NRI: Integrated Soft Wearable Robotics Technology to Assist Arm Movement of Infants with Physical Impairments

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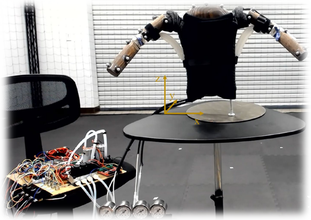
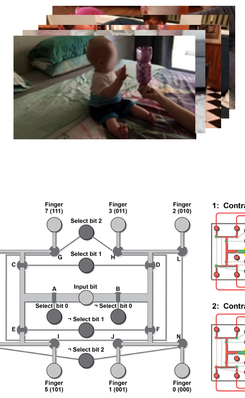
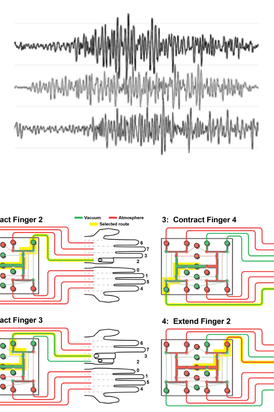
Motivation & Goal

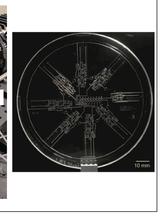
- Need to develop highly adaptive pediatric devices that detect, measure, inform, and adjust to changes in learning and growth
- Focus on iterative design, development and evaluation of the performance of a novel actuated, adaptive and user-centered pediatric upper extremity (UE) soft wearable robotic device

Objectives

- Multi-modal Sensing: 1) Inferring intention of UE movement through multi-modal sensory feedback; 2) Object recognition and tracking of infant arm motion via ego-centric lensless visual sensing
- Actuation, Control & Computation: 1) Motion generation for the wearable robotic device via synergistic soft pneumatic actuators; 2) Offering assistive feedback via data-driven shared human-robot admittance control; 3) Onboard sensing and control via real-time embedded computation
- Participatory & Iterative Design Process: 1) Collection of kinematic, physiological and behavioral data from infants; 2) Evaluation of the device's potential to effectively assist infant arm movement



Significant Results

- Combined coded illumination with lensless cameras and proposed algorithms for robust and high-resolution reconstruction and recovery of 3D volume, along with performing theoretical analysis of spatial and axial resolution of mask-based lensless cameras
- Introduced new set of soft actuators and controllers (both linear point tracking ones as well as learning-based trajectory tracking ones) for improved device performance
- Created a "pneumatic error detector" where microfluidic valves compute parity bits and detect errors (like leaks) during operation of soft pneumatic systems

Broader Impacts

- Advancing fundamental engineering knowledge of pediatric assistive devices via soft robotics
- Creating significant potential for long-term impact on the pressing area of pediatric rehabilitation
- Broadening participation of underrepresented groups in highly interdisciplinary research

Products

- Y. Zheng and M. S. Asif, "Coded Illumination for Improved Lensless Imaging," IEEE Transactions on Computational Imaging, 2023
- Y. Zheng and M. S. Asif, "Coded Illumination for 3D Lensless Imaging," IEEE Open Journal of Signal Processing, 2022
- Y. Hua, M. S. Asif and A. C. Sankaranarayanan, "Spatial and axial resolution limits for mask-based lensless cameras," Optics Express, 2023
- I. Sahin, J. Dube, C. Mucchiani, K. Karydis and E. Kokkoni, "A bidirectional fabric-based pneumatic actuator for the infant shoulder: Design and comparative kinematic analysis," IEEE RO-MAN, 2022
- C. Mucchiani, Z. Liu, I. Sahin, J. Dube, L. Vu, E. Kokkoni and K. Karydis, "Closed-loop position control of a pediatric soft robotic wearable device for upper extremity assistance," IEEE RO-MAN, 2022
- L. Shi, C. Mucchiani and K Karydis, "Online Modeling and Control of Soft Multi-fingered Grippers via Koopman Operator Theory," IEEE CASE, 2022
- S. Hoang, M. Shehada, K. Karydis, E. Kokkoni, P. Brisk and W. H. Grover, "Error detection using pneumatic logic" (in prep)

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