Design of a Haptic System for Sensory Feedback in Pediatric Prostheses

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Introduction and Background

Prosthesis wearers tend to face difficulties with dexterous object manipulation and touch-based exploration; users compensate for limited somatosensory feedback by relying more on auxiliary senses [1,2].
This creates a need for prosthetic systems that:

- Provide tactile information
- Reduce cognitive load
- Improve user experience

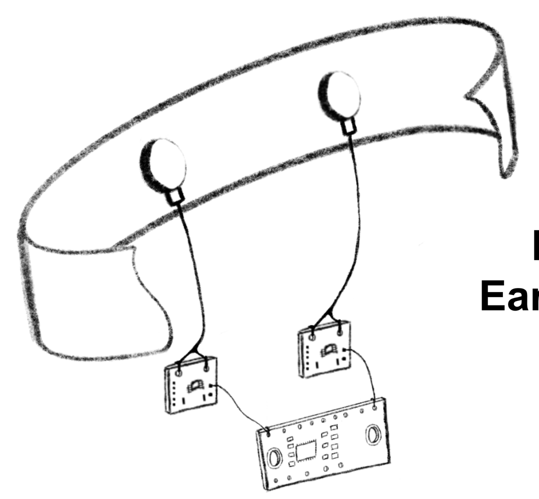


Figure 1: Early Concept Sketch

The project proposes a vibrotactile array for the Limbitless prosthesis to provide haptic feedback and improve user interaction by delivering intuitive cues indicating contact with objects.

System Design

Design Criteria*

- Intuitiveness
- Comfort of Wearable
- Comfort of Sensation
- Discreetness
- Adjustability
- Manufacturability
- Cue Differentiability
- Simplicity
- Cost Feasibility
- Aesthetics
- Technological Maturity
- Extensibility

**ordered in terms of weighting*

System Features

- 1 velcro armband
  - Worn on non-dominant arm
- 4 vibration motors
  - SparkFun Electronics®
  - Linear array
- Discrete feedback
  - event-driven sensory feedback control paradigm
- No additional sensor hardware
  - Reads motor current draw

Why 4 Haptic Motors?

- Initial limiting factors:
  - One input per finger
  - 5 distinct dermatomes [3]
- However, arm circumference in young children allows for only 4 motors given 2-point discrimination distance [4]
- Empirical support for 1x4 armband-style arrays in prior studies [1]
- Signal pooling
  - Fingers 4 and 5

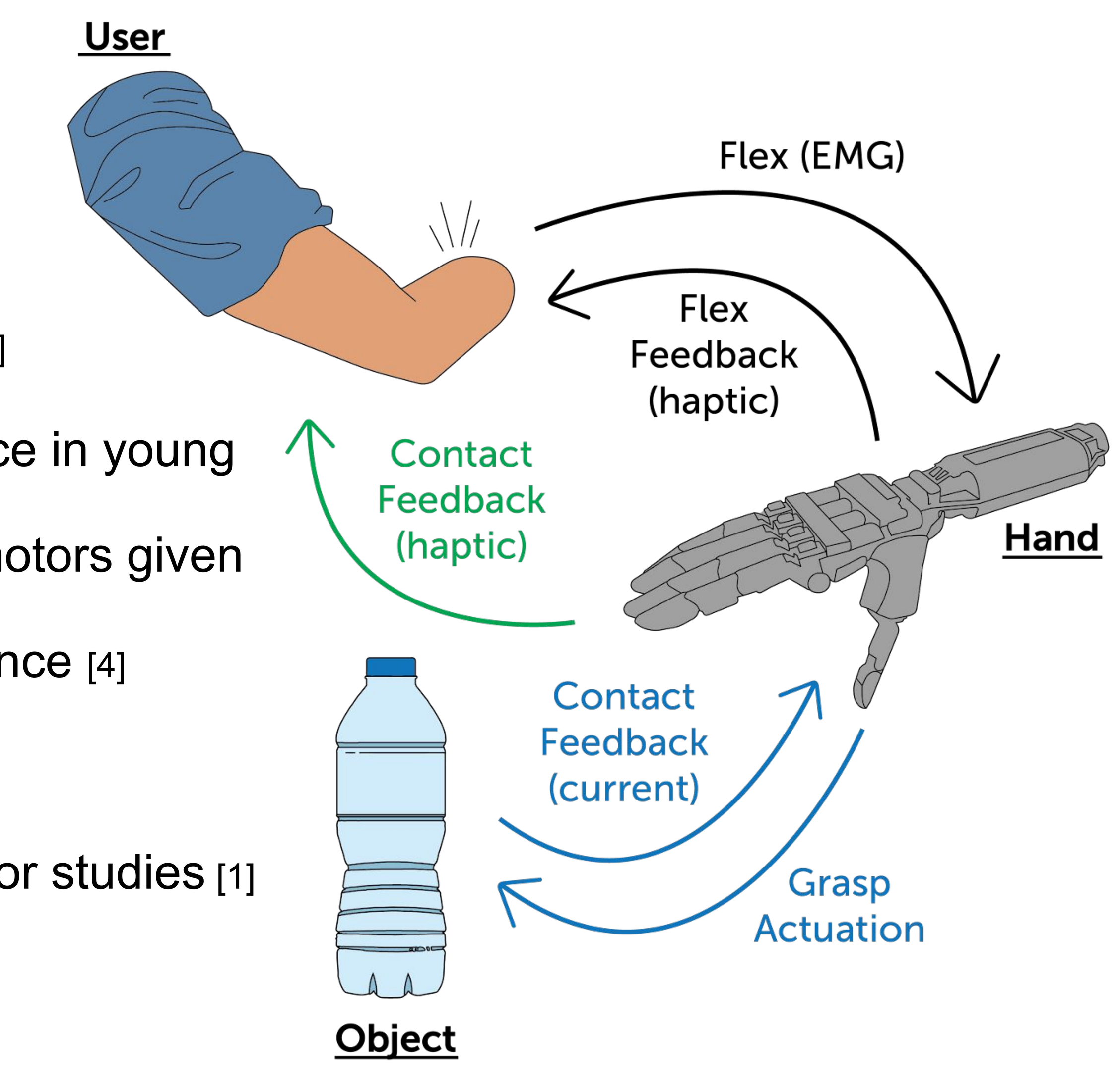


Figure 2: Control Flow Diagram

Test Design

Human subjects study with (N = 30) participants, pending IRB approval. Participants must be healthy adults aged 18–64 with full control and sensation in upper extremities.

PART 1

Stimulus Localization

- Participants identify which of 15 possible motor combinations (1–4 motors active) was vibrating
- Accuracy of identifying spatial motor patterns
- Recorded via a custom testing interface
- Goal: recreating/validating similar studies [1]

PART 2

Mapping Intuitiveness

- Haptic motors mapped to hand regions (e.g., thumb, index, etc.) in predefined schemes
- Participants feel a vibration and select which gesture it corresponds to (e.g., pinch, grasp)
- Response time measured via custom interface

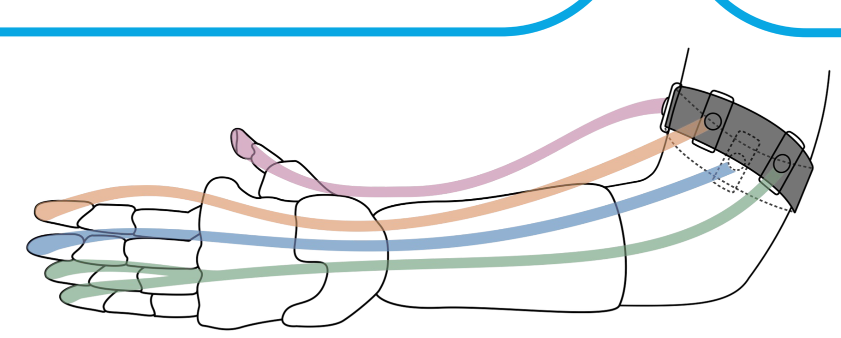


Figure 3: Input-Output Mapping

Post Assessment Survey

- Assesses confidence, comfort, intuitiveness, fatigue, and usability.
- Includes System Usability Scale (SUS) [5] and NASA-TLX [6]

Future Work

Device Optimization

- Bluetooth for improved portability by eliminating wiring
- Psychophysical calibration protocols to tailor to individual
- Waterproofing for cleanability

Modality Matching

Transition to a mechanotactile armband

- Pros:
  - More comfortable sensations
  - More intuitive and interpretable sensations [7]
  - More targetable receptive fields of corresponding mechanoreceptor
- Cons:
  - Bulky; less-slim profile

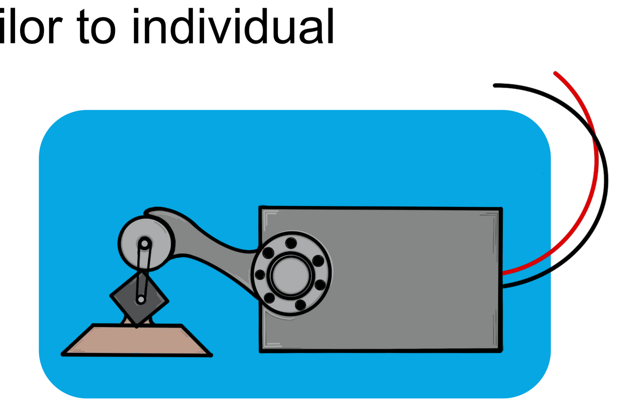


Figure 4: Mechanotactile Pusher

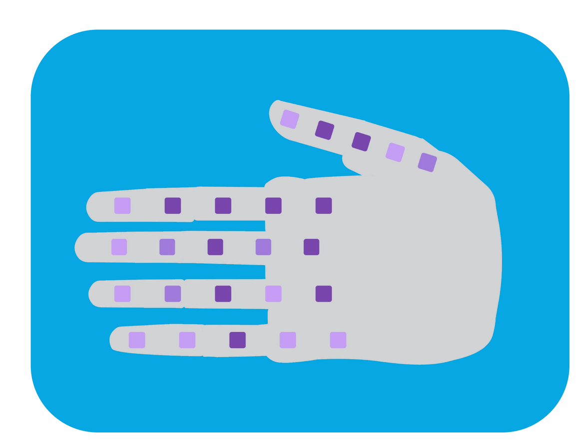


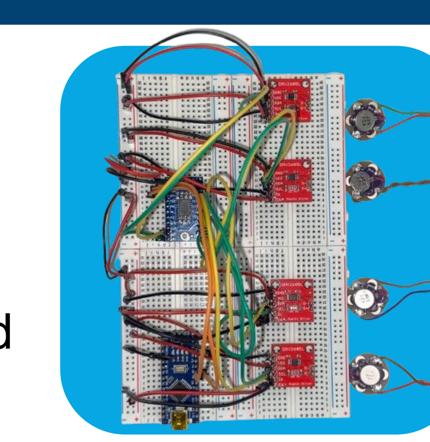
Figure 5: Pressure Sensors Map

Input Proliferation

Incorporating pressure sensors to add inputs

- Thin film pressure sensors
- Conducive to "feeling around" one's environment
- Capture continuous time-variation of pressure
- Exploring Xu et al.'s [8] 25-sensor array concept
  - convey object geometry via low-resolution pressure maps
  - Useful even without active force control
  - 5×5 vibrotactile array on the back may be most appropriate output

Conclusion



The system demonstrates potential as a lightweight, intuitive, and cost-effective solution for integrating low-resolution sensory feedback into devices that previously lacked haptic capabilities. Insights derived from the proposed data collection will be used to inform subsequent iterations of the design, allowing for continuous enhancement. In addition, the alternative concepts outlined in future work are compelling paths for further research.

References and Acknowledgments

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