

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

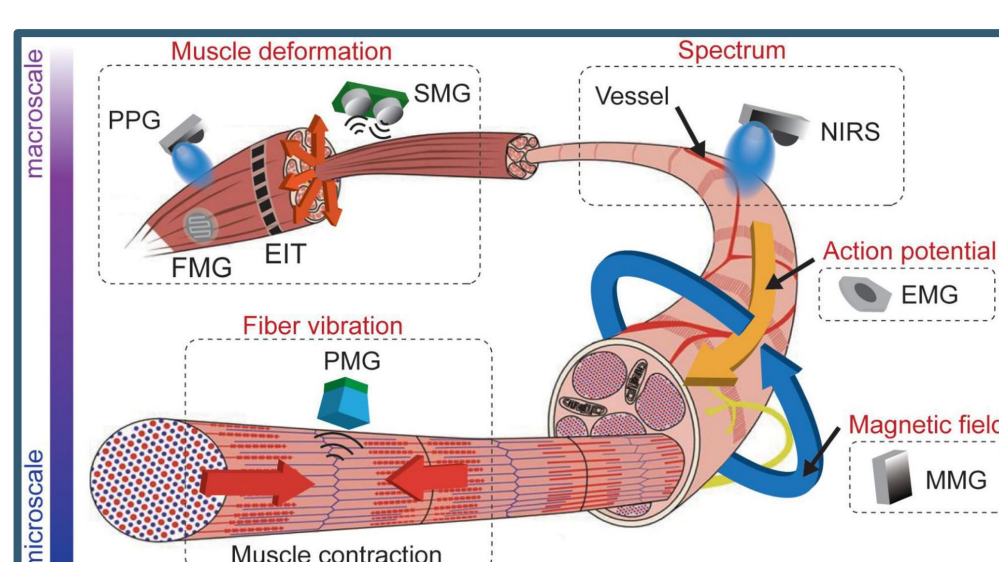
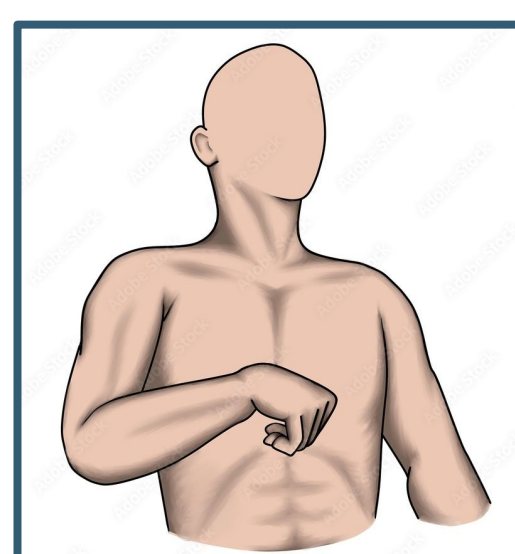
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## Introduction

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

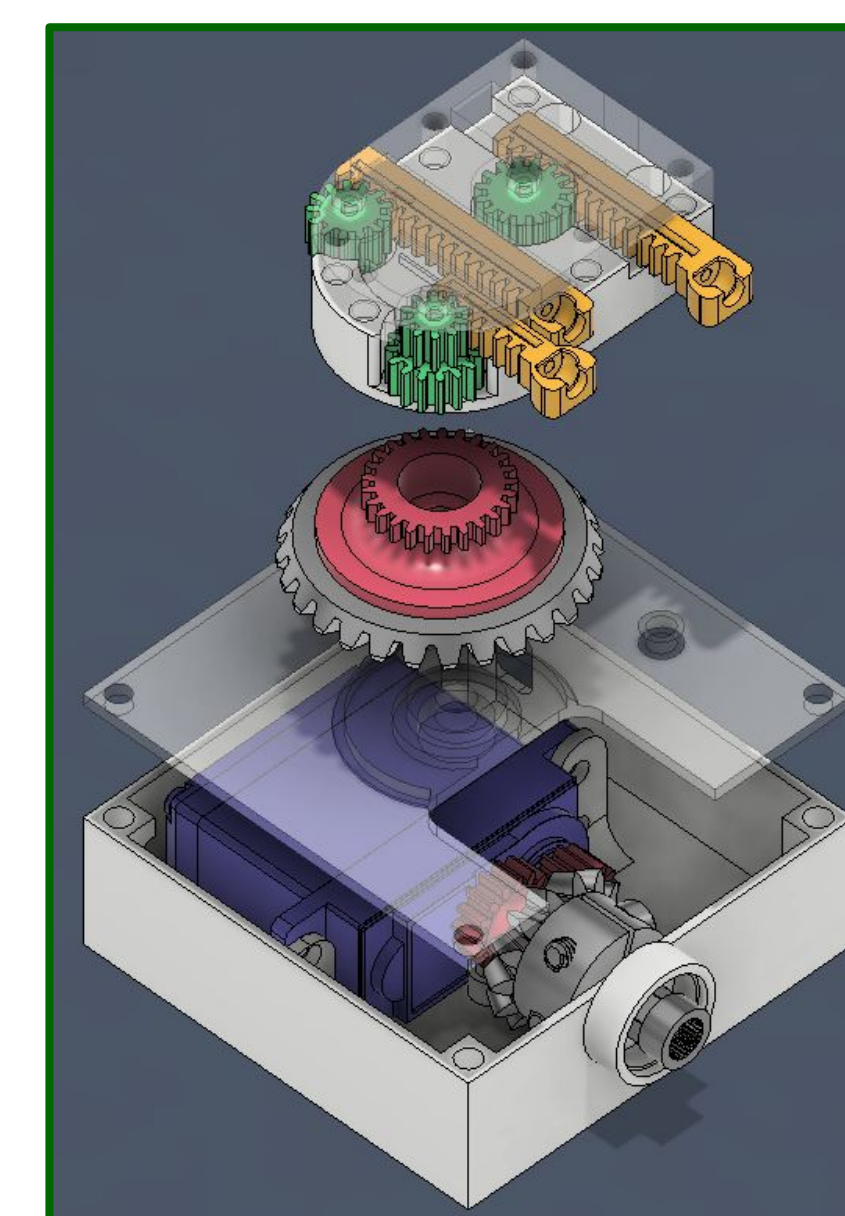
### Actuation

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

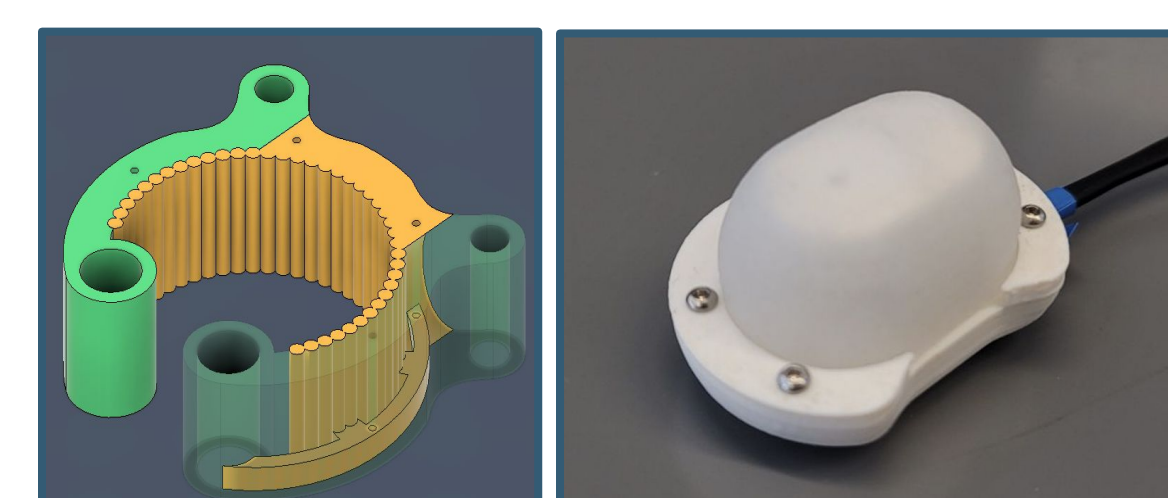
Three preset positions

Magnetic locking mechanism

### Clasps

Open compliant design

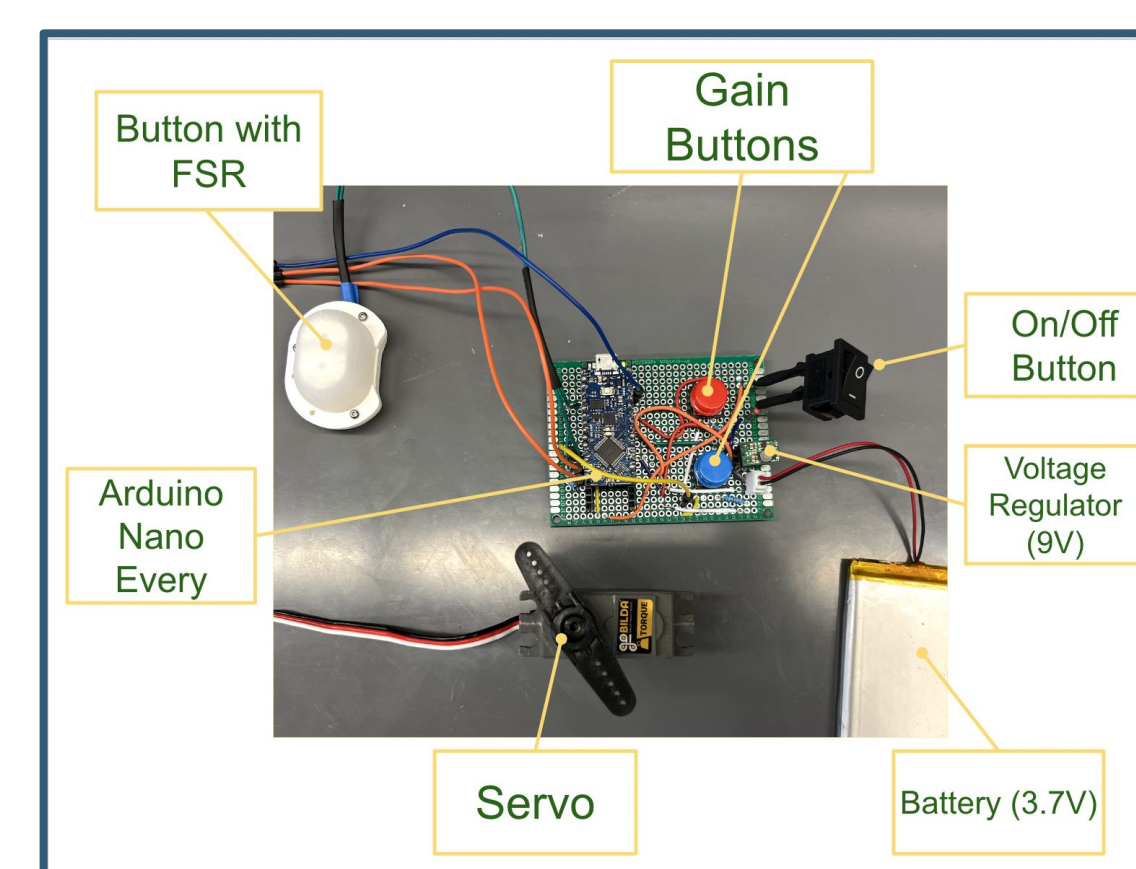
Combination of PLA and TPU for rigidity and flexibility



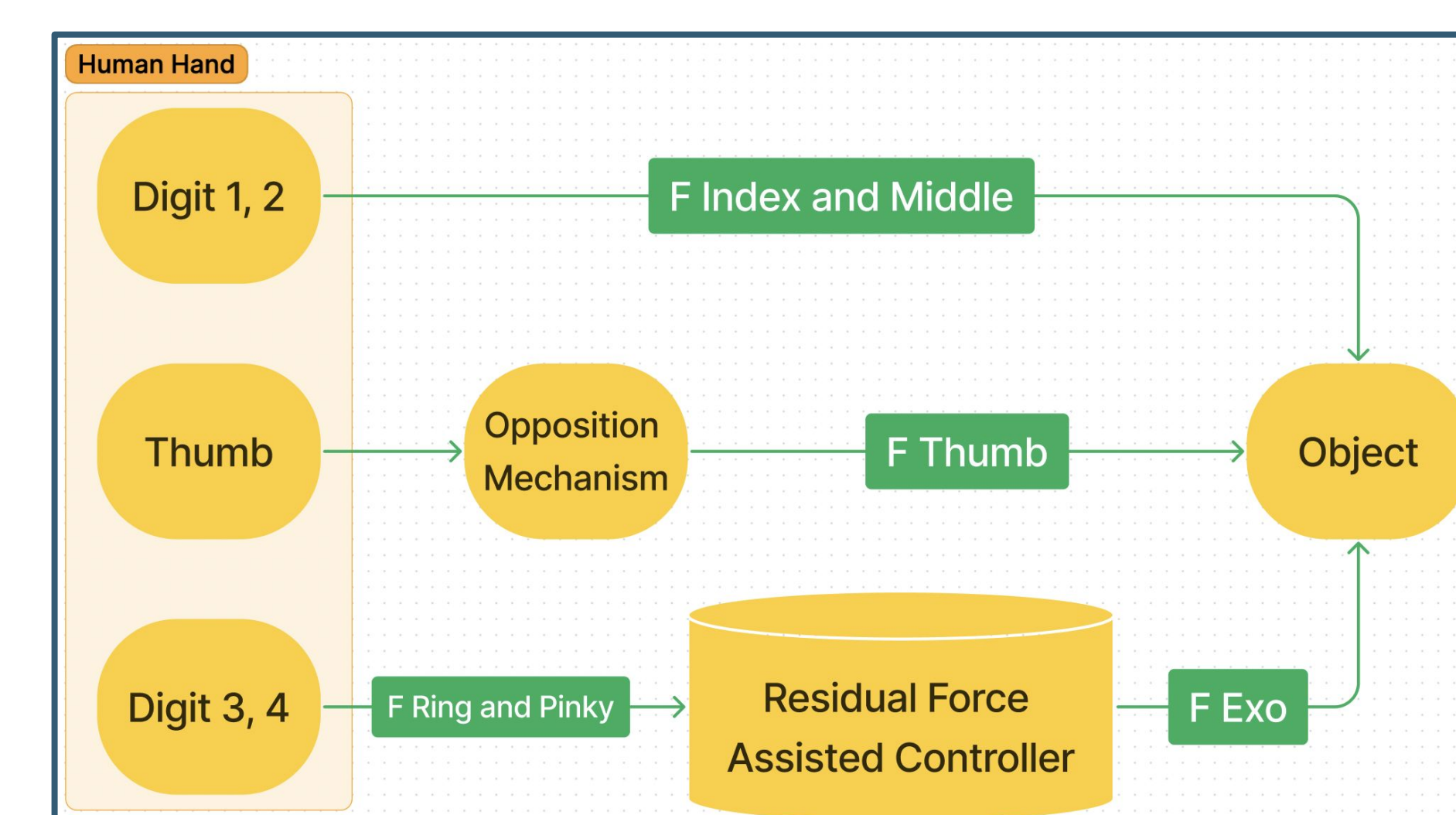
### Button

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 intetion 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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