Enhancing 6-DoF Rehabilitation Task Guidance with Augmented Reality

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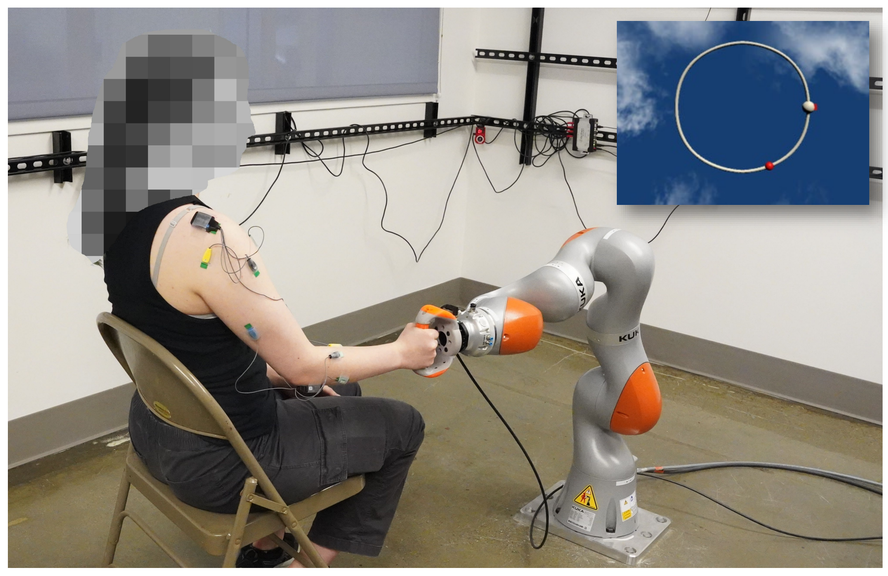
HRELab HUMAN–ROBOT EMPOWERMENT

Motivation & Aims

- **Robot-assisted rehabilitation** is a promising tool for upper-limb motor recovery, but **most systems allow only planar and/or otherwise constrained motion**, limiting (outcome-critical) training of activities of daily living.
- To rehabilitate more natural motions, we have developed a **rehabilitation robot platform** to **prescribe exercise in the full 6D** (3 positional, 3 rotational) **space** traversed by the hand during natural motion [1].
- This system currently directs user motion by displaying goal end effector trajectories on a screen, but **this 2D display is limited and unintuitive** for motions specifying more than a few degrees of freedom (DoF). In practice, due to these constraints, our initial studies ignored some DoF completely (e.g., pitch) and remapped others in suboptimal ways (e.g., in–out to up–down).
- Thus, in this work, we aim to construct an **augmented reality (AR) display that projects the desired trajectory at the real-world location of the robot end-effector**, allowing immediate comprehension by the user.



Rehabilitation robot gaming platform [1] with original 2D display superimposed, which we aim to port to AR in this work.

Augmented Reality System Design

Design Constraints

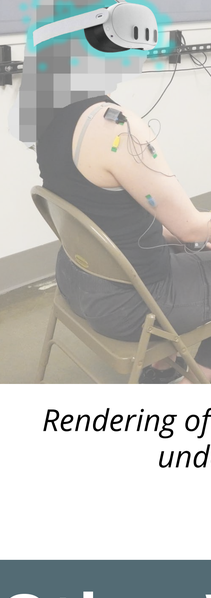
To enable use by cognitive- and motor-impaired users, we require the system to be:

- easy to don and doff;
- resilient to lag to **prevent motion sickness**;
- simple to navigate, with **easy-to-understand guiding visuals**;
- comfortable for long-term wear, to enable completion of many tasks in a single sitting; and
- **non-occlusive of user surroundings**, to prevent any incidental collisions with obstacles, especially involving the rehabilitation robot.

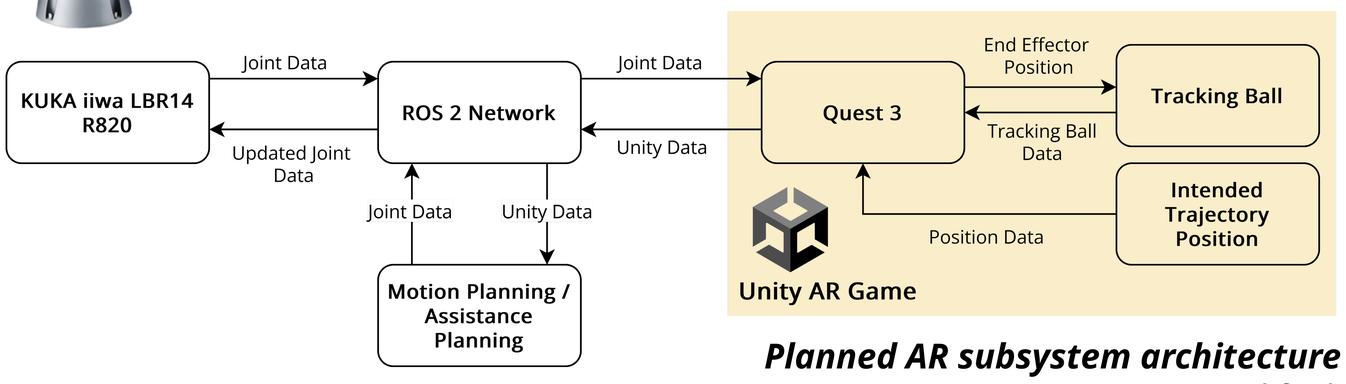
Pilot Study

A planned user study will **evaluate the impact of different feedback modalities on engagement during rehabilitation tasks**. Participants will complete the same tasks under three conditions: with no visual feedback, with the original 2D screen-based display, and with the full AR interface. This comparison is intended to **isolate the effect of the AR system** by examining differences in user engagement, attention, and pacing across the three setups, and will provide insight into how immersive feedback influences participation in rehabilitation.

Architecture & Display



Current development efforts focus on **wirelessly integrating** the Meta Quest 3 into the ROS2 network to support **untethered, standalone operation**. This advancement removes the need for a dedicated host computer, allowing the user to **move freely and better utilize the robot's full operating space**. Connecting the Quest directly to ROS2 also streamlines communication with other subsystems under development, including motion capture and real-time trajectory assistance.



Planned AR subsystem architecture *(simplified)*

Rendering of AR interface and display under development.

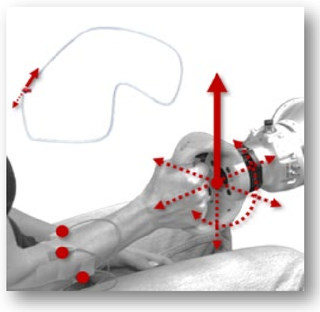
The AR display aims to preserve the simplicity and clarity of the original 2D system's trajectory visualization. The system displays a **goal trajectory** and a **red target position** along the trajectory, encouraging consistent pacing. Users' actions — previously, isometric forces and torques, now 6-DoF positions and orientations — are mapped to the location of a virtual avatar that users are instructed to **move to match the target position**.

The tracking and trajectory markers are designed with **partial transparency**, allowing the user to see their hand and surrounding environment through the visualization.

Context & Other Work

This work was undertaken as part of the Utah HRELab's **OpenRobotRehab** project. Check out other related projects here at RehabWeek!

- ***An Extensible Platform for Measurement and Modification of Muscle Engagement During Upper-Limb Robot-Facilitated Rehabilitation*** (ICORR paper 277)
- ***Toward a Muscle-Synergy-Based Model of Post-Stroke Pathology in Robot-Assisted Rehabilitation*** (late-breaking abstract)



Acknowledgements / References

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[1] Ajay Anand, et al. "An extensible platform for measurement and modification of muscle engagement during upper-limb robot-facilitated rehabilitation." in IEEE RAS/EMBS International Conference on Rehabilitation Robotics (ICORR). IEEE, 2025. (In press.)