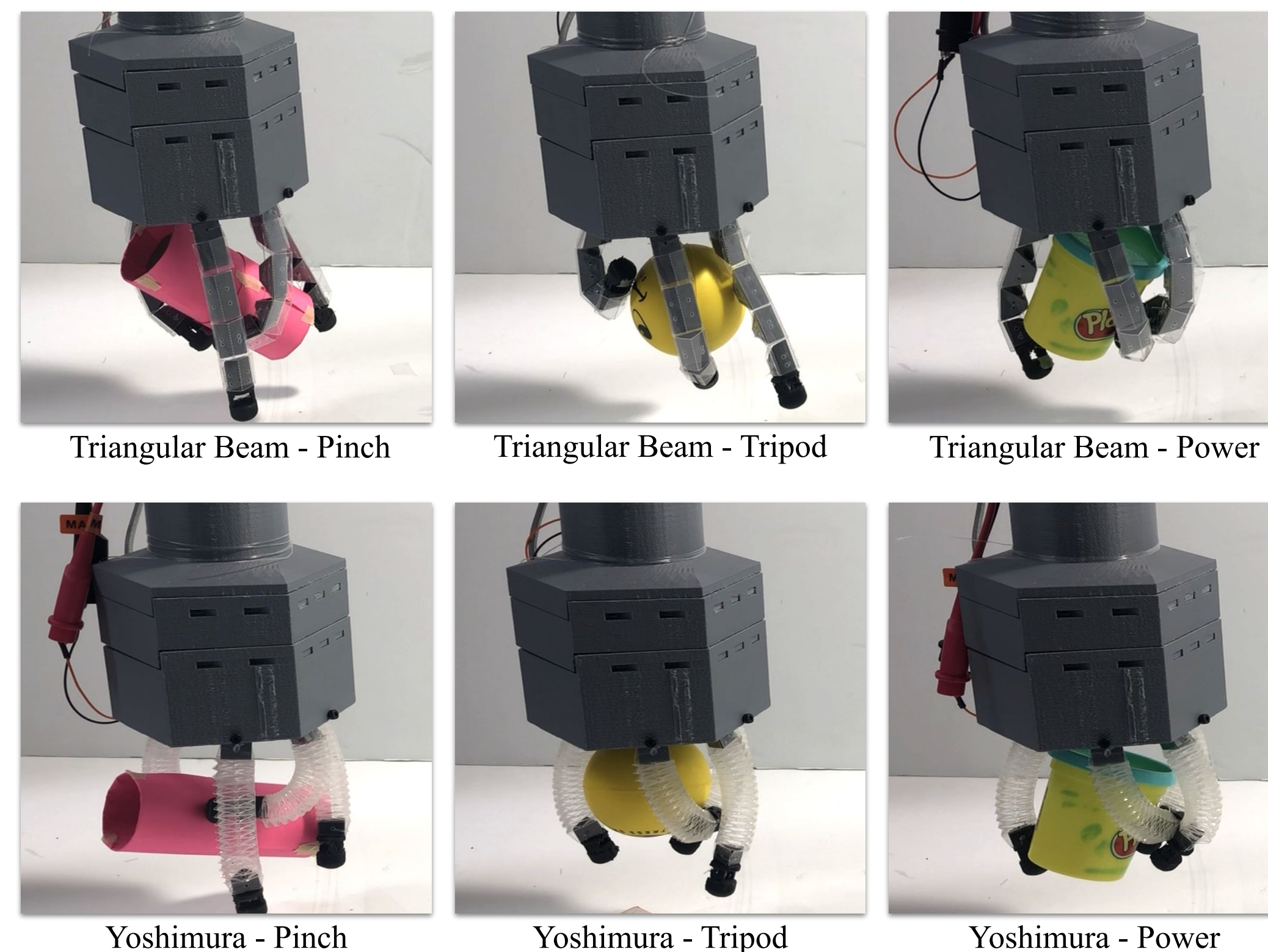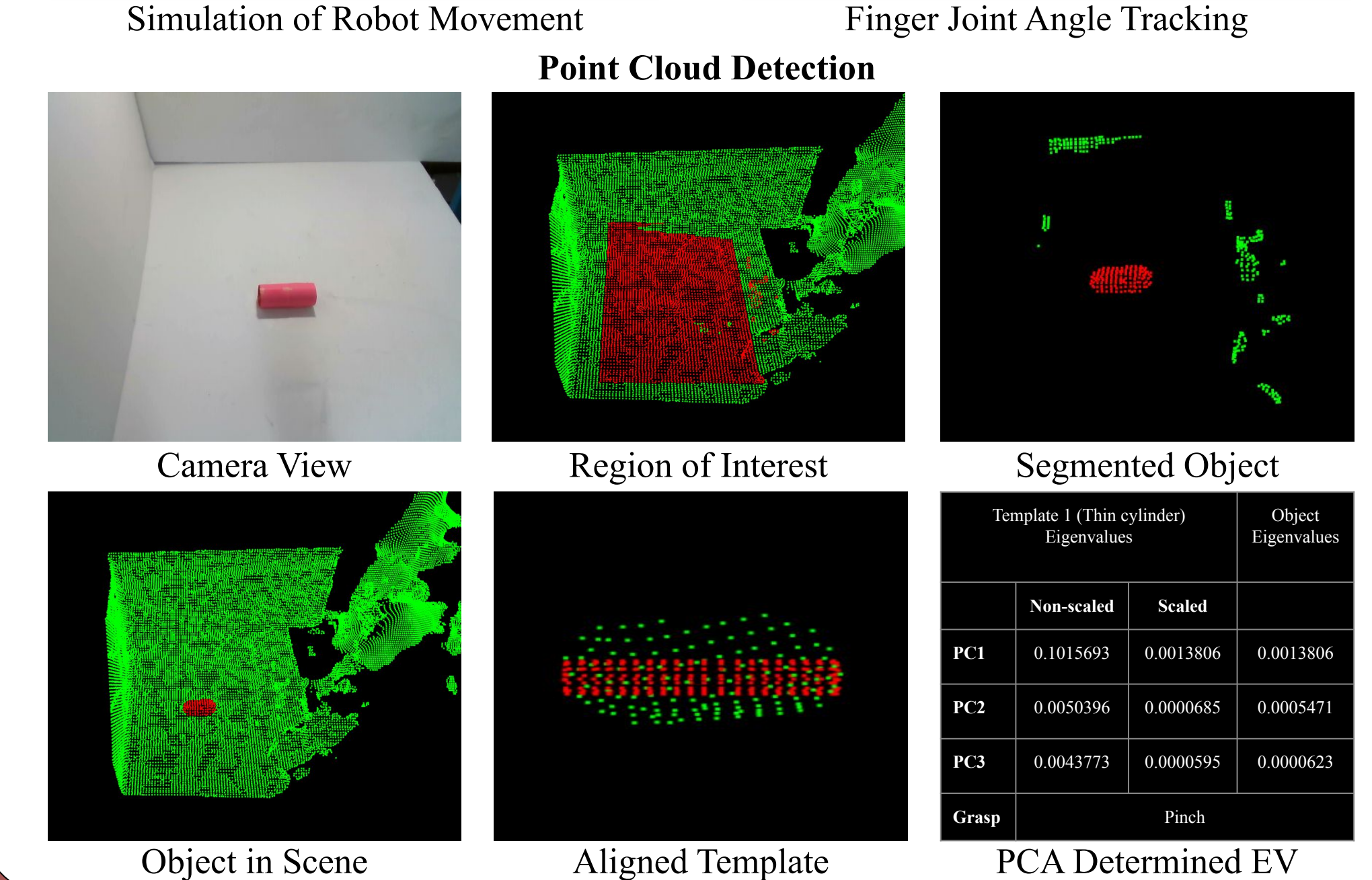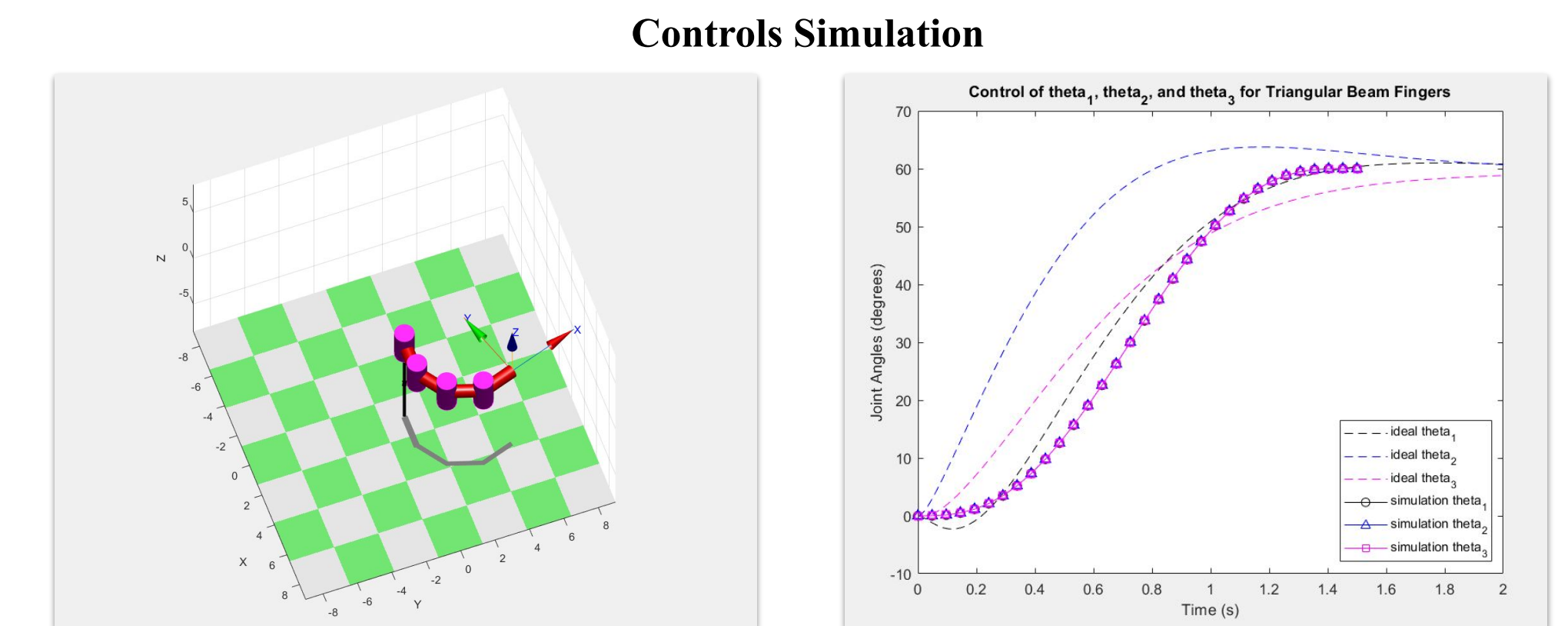- Utilize computer vision to augment the gripper's capabilities

Mechanical Design and Grasp Experiments

Prototyping

Yoshimura Folds

Triangular Beam Folds

Final Designs

Fingers Expanded

Fingers Contracted

Assembled Gripper

Open Configuration

Gripper Configurations

Pinch - 2 Fingers

Tripod - 3 Fingers

Power - 4 Fingers

Triangular Beam and Yoshimura Finger Grasps

Triangular Beam - Pinch

Triangular Beam - Tripod

Triangular Beam - Power

Yoshimura - Pinch

Yoshimura - Tripod

Yoshimura - Power

Modeling, Control, and Object Detection

Controls Simulation

Control of theta$_1$, theta$_2$, and theta$_3$ for Triangular Beam Fingers

Simulation of Robot Movement

Finger Joint Angle Tracking

Point Cloud Detection

Camera View

Region of Interest

Segmented Object

Object in Scene

Aligned Template

PCA Determined EV

Template 1 (Thin cylinder) Eigenvalues		Object Eigenvalues
	Non-scaled	Scaled	
PC1	0.1015693	0.0013806	0.0013806
PC2	0.0050396	0.0000685	0.0005471
PC3	0.0043773	0.0000595	0.0000623
Grasp		Pinch	

Recommendations

- Experimentation of different joint stiffnesses along the triangular beam finger
- Exploration of Yoshimura and triangular beam finger combinations
- Improve upon the control to incorporate a closed-loop control system
- Improve upon detection of smaller and irregular objects

References

[1] S. G. Faal, F. Chen, W. Tao, M. Agheli, S. Tasdighikalat, and C. D. Onal, "Hierarchical Kinematic Design of Foldable Hexapedal Locomotion Platforms," *Journal of Mechanisms and Robotics*, vol. 8, no. 1, Aug. 2015.

[2] A. M. Votta, S. Y. Gunay, D. Erdogmus, and C. Onal, "Force-Sensitive Prosthetic Hand with 3-axis Magnetic Force Sensors," presented at the *2019 IEEE International Conference on Cyborg and Bionic Systems (CBS)*, Sep. 2019.

[3] J. Santoso, E. H. Skorina, M. Luo, R. Yan, and C. D. Onal, "Design and analysis of an origami continuum manipulation module with torsional strength," presented at the *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Sep. 2017.