Design of Soft Cable-Driven Supernumerary Robotic Limb

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Introduction

Wearable technologies like prosthetics were once designed to match human functionalities, but with the advancement of this growing field of robotics, state-of-the-art research is now to enhance human abilities beyond what is anatomically possible. The design of supernumerary robotic upper limb for human augmentation can be used for both enhancing a person's ability or compensating for missing abilities.

Advantages

- The **lightweight** design is accomplished through the flexible continuum structure of the Superlimb. It is actuated via cables, allowing for compactness of the system.
- The Superlimb is **reconfigurable** for different purposes using different end effector attachments.

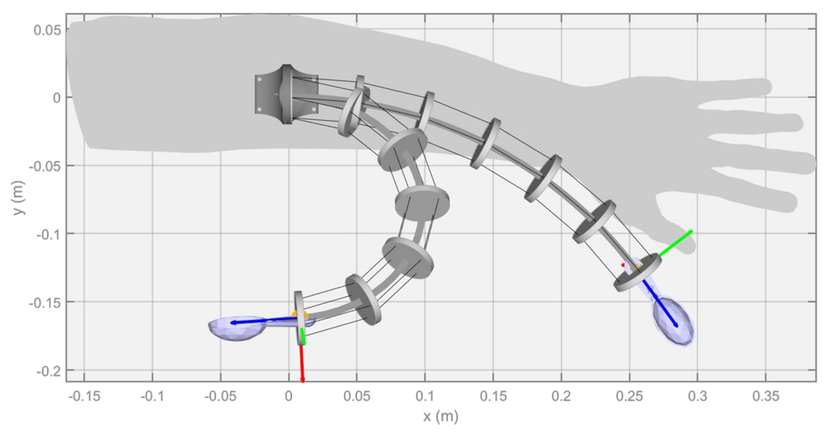
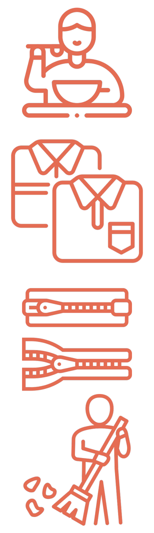


Figure 1: Continuum robot configuration with utensil end effector

RESEARCH GOALS

This work is unique in that it focuses on the Superlimb being modular, with interchanging task-specific end-tools.



For example, bimanual manipulation tasks:

- Eating with a utensil
- Folding laundry
- Zipping a zipper
- Sweeping the floor

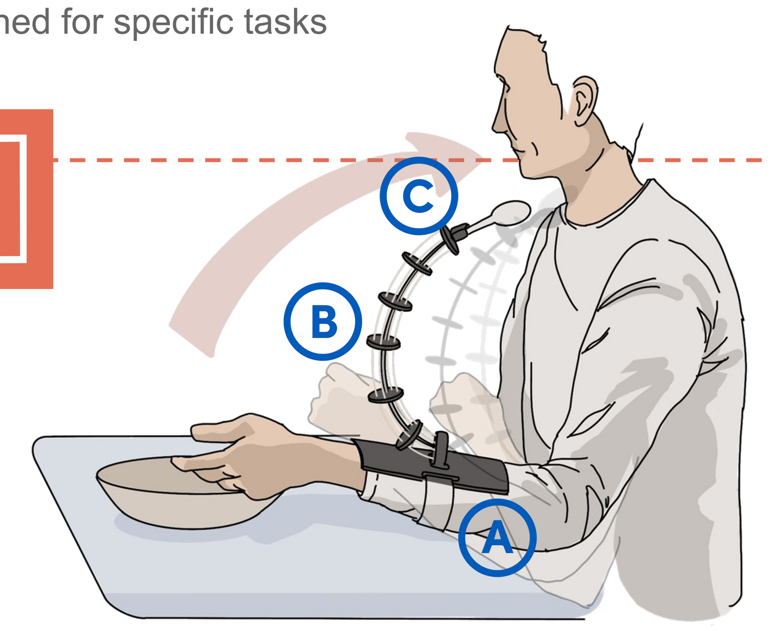
Furthermore, trimanual manipulation[1] tasks will be explored.

Design

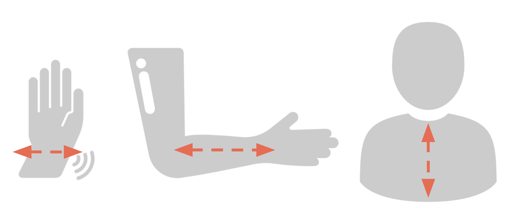
The purpose of the overall design is to create a task-specific, cable-driven soft Superlimb. To accomplish this fully functional Superlimb, **three design components** were focused on as depicted in figure 2:

A. The Superlimb brace to be attached to the user
B. The soft cable-driven continuum
C. Interchangeable adapter connected to the Superlimb with various end-tools designed for specific tasks

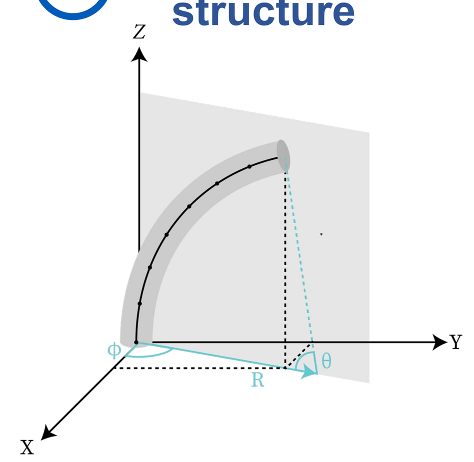
Figure 2: Superlimb with end effector for feeding task



(A) Various brace mounting locations



(B) Continuum structure



(C) Interchangeable end tools

Hardware

A physical prototype was developed for experimental validation.

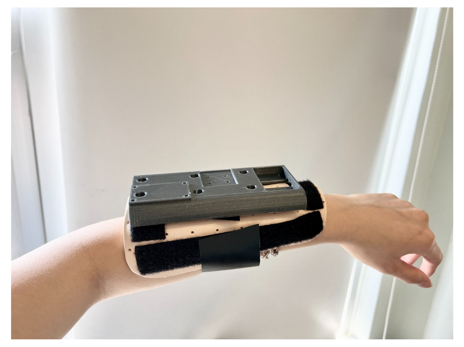


Figure 3a: Arm brace with motor mount

Figure 3b: Two motor and pulley configuration

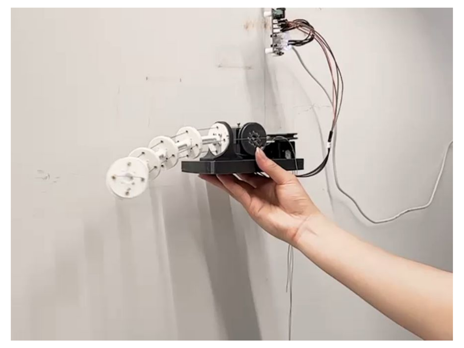


Figure 3c: Continuum robot on motor base

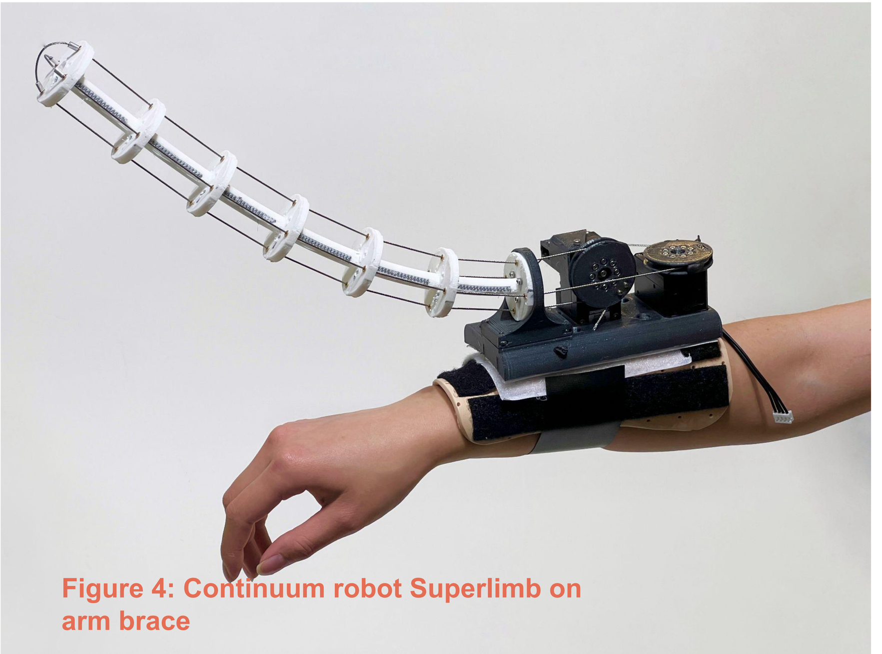


Figure 4: Continuum robot Superlimb on arm brace

Human-Superlimb collaboration

The Superlimb is mounted to a Universal Robot (UR) which provides set trajectories resembling the movement of a human arm. Therefore, the base is able to move in conjunction with the cables actuating the continuum.

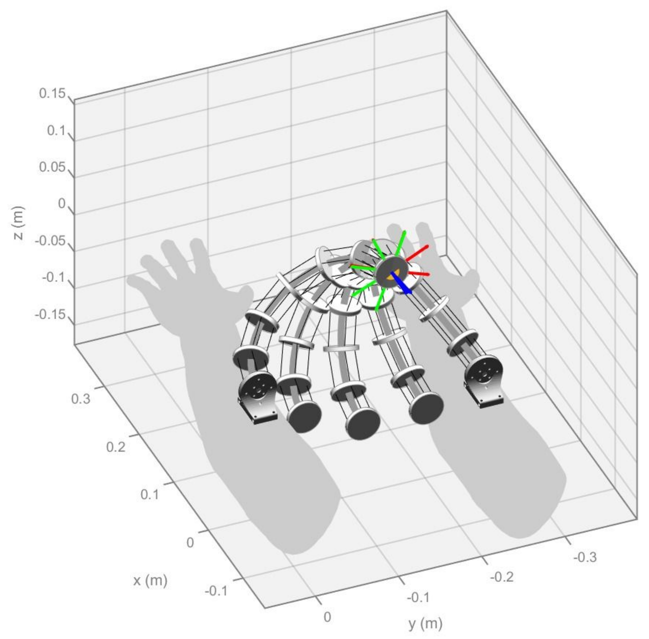


Figure 5a: Superlimb modeling with base between two locations and a fixed tip position

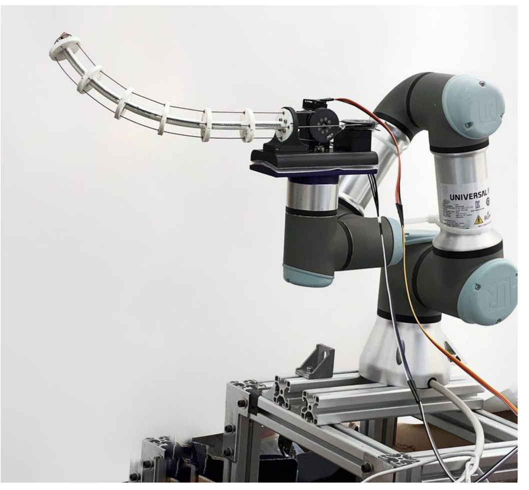
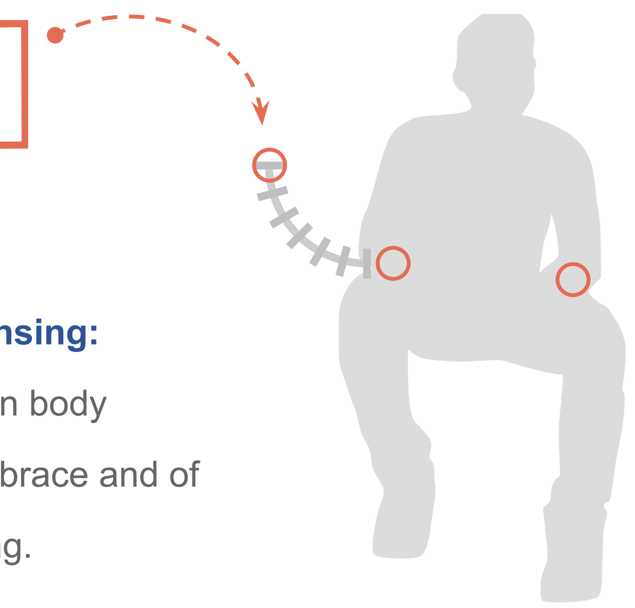


Figure 5b: Superlimb mounted on UR robot for experimental testing

The wearers arm position and specific triggers would allow trajectories to be performed for different tasks.



Task specific human intention sensing:
Motion sensors placed on the human body detect the posture of the Superlimb brace and of other limbs used for motion triggering.

For example in a **eating task**, the continuum robot's trajectory will be defined from the bowl to the wearer's mouth position:

Position of Superlimb

Trigger of opposing arm reaching to bowl

→ Determine end effector position to move from the bowl to the mouth

Future work

Controller development for human-robot collaboration allows for intuitive control of the Superlimb, reducing the mental load of the wearer. In future work, instead of arm position triggering a specific action, the Superlimb's ability to guess human intention will be explored.

References

1. Y. Huang, J. Eden, E. Ivanova, S. J. Phee, and E. Burdet, "Trimanipulation: Evaluation of human performance in a 3-handed coordination task," *2021 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 2021.