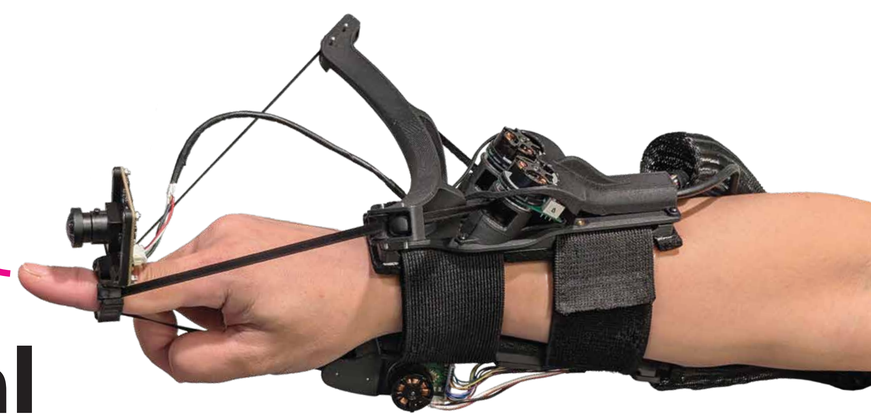
Camera-Based Closed-Loop Fingertip Deflection Guidance: Pilot Demonstrations in Target Acquisition and Object Retrieval



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1 Challenges in Interaction Guidance Motivate the NURing's Design Goals

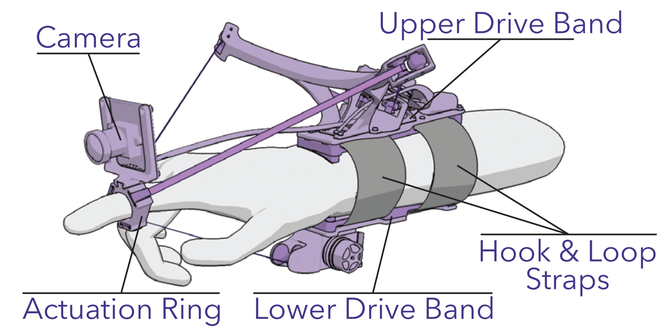
For individuals who are blind or vision-impaired...

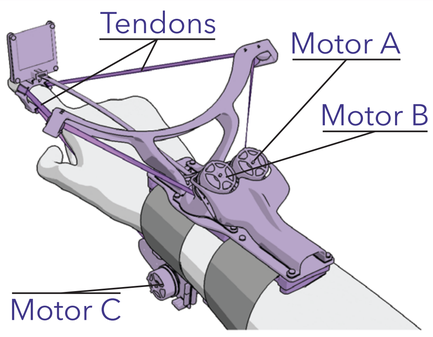
...using wearable tools can impede on the natural abilities of the hand or fingers **+** ...using tools that rely on symbolic decoding can lead to increased cognitive loading **+** ...finding and retrieving small objects can be frustrating and time-consuming **+** ...finding and navigating touchscreen interfaces can be challenging or outright impossible **=**

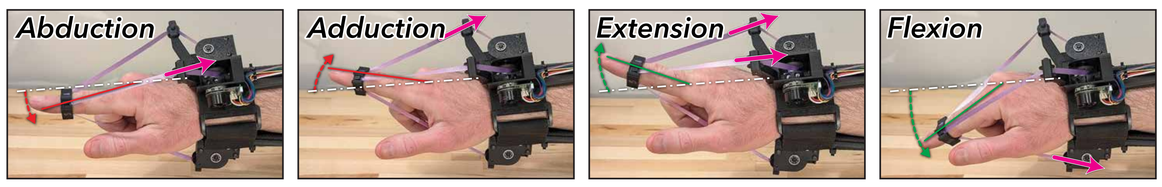
Design Goals:

1. Preserve hand function
2. Provide continuous, embodied guidance
3. Maintain user agency
4. Support navigation-to-interaction guidance

2 NURing: Combining Fingertip Deflection Kinesthetic Feedback with Camera-Based Closed-Loop Guidance

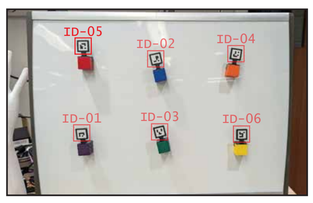






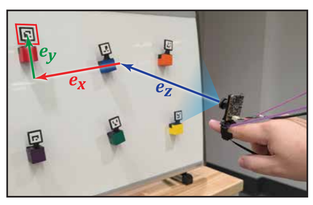
The NURing generates directional fingertip deflection through coordinated tendon actuation, allowing the device to continuously bias the user's hand toward a desired direction during reach.

Sense - Compute - Guide



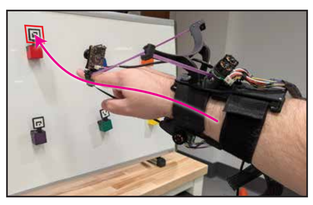
S1 The ring-mounted camera captures a fingertip-centric view aligned with the hand (1600x1200 px, 60 Hz, 120° FOV).

S2 Each frame is processed to remove distortion, and ArUco markers are identified.



C1 Calibrated marker pose estimation yields a direct error vector $\boldsymbol{e}=[e_x, e_y, e_z]^T$ between the camera and the target.

C2 The controller computes the desired motor contributions based on the error vector, actuating the tendons.

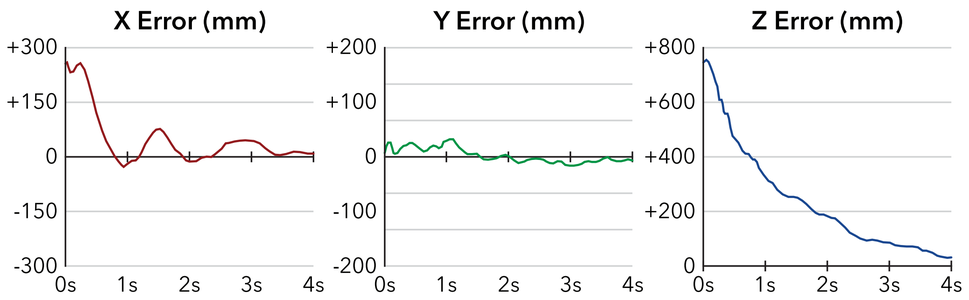


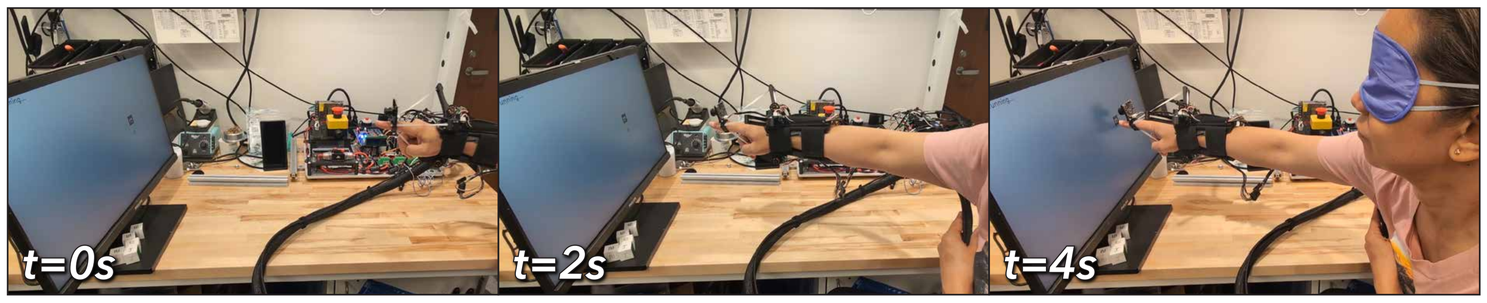
G1 As the arm moves forward, fingertip deflection gently biases the arm towards the target.

G2 The guided reach converges towards the target over time via continuous and intuitive deflection cues.

3 Pilot Demonstration: Target Acquisition for Enabling Precise Interactions

Goal: To visualize how the NURing's continuous deflection cues shape reach trajectories towards a target without visual guidance or symbolic interpretation.
Pilot Result: Participant trajectories converged on a touchscreen target ~700 mm away with <15 mm endpoint error in under 5 seconds[1].





4 Pilot Demonstration: Eyes-free Object Retrieval with Unencumbered Haptic Sensing and Tracking Loss Recovery

Goal: To demonstrate how full object retrieval while keeping the fingertips unencumbered for haptic exploration and grasp, with added recovery cue for tracking loss.
Pilot Result: Participant retrieved all 5 objects in ~40 seconds, including recovery from two tracking-loss events[1].

5 Future Work & Conclusion

Future Work:

- Developing natural interaction semantics for interfacing with the NURing.
- Exploring tracking loss and tracking recovery behaviors.
- Transitioning to markerless tracking using existing computer vision tools.
- Implementing two-stage navigation-to-interaction guidance.

Conclusion:

By shaping arm motion through direct, embodied cues without relying on vision, this work highlights camera-enabled fingertip deflection as a practical guidance modality for real-world interaction, supporting future assistive and collaborative systems that guide action through intuition rather than symbolic, cognitive translation.

[1] The participant shown in these pilot demonstrations is considered a novice user with <2 hours of device use; the plots and video sequences above serve to demonstrate technical feasibility, and do not serve to provide a systematic evalution or generalized usability findings. We are preparing a user study with BVI participants to evaluate task performance (success rate, completion time, path efficiency) and subjective user experience (NASA-TLX workload, perceived agency, confidence ratings, comfort), among other metrics.

Experience the NURing's Fingertip Deflection Guidance Yourself at Booth #1289!

Northwestern HAPTICS LAB

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For more information on the NURing, please contact Tomasz Trzpit at ttrzpit@u.northwestern.edu or scan the QR code to the right