

Phlexor: A Force Controlled, Synergy-Based Hand Exo for Grasping Assistance

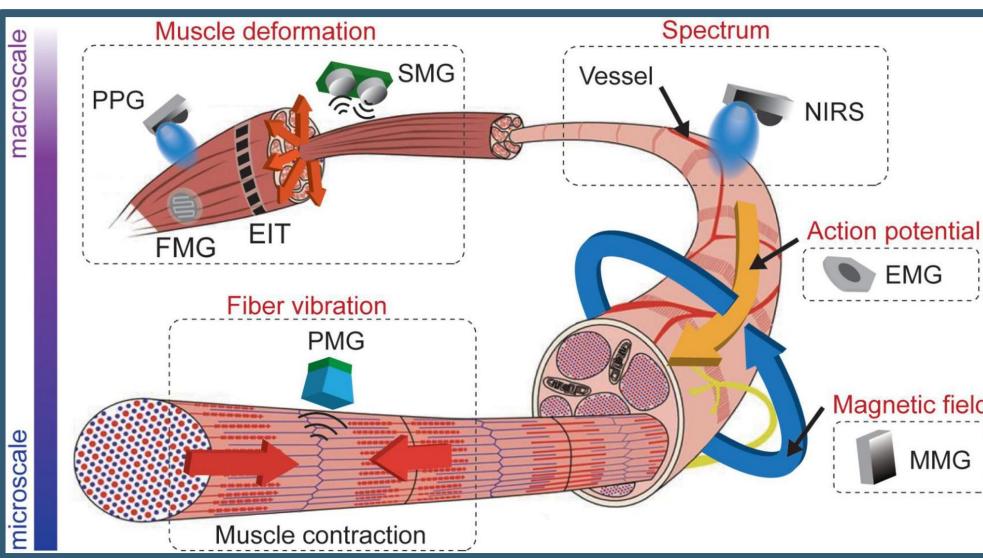
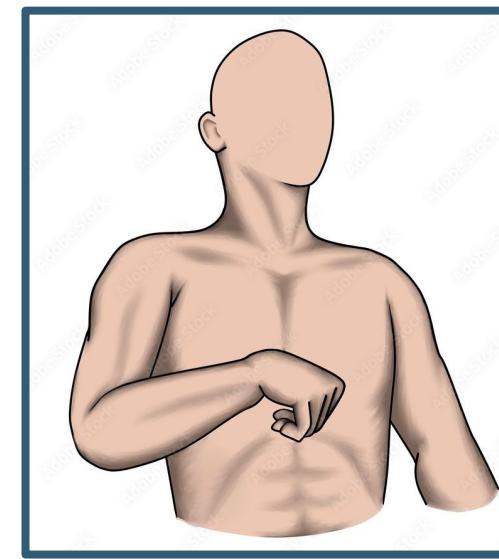
Diya Bengani¹, Akul Dixit¹, Catherine Qu¹, Quentin Sanders^{1,2}

¹Department of Bioengineering, College of Science, George Mason University ²Department of Mechanical Engineering, College of Science, George Mason University

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Introduction

As a result of stroke, millions across the United States struggle with limited upper extremity function, specifically limited hand dexterity. Hand exoskeletons are designed to improve and restore hand motor function as well as quality of life.



Providing robust and intuitive user control remains challenging due to reliability issues or limited applicability to daily life scenarios.

Phlexor allows its user to perform Acts of Daily Living, through intuitive control guided by a force sensor, compliant clasps for easy donning/doffing, and lightweight actuation, which simulates the natural postural synergies of the hand..

Design Criteria and Methods

Actuation:

- Tendon vs. Push/Pull (pulley vs. linear actuators)
- Pneumatics vs. Linear Actuators

Thumb Opposition:

- Fixed vs. Adjustable
- Methods of adjusting
- Which DoF to actuate

Clasps:

- Wrapping vs. Clipping
- Differences in material compliance

Control Methods:

- EMG, switch-based, wrist control via flex sensor, voice control
- Standalone sensor, springed FSR

Experimentation Methods:

- Phlexor's dimensions, actuation, and control methods were compared to other hand exos on market
- Dynamometer used to calculate force output

Design Criteria:

Dorsal side volume: 5x5x3cm
Weight: 200g
Fingertip force: 10N
Accuracy: 90% accuracy, 300ms delay

Final Design

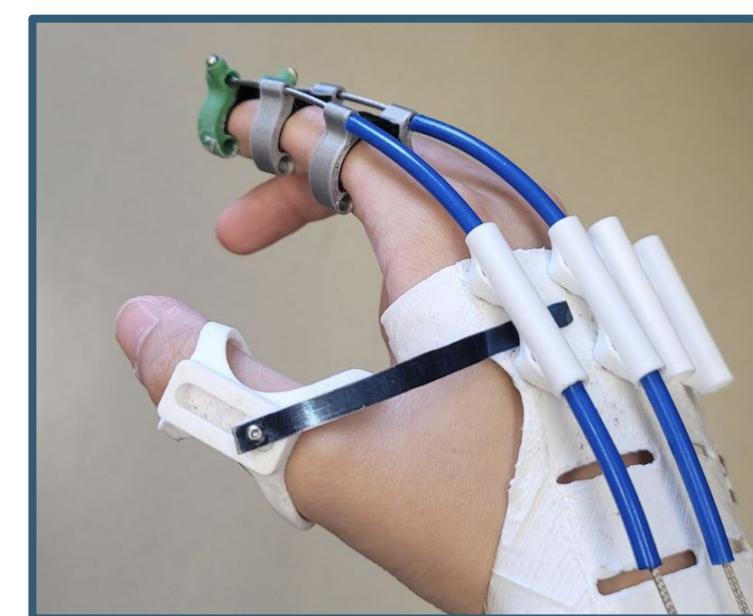
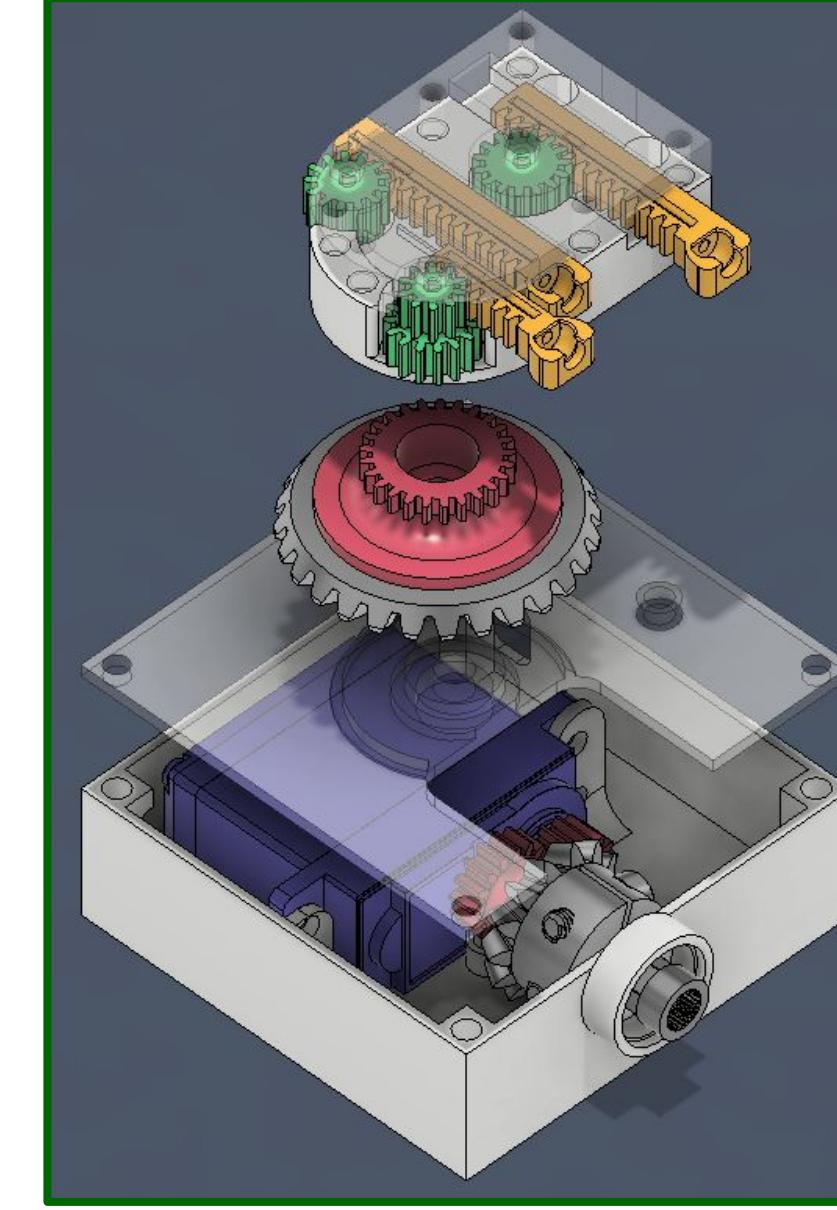
Actuation

High-torque servo to actuate bowden cables

Bevel gear allows gearbox to be parallel with servo, increasing space efficiency

Three rack and pinions with various-sized spur gears simulate hand postural synergies

Durable custom 3D printed nylon gears

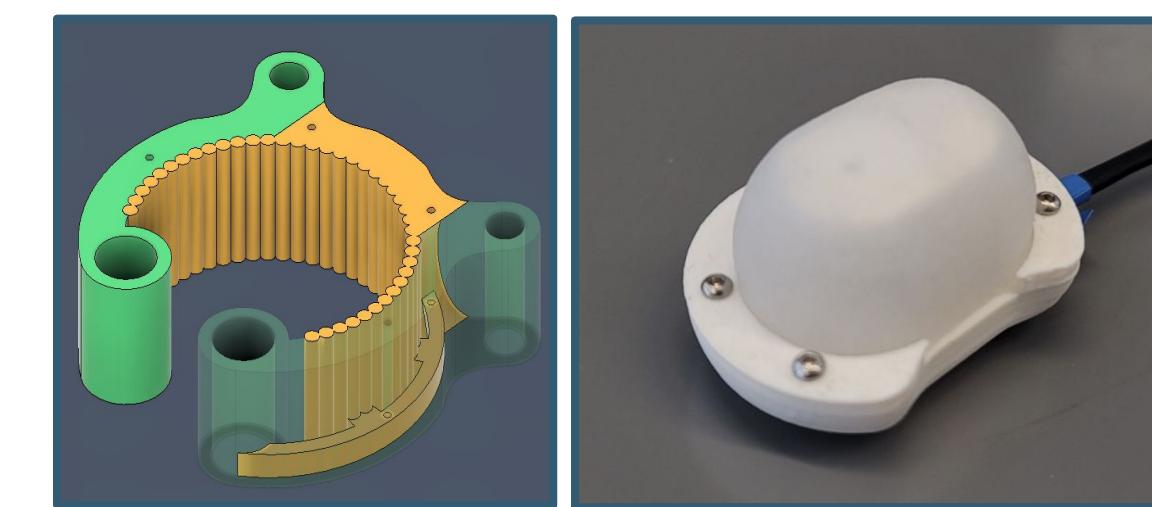


Thumb Opposition

User-adjustable design

Three preset positions

Magnetic locking mechanism



Clasps

Open compliant design

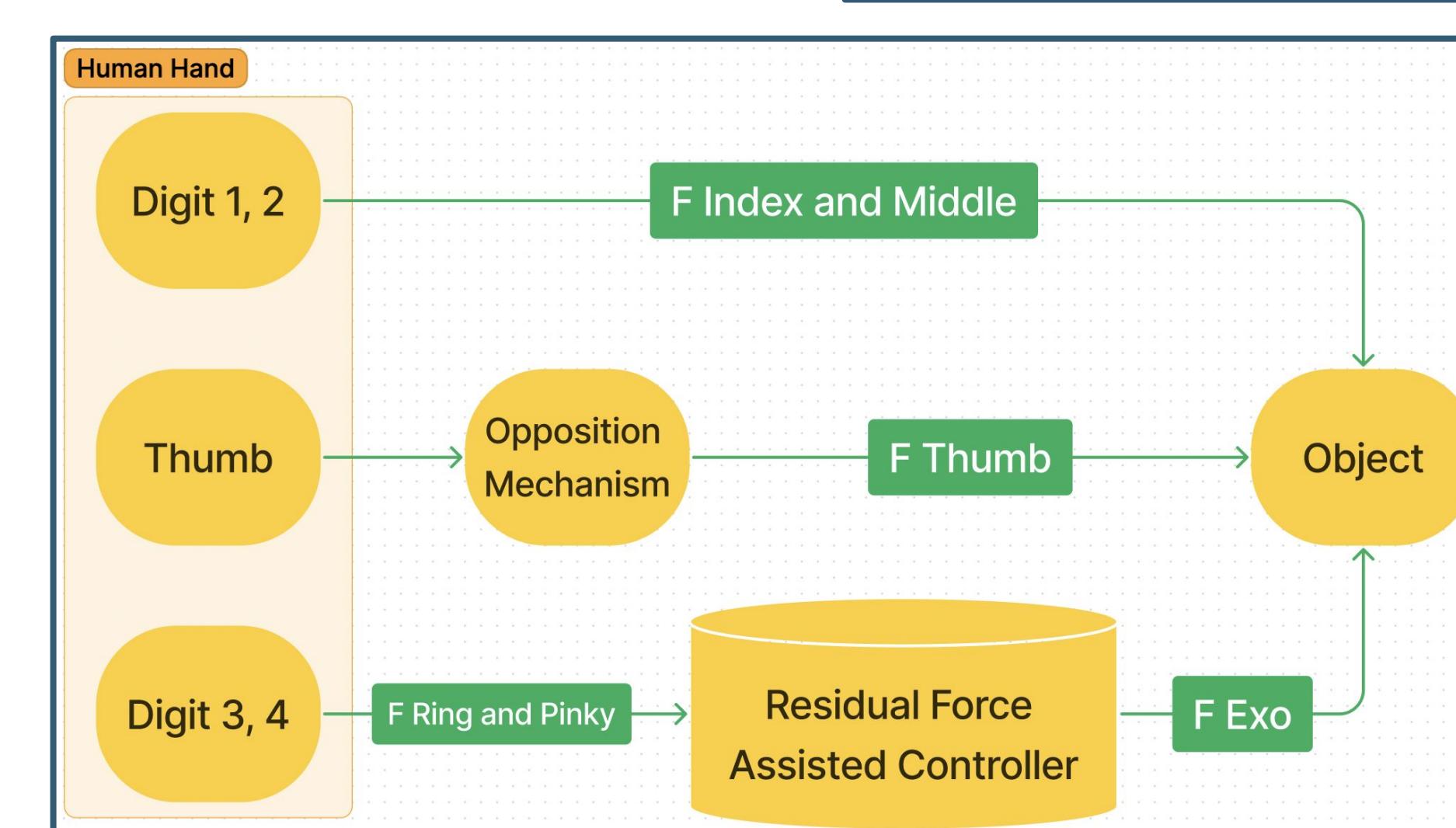
Combination of PLA and TPU for rigidity and flexibility

Button

Silicone casing

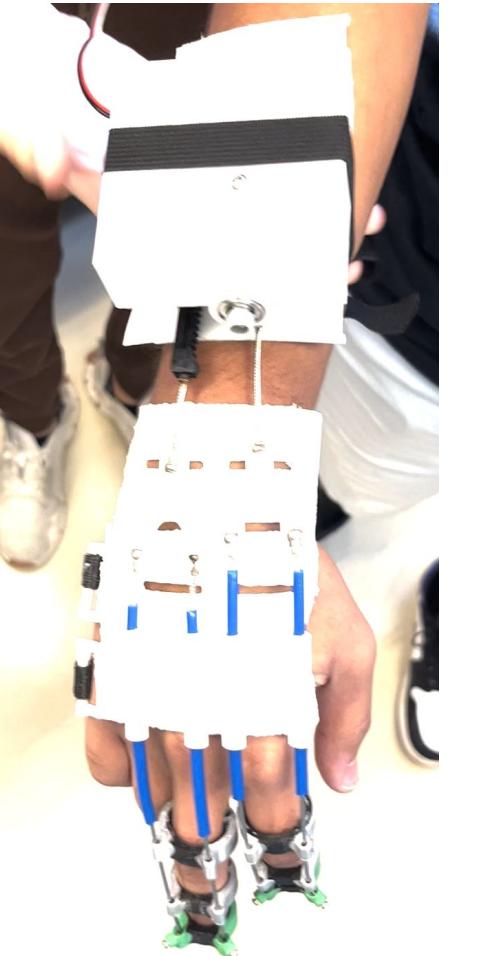
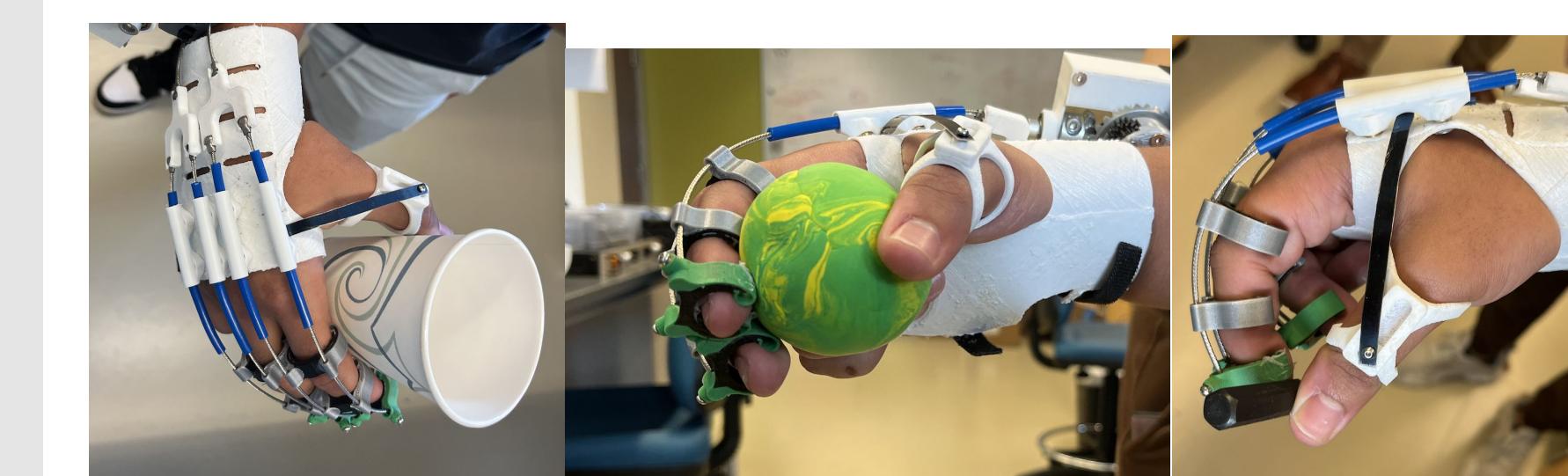
Spring-loaded design for intuitive control

Control



Results

Design characteristic	Phlexor	Bützer et al.	Exo-glove poly II
Supported fingers	2 + Thumb	4 + Thumb	2
Distal mass (g)	109	148	104
Proximal mass (g)	221	52	1140
Actuation method	Bowden cable	Compliant mechanism	Tendon
Actuation location	Forearm	Backstrap	Freestanding
Control method	Force sensor using residual isometric grip force	Smart phone interface	Freestanding intention button



Conclusions and Future Work

The inexpensive design prioritizes a lightweight and compact profile on the hand and arm while achieving smooth movement.

Future studies look to validate the functionality of Phlexor to both restore the user's ability to perform acts of daily living and rehabilitate natural biomechanical functionality.

Start testing with stroke patients to understand Phlexor's full capability

References

- Sanders, Quentin, et al. "Force Acquisition Frequency Is Less Impaired Compared to Grip Strength or Hand Dexterity in Individuals with Chronic Stroke." *Experimental Brain Research*, vol. 240, no. 9, 19 Aug. 2022, pp. 2513-21, <https://doi.org/10.1007/s00221-022-06432-5>.
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Acknowledgements

This research was made possible through the support of George Mason University's College of Science, which supports the ASSIP Program. We would also like to thank Dr. Nelson Glover, Mr. Randy Warren, and Mr. Ahmed Bashatah for their assistance on our project as well!