Mantis shrimp inspired ankle foot prosthesis

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Background



Figure 1. (a) Passive prosthesis [1] (b) Active prosthesis [2,3]

- 1 million amputee live in the US, this expected doubled by 2050.
- Passive prostheses limitations: increased metabolic cost, slow walking speed, gait asymmetry, joint pains.
- Active prostheses limitations: Heavy, Bulky, high electrical energy consumption.

Objective: Developing a Mantis-shrimp inspired, lightweight, compact prosthesis with adjustable stiffness to enhance mobility and comfort with minimized energy consumption

Mechanism

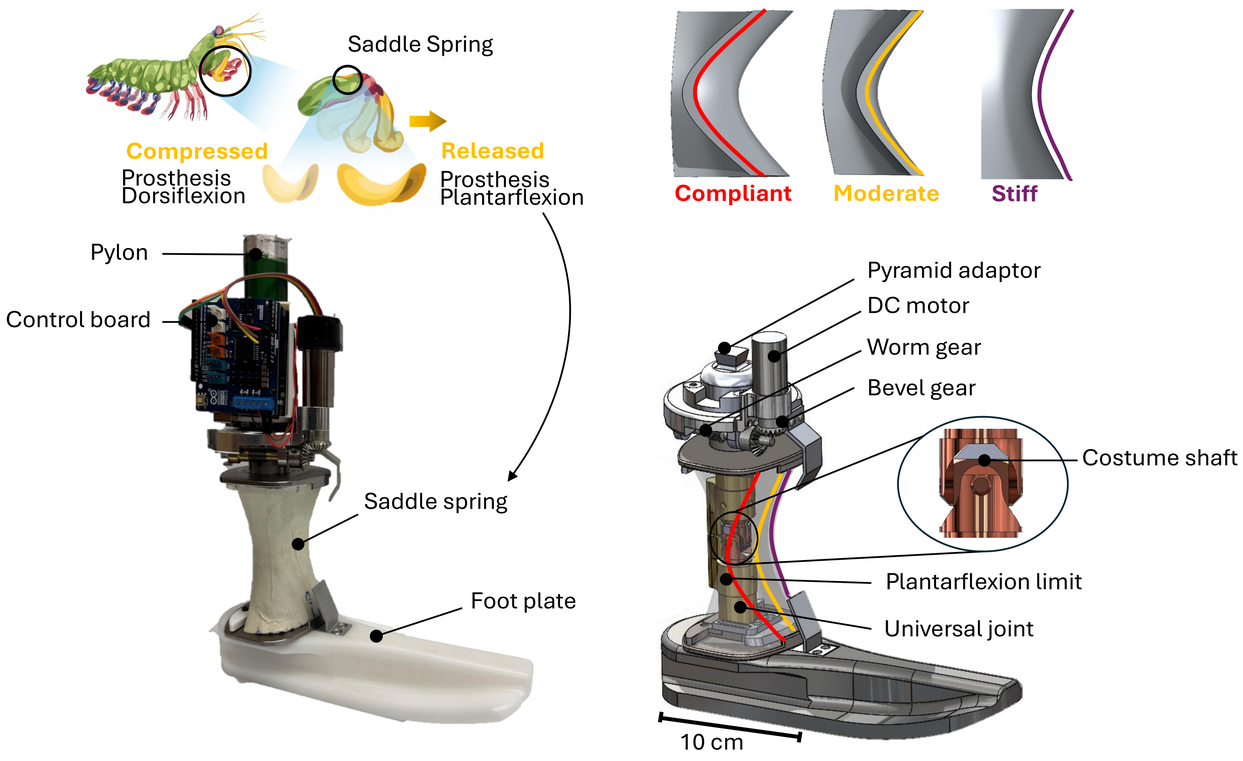


Figure 2. Mantis Shrimp-inspire Ankle-Foot Prosthesis

Methods

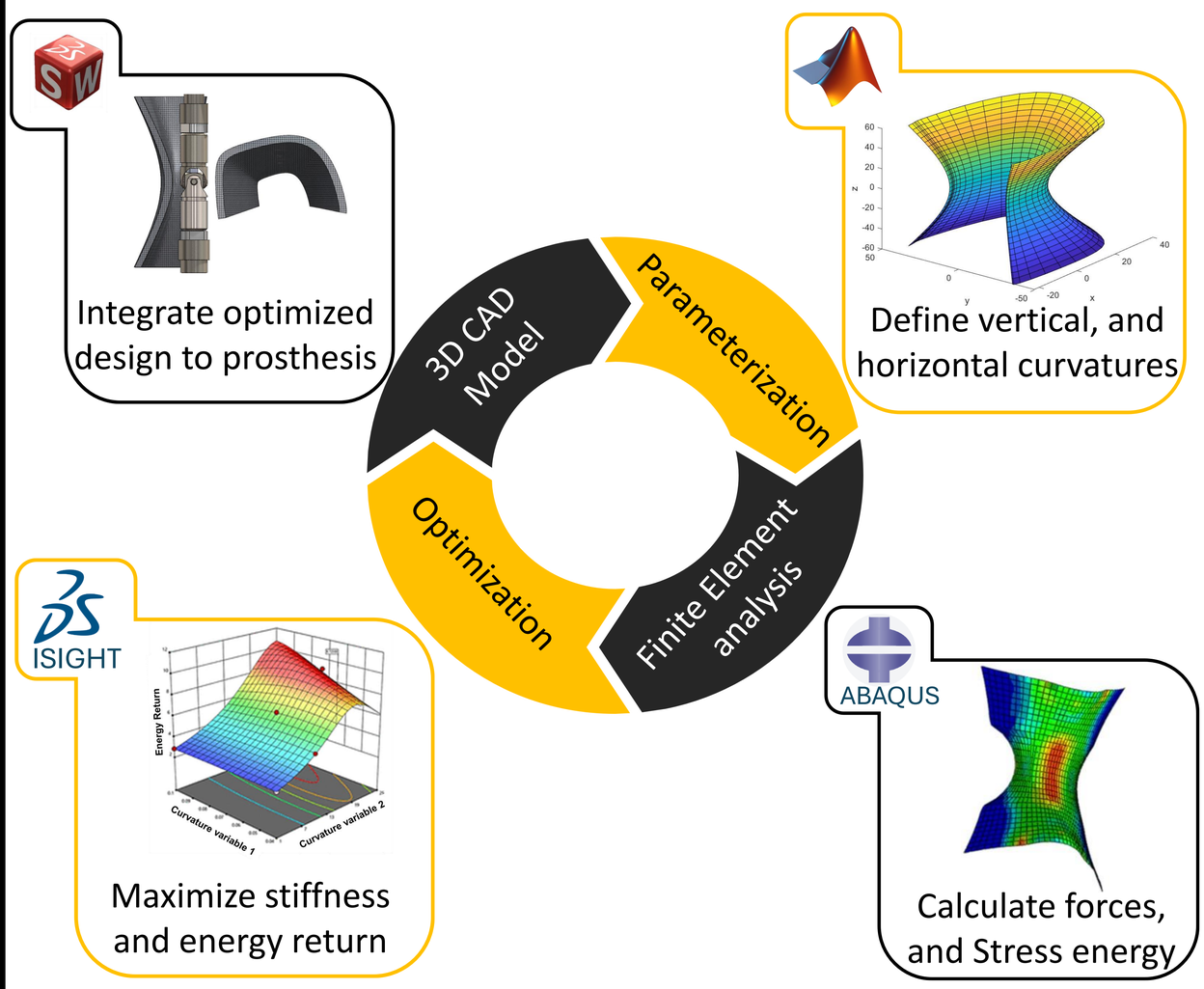


Figure 3. Optimization Workflow for the saddle spring design

Results

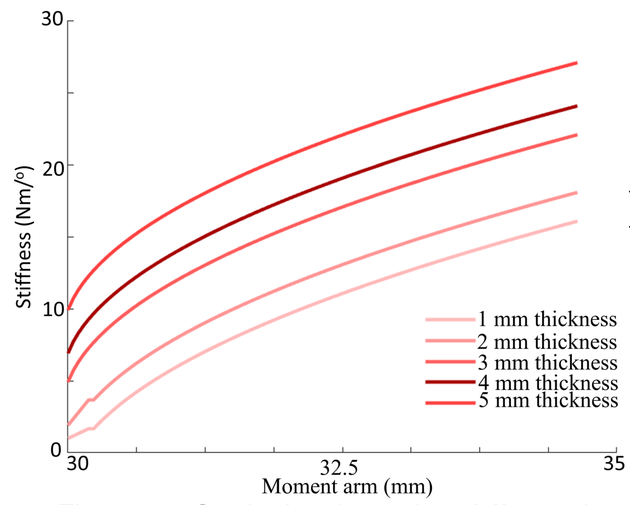


Figure 4. Optimization of saddle spring

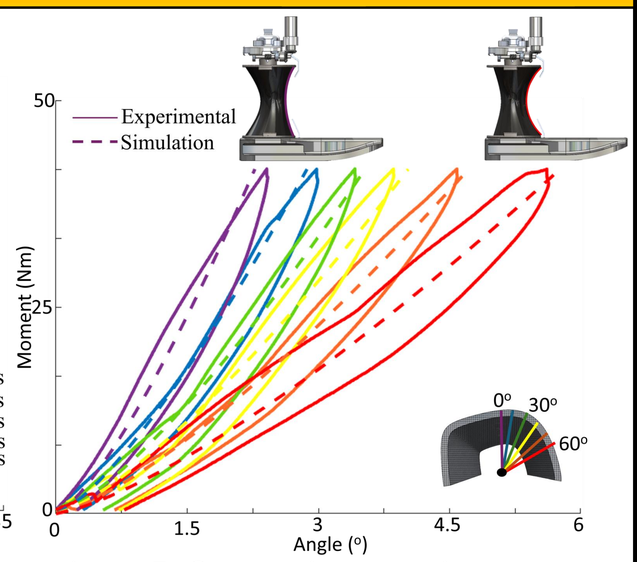


Figure 5. Comparing experiment and simulation stiffness

Table 1. Stiffness error between calculation and experiment

Saddle spring orientation	Stiffness (Nm/°)		
	Experiment	*Calculation*	*RMSE*
0°	18.46	19.62	1.69
10°	16.97	18.51	1.20
30°	14.47	13.86	1.60
40°	12.19	11.18	2.35
50°	9.63	9.05	2.78
60°	8.63	7.85	3.89

Discussion

- This prosthesis is lightweight, and compact. The overall weight of the device is 2 Kg (including DC motor, excluding batteries), and height of 19 cm (excluding pyramid adaptor and pylon).
- This mechanism is fast response. The response time for stiffness adjustment is 0.3 seconds, allowing for abrupt movement changes.
- A machine learning based design optimization maximized energy return while providing a wide range of stiffness.
- The saddle spring can be customized based on each user's biological condition.

Future works

- Evaluating the prosthesis with human experimental tests.
- Apply clutch mechanism to the prosthesis to control the timing of energy release actively.
- Design a mechanism to have eversion and inversion like biological foot.
- Observing effect of different cost functions for the design optimization.

References

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Acknowledgement

- This Research is supported by the National Science Foundation (NSF) under Grant No. 2231032.
- We would like to thank Michael Carroll, Michael Varro, Scott Anderson for their clinical advice on the prosthetic device design and saddle spring fabrication in this research project.