Gaze and Motion Synergies in VR Reaching Tasks towards Multi-Joint Prosthetic Arm Control

Eitan Gerber, Nili E. Krausz

Neuro-Robotics and Bionic Limbs (eNaBLe) Lab

Faculty of Mechanical Engineering, Technion

Introduction

- Upper limbs have over 30 DOFs (arm+hand) in total [1]
- Amputees are **unable** to coordinate multi-joint prostheses
- **Motor synergies** could provide a predictive input for full arm semi-autonomous control.
- We propose leveraging Gaze and EMG synergies to improve prediction *timing* and *accuracy* (see Krausz et al.[2])

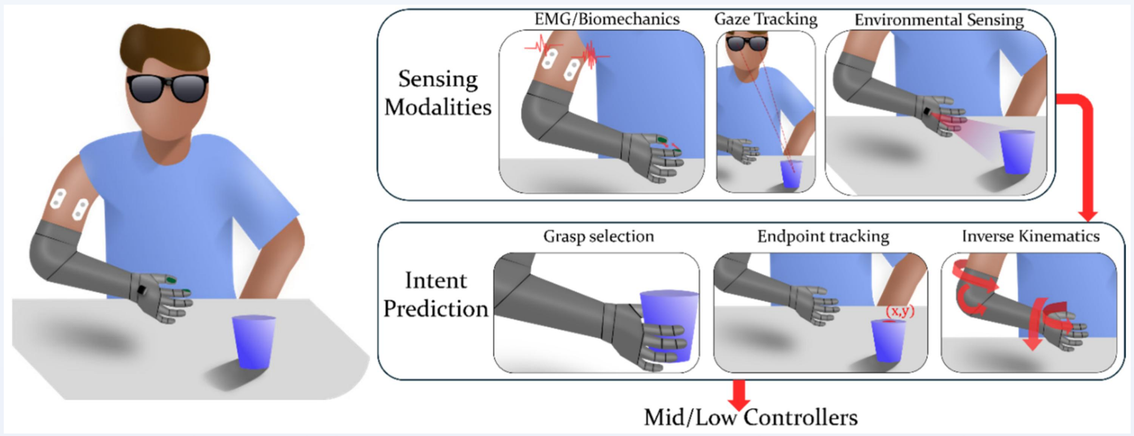


Fig 1. Multi-modal semi-autonomous prosthesis control concept from MOST *BIONAC* project

Methods

- Analyzed data from the 3D-ARM-Gaze dataset [3]
- Hand and gaze **Velocities** and **Accelerations** were computed
- Outliers were removed from the data
- Velocity and Acceleration were filtered via 5Hz LPF

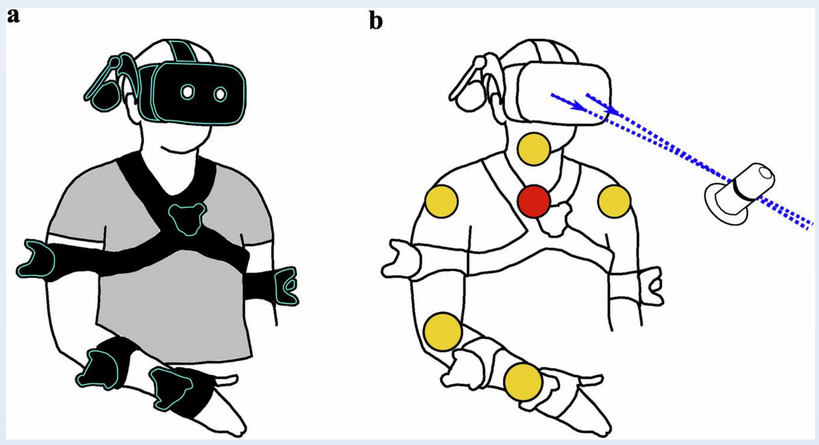


Fig 4. Illustration of the 3D-ARM dataset's collection method.
a) The VR headset and MoCap trackers.
b) Estimated joint centers and gaze vectors.
Adapted from [3]

Preliminary Results

- Gaze point velocity **anticipates** hand velocity during reaching.

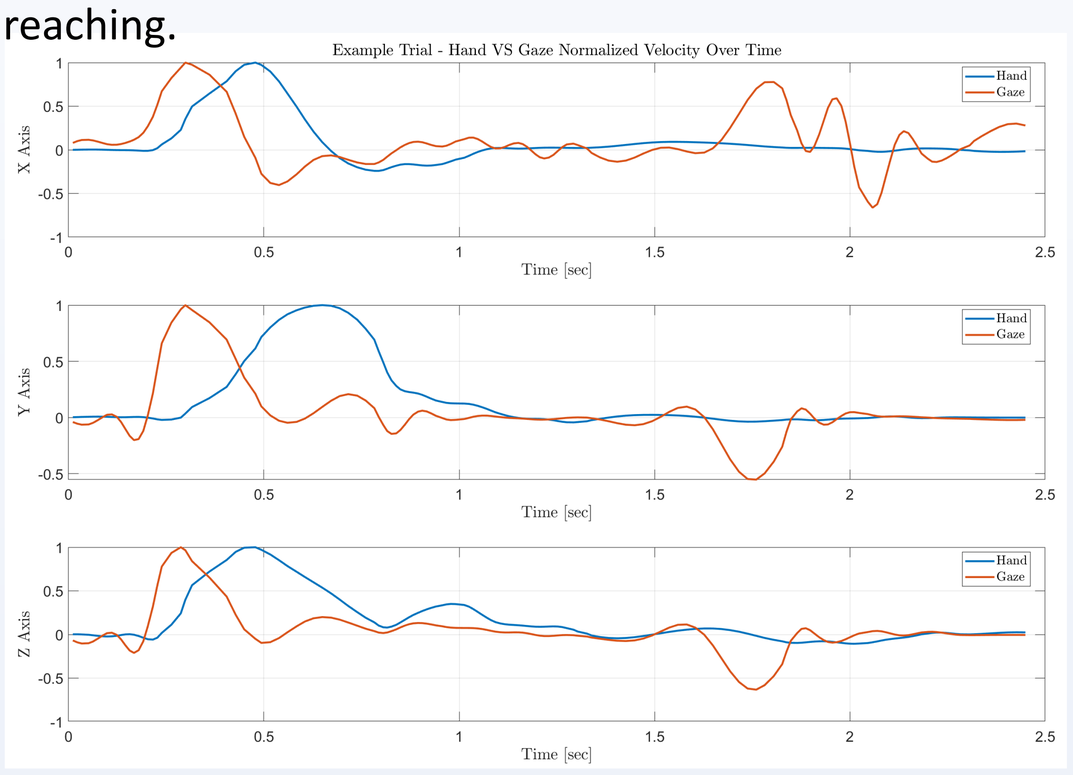


Fig 2. Normalized hand and gaze velocities during a sample trial

- Gaze and hand position **converge** leading up to a grasp.

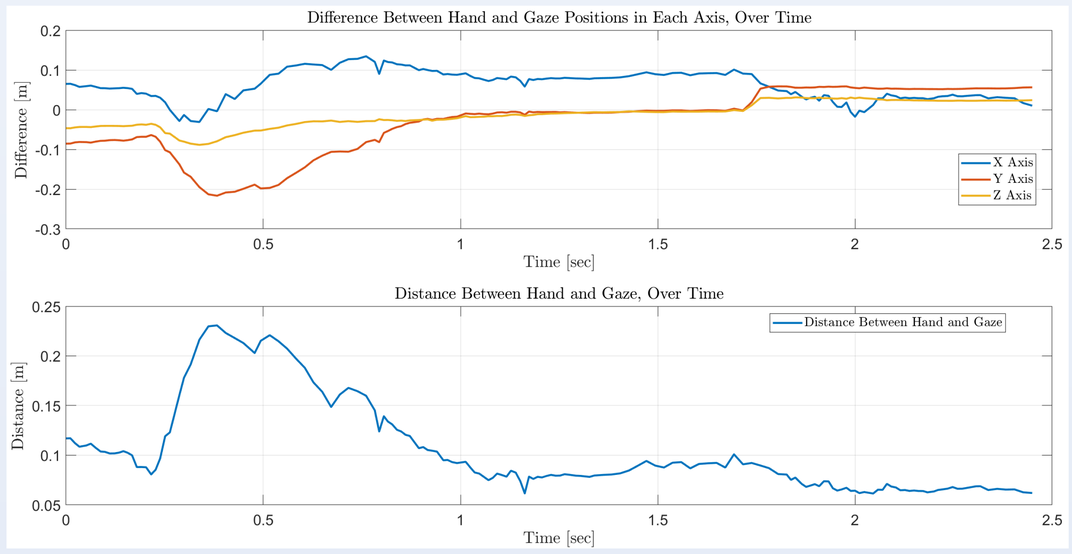


Fig 3. Difference in hand and gaze locations during a sample trial

- Ongoing work to determine how VR may affect behavior

Gaze tracking may help illuminate reaching intent

Future Work

- Develop **integrated platform** for recording multi-modal gaze, sEMG and kinematics
- Conduct "in-house" study including naturalistic activities in real-world settings (versus VR).
- We want to better understand muscle, postural, and gaze synergies during upper limb movements.
- Early motor synergies will be leveraged for **predicting user intent**.
- These will be implemented in a prosthetic arm controller.

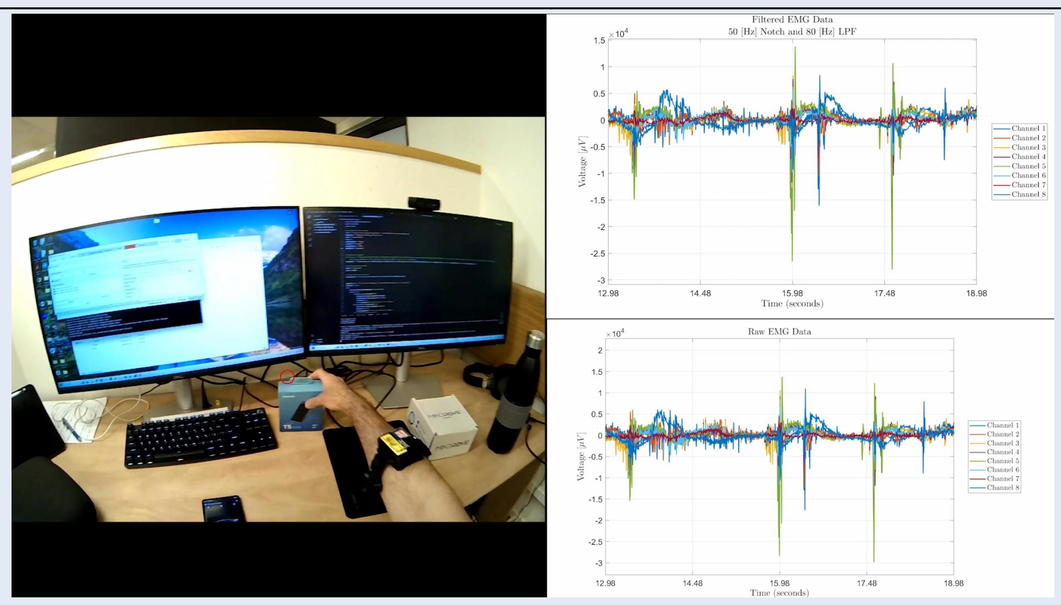


Fig 5. Screencap from demo video showing gaze tracking and sEMG

[1] M. Kutz, *Biomedical Engineering and Design Handbook, Volume 2*, Second Edition., vol. 2. McGraw-Hill Education, 2009. Accessed: Apr. 09, 2025. [Online]. Available: https://www.accessengineeringlibrary.com/content/book/9780071498395

[2] N. E. Krausz, D. Lamotte, I. Batzianoulis, L. J. Hargrove, S. Micera, and A. Billard, "Intent Prediction Based on Biomechanical Coordination of EMG and Vision-Filtered Gaze for End-Point Control of an Arm Prosthesis," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 28, no. 6, pp. 1471–1480, Jun. 2020, doi: 10.1109/TNSRE.2020.2992885.

[3] B. Lento *et al.*, "3D-ARM-Gaze: a public dataset of 3D Arm Reaching Movements with Gaze information in virtual reality," *Sci Data*, vol. 11, no. 1, p. 951, Aug. 2024, doi: 10.1038/s41597-024-03765-4.

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