Intuitive, Wearable Haptic Devices for Communication with Ubiquitous Robots

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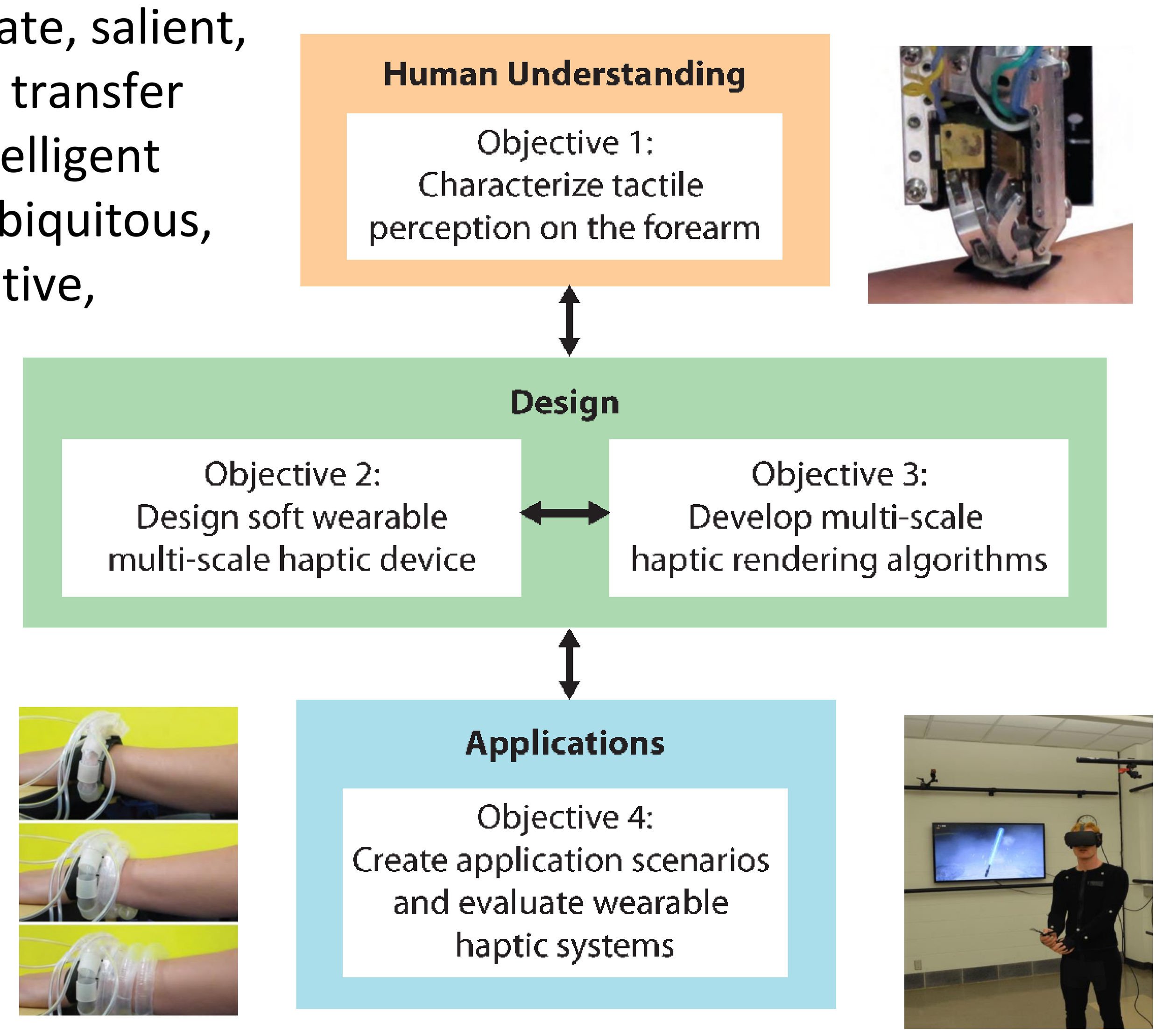
Motivation and Objectives

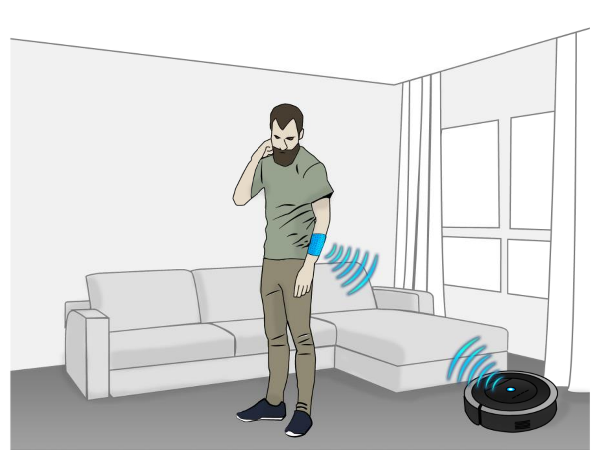
Haptic devices allow private, salient, touch-based information transfer between humans and intelligent systems. In order to be ubiquitous, the devices must be intuitive, unobtrusive, and wearable.

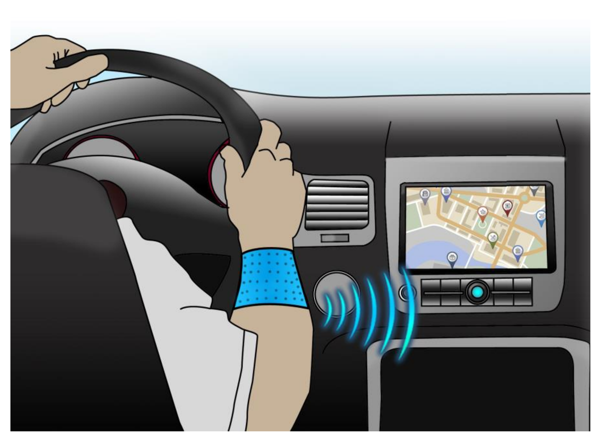
Our project aims to overcome the inherent trade-off between where we want to place devices for maximum wearability and where the skin exhibits the highest density of touch receptors.



Broader Impacts

Haptic Devices offer a wide range of potential applications, including communication between:


Humans and Robots


Humans and Agents


Humans and Humans

This communication will improve human health and quality of life by facilitating safe and efficient human-machine interactions, guidance and feedback, and aging in place.

Our project is broadening participation in STEM through haptics education (including online teaching and outreach programs), mentorship of a diverse population of students, and focus on making technology accessible to a wide variety of users.

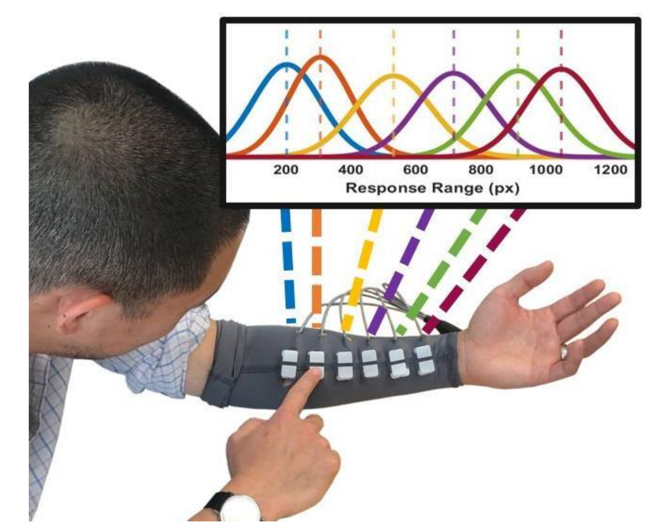
Research Activities and Results

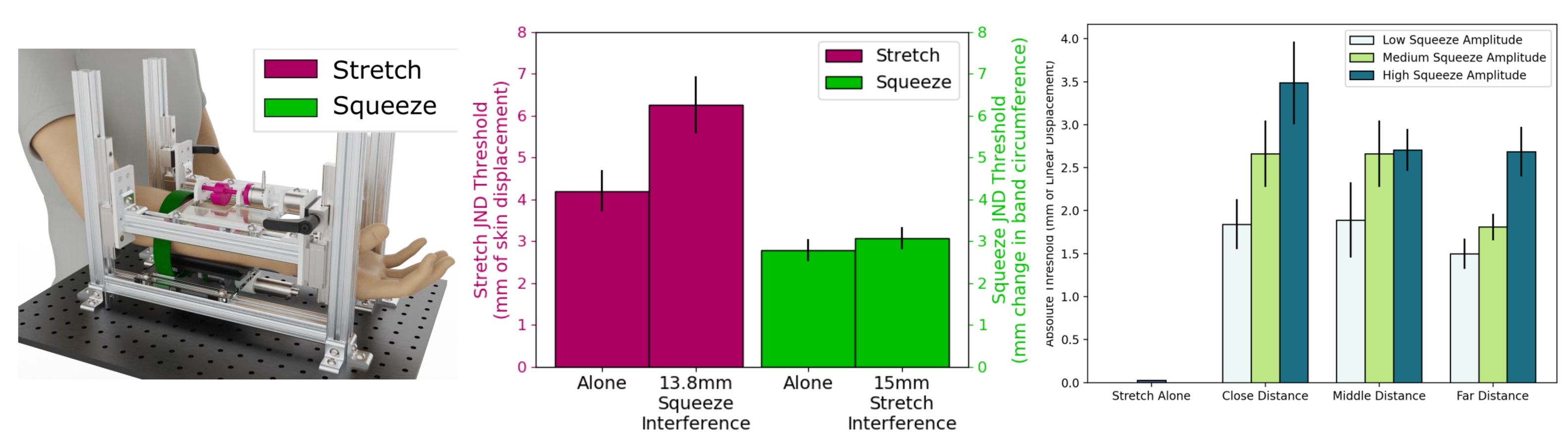
Snaptics[1] (snaptics.org)

- We developed Snaptics[1], an open source, low-cost, platform for accessible prototyping of haptic devices
- Modules offer vibration, stretch, and twist cues with untethered, battery-powered operation

Psychophysical Testing Results[2,3]

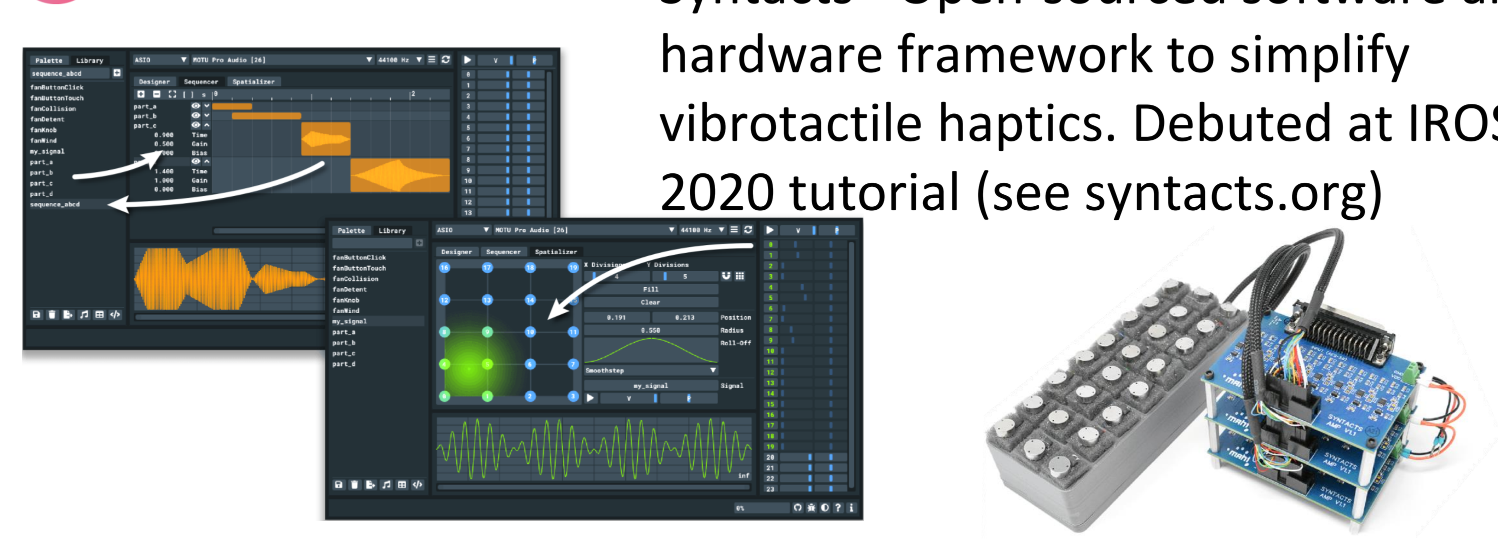
- Stretch discrimination is affected by squeeze masking
- Stretch and squeeze detection is affected by masking
- We are also investigating how cue parameters and training affect localizability of tactile cues





Applications of Wearable Haptics[4]

- Syntacts - Open-sourced software and hardware framework to simplify vibrotactile haptics. Debuted at IROS 2020 tutorial (see syntacts.org)



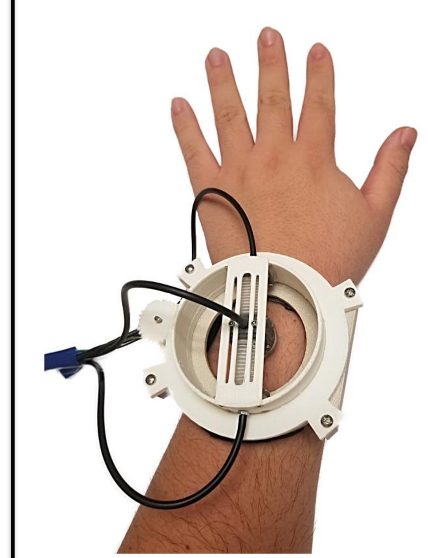
[1]**Z. A. Zook, O. O. Ozor-Ilo, and M. K. O'Malley.** (2021) Snaptics: Low-Cost Open-Source Hardware for Wearable Multi-Sensory Haptics. *In Review.*

[2]**Z. A. Zook, J. J. Fleck, and M. K. O'Malley.** (2020) Effect of Interference on Multi-Sensory Haptic Perception. *In Review.*

[3]**A. K. Low, Z. A. Zook, J. J. Fleck, and M. K. O'Malley**. (2021) Effects of Interfering Cue Separation Distance and Amplitude on the Haptic Detection of Skin Stretch. *In Review.*

[4]**E. Pezent, B. Cambio, and M. K. O'Malley.** (2020) Syntacts: Open-Source Software and Hardware for Audio-Controlled Haptics, IEEE Transactions on Haptics.

3-DoF Wearable Haptic Device[5]



- We use soft actuators for linear motion and a DC motor for rotation
- The device delivers normal, shear, vibration, and torsion feedback cues
- A set of 19 linear stretch, normal indentation, torsion, and angular stretch cues can be used for communication or directional feedback

Simultaneous Vibrations Delivered to the Forearm and Fingertips[6]

- We investigate effects of simultaneous vibrations from a wearable device to both the fingertips, forearm, and fingertips and forearm together.
- The fingertips-only and fingertips-and-forearm conditions are not statistically significantly different at high amplitudes (3-6 g), indicating that a fingertips-and-forearm display has similar performance to a fingertip-mounted display.

4-DoF Origami Haptic Device[7]

- We use origami and layered manufacturing techniques to design a 4-DoF haptic device
- The device delivers normal, shear, and torsion cues to the fingertip
- The 4-DoF haptic device allows us to investigate the influence of torsion feedback on user performance

[5]**K. T. Yoshida, C. M. Nunez, S. R. Williams, A. M. Okamura, and M. Luo.** (2019) 3-DoF Wearable, Pneumatic Haptic Device to Deliver Normal, Shear, Vibration, and Torsion Feedback. *IEEE World Haptics Conference*, 97-102.

[6]**S. R. Williams and A. M. Okamura.** (2020) Body-Mounted Vibrotactile Stimuli: Simultaneous Display of Taps on the Fingertips and Forearm, IEEE Transactions on Haptics.

[7]**S. R. Williams, J. M. Suchoski, Z. Chua, and A. M. Okamura.** (2021) 4-DoF Wearable Origami Device for Normal, Shear, and Torsion Feedback. *In Preparation.*

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