4-DoF Origami Haptic Device

Sophia Williams[1], Jacob Suchoski[2], and Allison Okamura[2]
[1]Department of Electrical Engineering, Stanford University
[2]Department of Mechanical Engineering, Stanford University

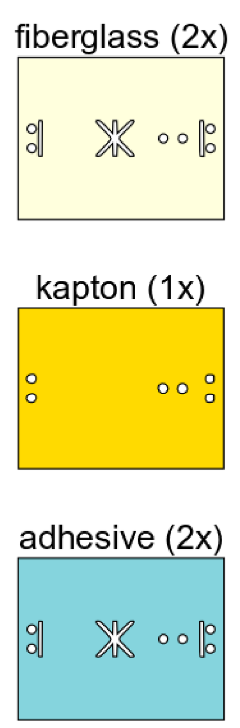
Abstract

We are developing a mesoscale robotic device that uses layered manufacturing techniques, like those seen in circuit design. The device is a lightweight and portable fingertip-mounted haptic device that aims to create more realistic touch by providing normal, shear, and torsional feedback to the fingertips. The device will be used to measure user experience and perception in virtual reality scenarios.

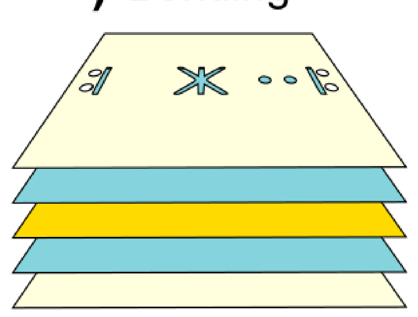
Fabrication

- Fiberglass used as rigid support material
- Kapton used as flexible material a joints
- Adhesive used to mount the device into final configuration

a) Laser cut layers

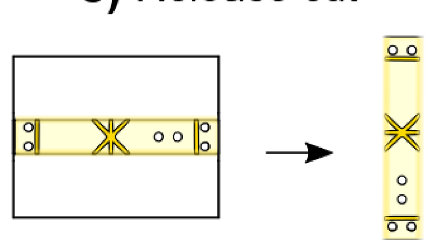


b) Bonding

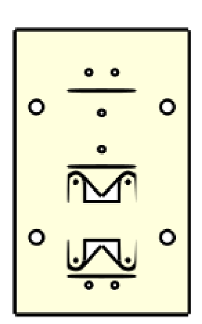


When assembling the layers, we can add additional stabilizing features such as pins. The layers are bonded together at high heat.

c) Release cut



d)



We propose adding additional layers, such that there are embedded linkages held together by pins that are added before the bonding step

Fig 1. The manufacturing process for one leg of a parallel mechanism. a) We laser cut the layers; b) the layers are bonded together at high heat; c) the layers are released to create a fully formed leg; d) adding additional layers we can create a system with embedded linkages.

4-DoF Parallel Mechanism Device Design

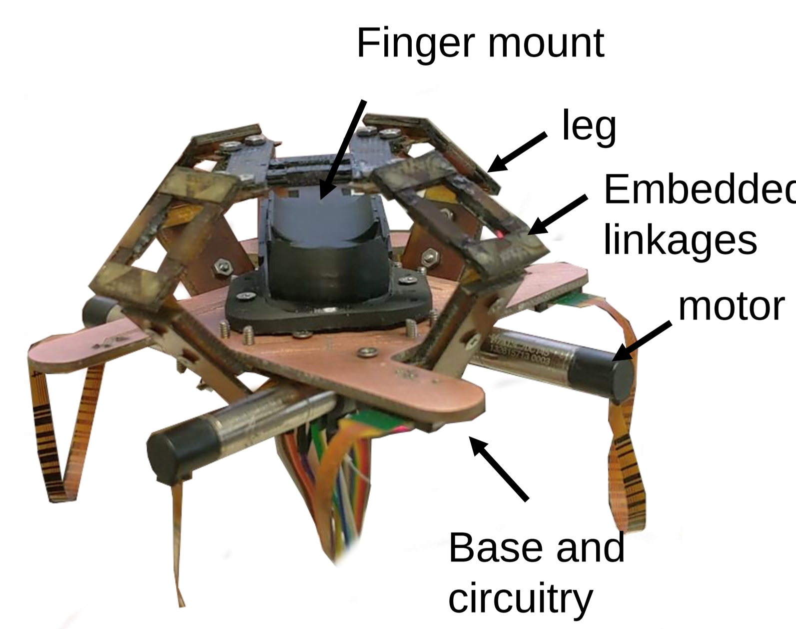


Fig 2. Device prototype with origami pin joints. Four maxon motors are mounted to the base of the device and control the position of the end effector.

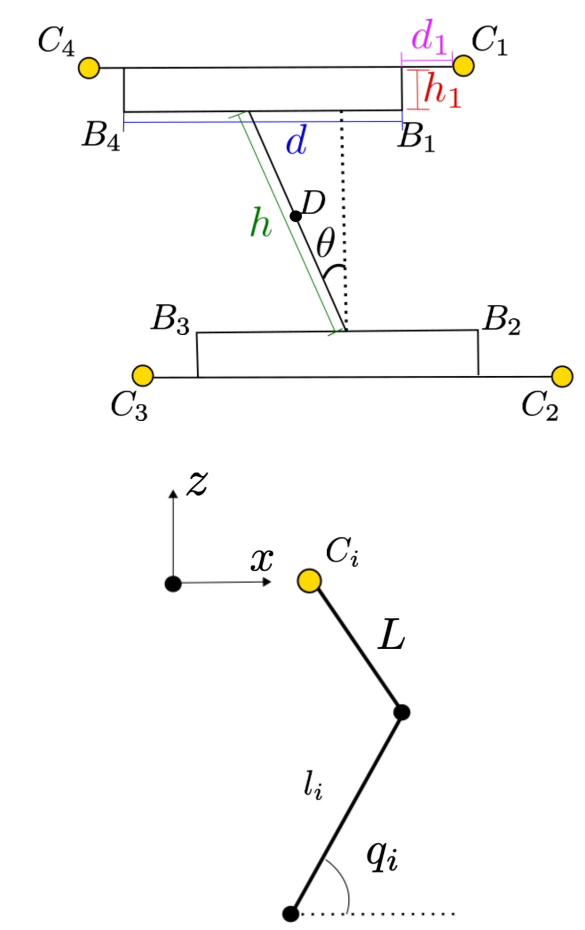


Fig 3. Simplified drawings of the device. a) top view of the mechanism. b) side view of leg $\phi_i = 0$

The kinematics are governed by the following system of 4 equations.

$$l_i^2 = \left\| \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \overrightarrow{DB_i} - \begin{bmatrix} L\cos\phi_i \cos q_i \\ L\sin\phi_i \cos q_i \\ -L\sin q_i \end{bmatrix} \right\|^2, \quad i = 1, ..., 4$$

Where DB is defined for each link.

$$\overrightarrow{DB_1} = \begin{bmatrix} -\frac{1}{2}h\sin\theta + d_1 + \frac{d}{2} \\ \frac{1}{2}h\cos\theta + h_1 \\ 0 \end{bmatrix} \quad \overrightarrow{DB_2} = \begin{bmatrix} -\frac{1}{2}h\sin\theta - d_1 - \frac{d}{2} \\ \frac{1}{2}h\cos\theta + h_1 \\ 0 \end{bmatrix}$$

$$\overrightarrow{DB_3} = \begin{bmatrix} \frac{1}{2}h\sin\theta - d_1 - \frac{d}{2} \\ -\frac{1}{2}h\cos\theta - h_1 \\ 0 \end{bmatrix} \quad \overrightarrow{DB_4} = \begin{bmatrix} \frac{1}{2}h\sin\theta + d_1 + \frac{d}{2} \\ -\frac{1}{2}h\cos\theta - h_1 \\ 0 \end{bmatrix}$$

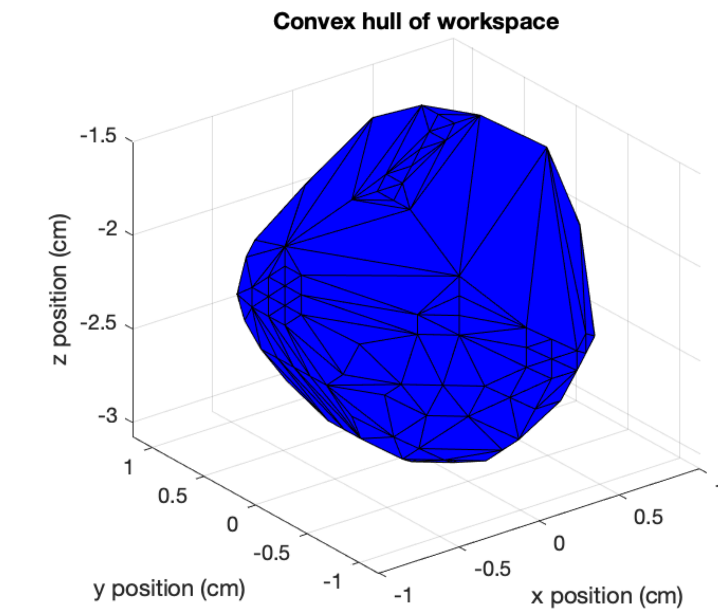


Fig 4. The kinematics allow us to calculate the achievable workspace of the 4-dof device given our link lengths. This workspace image was created with $l_i = 1.75cm$ and $L = 1.5cm$.

x-range:	-1.2 to $1.2\ cm$
y-range:	-1.5 to $1.5\ cm$
z-range:	-1.5 to $-3.2\ cm$
θ-range:	$-\pi/2$ to $\pi/2$

Virtual Reality Integration

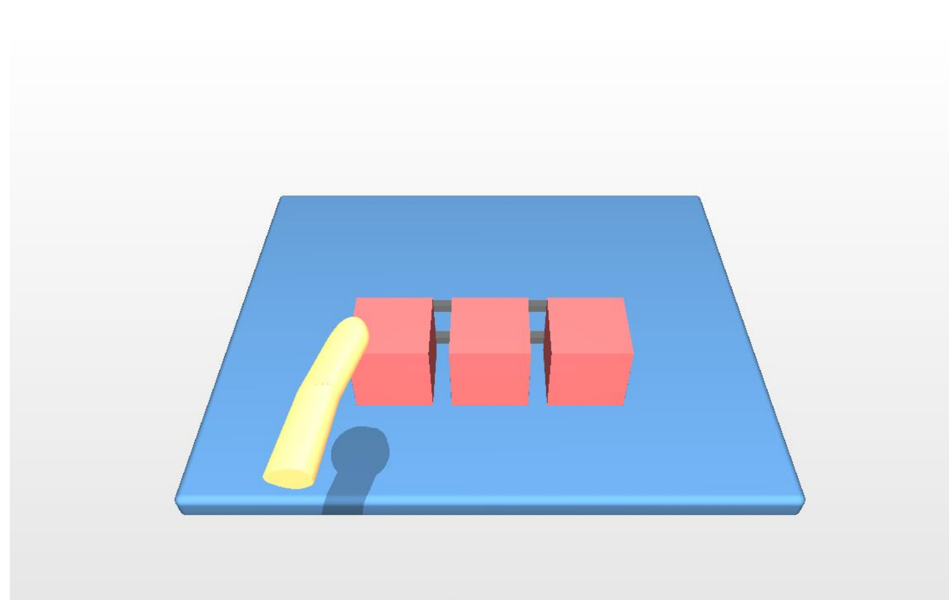


Fig. 5 Prototype of the virtual reality environment for user studies. The three cubes have different stiffness. The fingertip represents the user's virtual tool.

- A virtual reality environment will be used to assess user interactions the 4 Dof device
- A haptic rendering algorithm will be used to calculate the appropriate forces that should be delivered to the device.

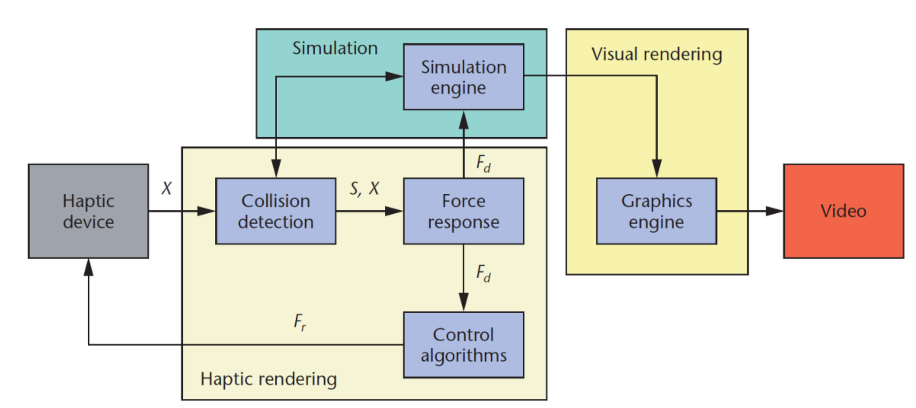


Fig 5. Image of closed loop haptic control with a virtual reality environment [1].

Conclusions

- Created an origami device with a rigid structure and flexible joints that applies forces to the fingertips for virtual reality interactions.
- The origami structure allows for incorporating sensing technology during the fabrication process
- The fabrication process allows for creating complex haptic technologies at low cost

Acknowledgements

- CHS: Small: Collaborative Research: Wearable Fingertip Haptic Devices for Virtual and Augmented Reality: Design, Control, and Predictive Tracking (NSF grant 1812966; in collaboration with Yu Sun at University of South Florida)
- NRI: FND: COLLAB: Intuitive, Wearable Haptic Devices for Communication with Ubiquitous Robots (NSF grant 1830163; in collaboration with Marcia O'Malley at Rice University)

[1] Salisbury, Kenneth, Francois Conti, and Federico Barbagli. "Haptic rendering: introductory concepts." *IEEE computer graphics and applications* 24.2 (2004): 24-32.