An Augmented Reality Display for 6-DoF Task Specification During Upper-Limb Robot-Mediated Rehabilitation

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Developed an **Augmented Reality (AR) display for robot-assisted rehabilitation** that enables visualization of and interaction with precisely defined 3D trajectories.

Problem

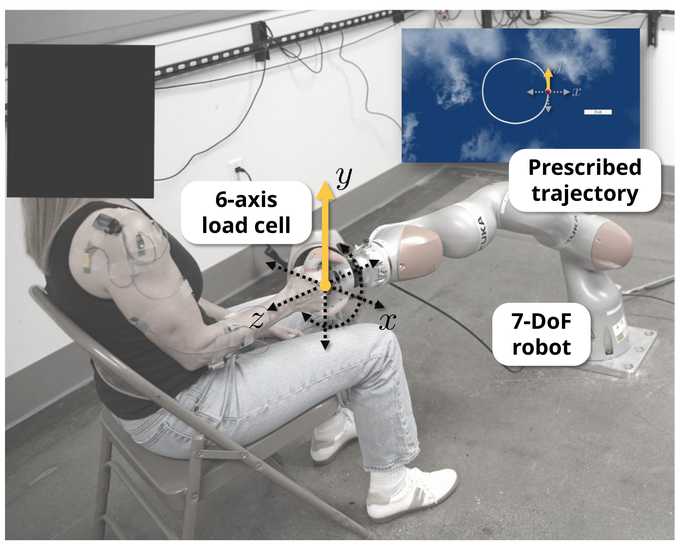
We aim to **characterize & guide neuromotor behavior during robot-mediated rehabilitation**, which requires precisely specifying end effector trajectories in **6-DoF** (x/y/z, r/p/y).

Previous work on our **OpenRobotRehab platform** [1] utilized a **2D trajectory** on a screen, which resulted in unspecified movement along the z-axis into the screen. This meant users could unintentionally **apply forces along this undefined axis**.

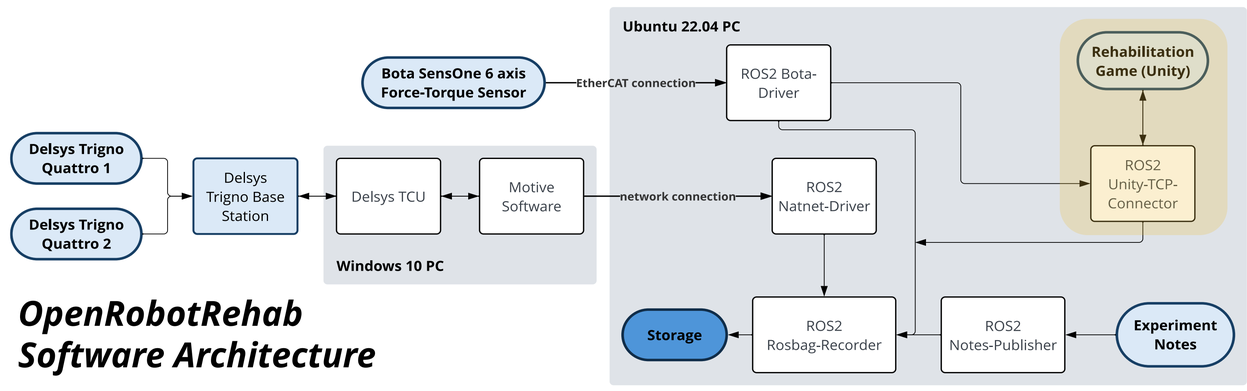
Contributions

- Created an AR visualization using the Meta Quest 3 headset to allow for **precise 6-DoF trajectory definition** during end effector robot-mediated therapy on the OpenRobotRehab platform.
- Developed a modular Unity package to allow for future system expansion.

OpenRobotRehab Platform [1]



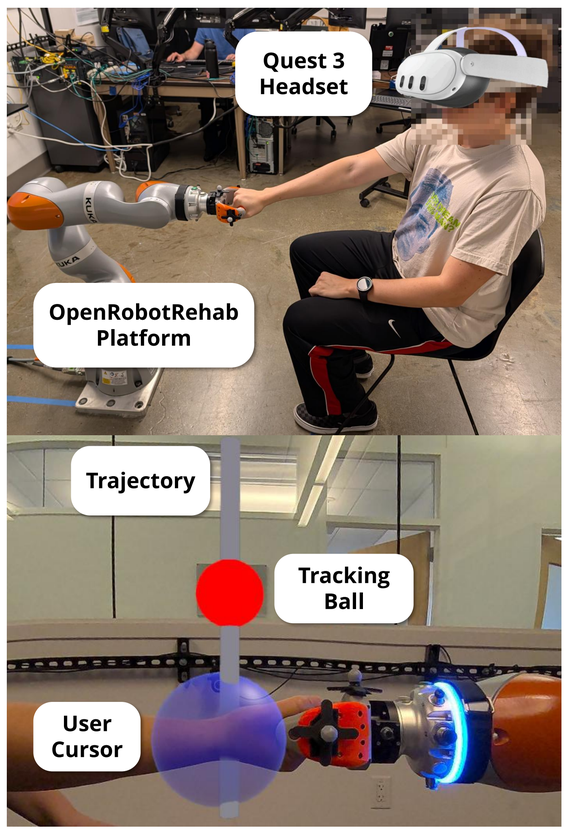
Users follow trajectories displayed on a 2D screen by transmitting **forces and torques** through a Bota Systems SensONE 6-axis load cell to move a **KUKA LBR iiwa 14 R820 7-DoF cobot**.

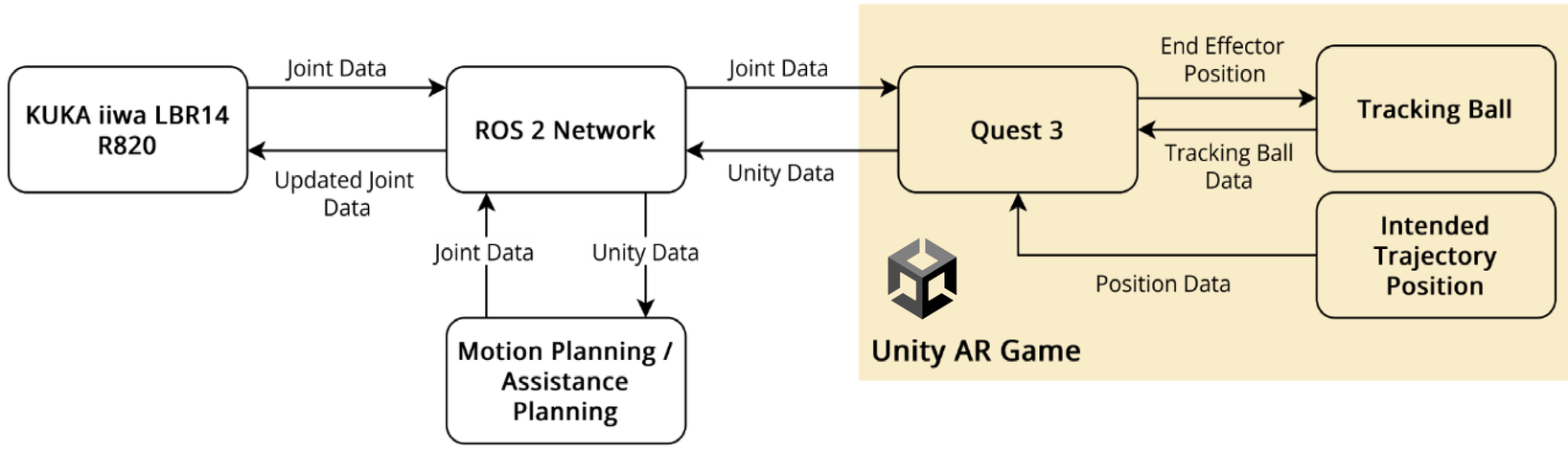


OpenRobotRehab Software Architecture

The initial platform used **Unity** to create and display the 2D trajectories, as well as for communicating tracking information over the **ROS 2 network**.

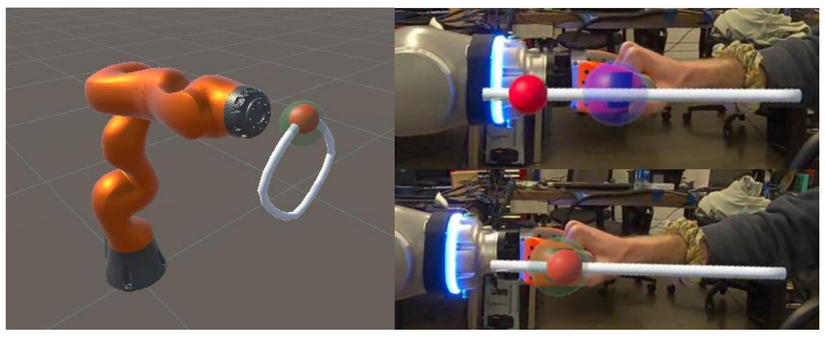
AR Visualization System Design





Robot joint state and kinematic data are published over ROS 2 by the **KUKA cobot** and streamed to a **Unity-based application** via the **Unity-TCP-Endpoint**, which bridges ROS 2 messages into the Unity game on the Quest 3. A **virtual kinematic model** of the robot is **spatially aligned** with its physical counterpart. Rehabilitation trajectories are rendered as **3D paths overlaid on the workspace** using the Quest 3's video passthrough, enabling **spatially complex trajectories across all three axes**.

To provide supplementary feedback on tracking performance, the user-controlled cursor **changes color to green when within one inch of the target sphere** along all three spatial axes. All **trajectory deviation data is continuously logged** over the ROS 2 network, including confirmation when the user is tracking correctly. This data is then fed into the **assistance planning algorithm***, which calculates and applies corrective actions to the robot in response to deviations.



Future Work

- Continued development of assistance planning module
- **AR-augmented OpenRobotRehab data set** collection
- User study on **task engagement** when using the AR vs. 2D display

References / Sponsors / Acknowledgments

[1] Ajay Anand, et al. (2025). "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).

This work was supported by the Department of Mechanical Engineering at the University of Utah.

We recognize Ajay Anand, Carson J. Wynn, and Gabriel Parra for their contributions to this work.

*This module is currently under active development.