Immersive robot teleoperation through a real time updating virtual reality environment

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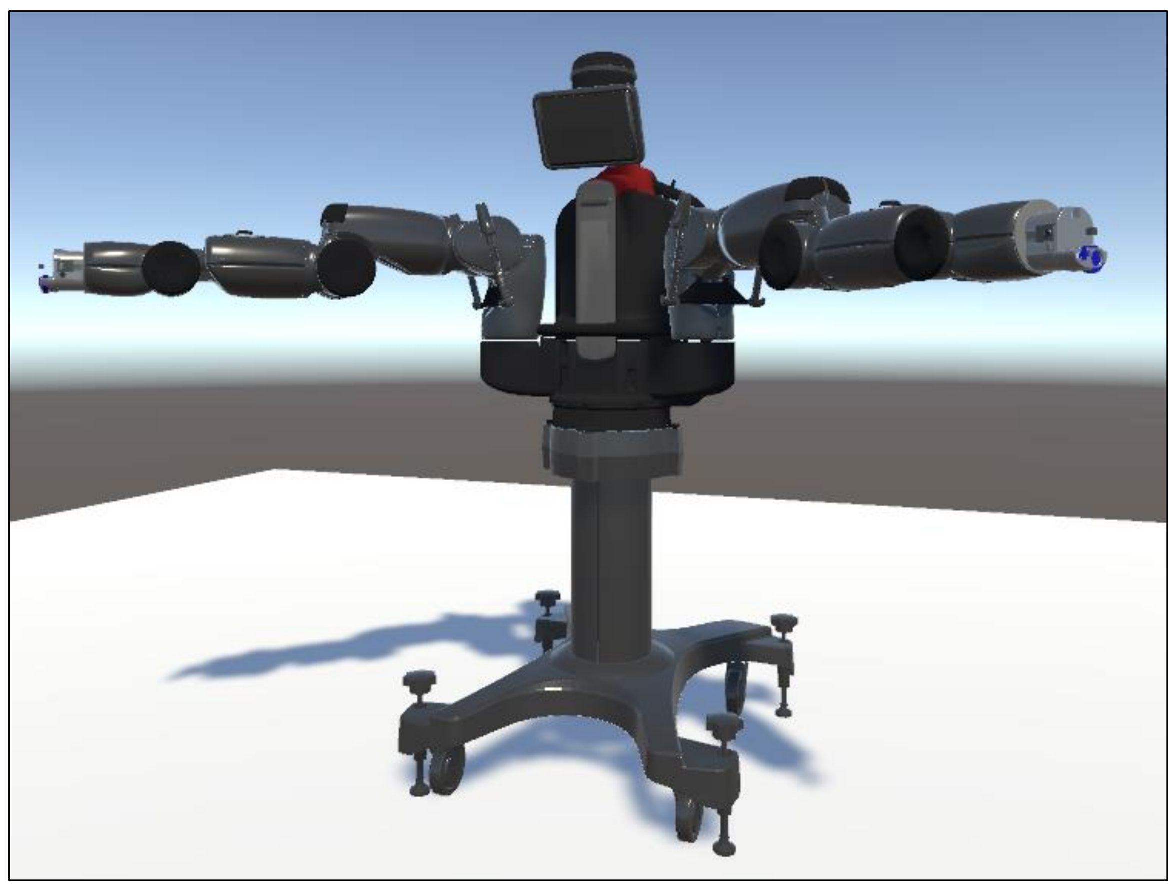
Motivation

With the arrival of Industry 4.0 there have been rapid advancements in the field of collaborative robots. Similarly the last decade has seen major advances in affordable Virtual Reality (VR) technologies. Our ambition is to utilise these technological advancements in combination with additional sensory equipment for the ongoing development of a VR teleoperation system. The proposed system is one wherein an operator, controlling from a VR environment, can reliably and intuitively perform a dual arm manipulation task at a remote location.

The following are the three main areas of impact:

- The proposed system aims to offer blue collar workers the ability to have telepresence into the work environment from home, enabling them privileges typically only given to white collar workers.
- The system aims to provide an intuitive control method for robots in hazardous environments.
- Industrial production lines are typically not disability friendly. Use of the proposed system will enable those with disabilities to work within this sector which is normally closed off from them.



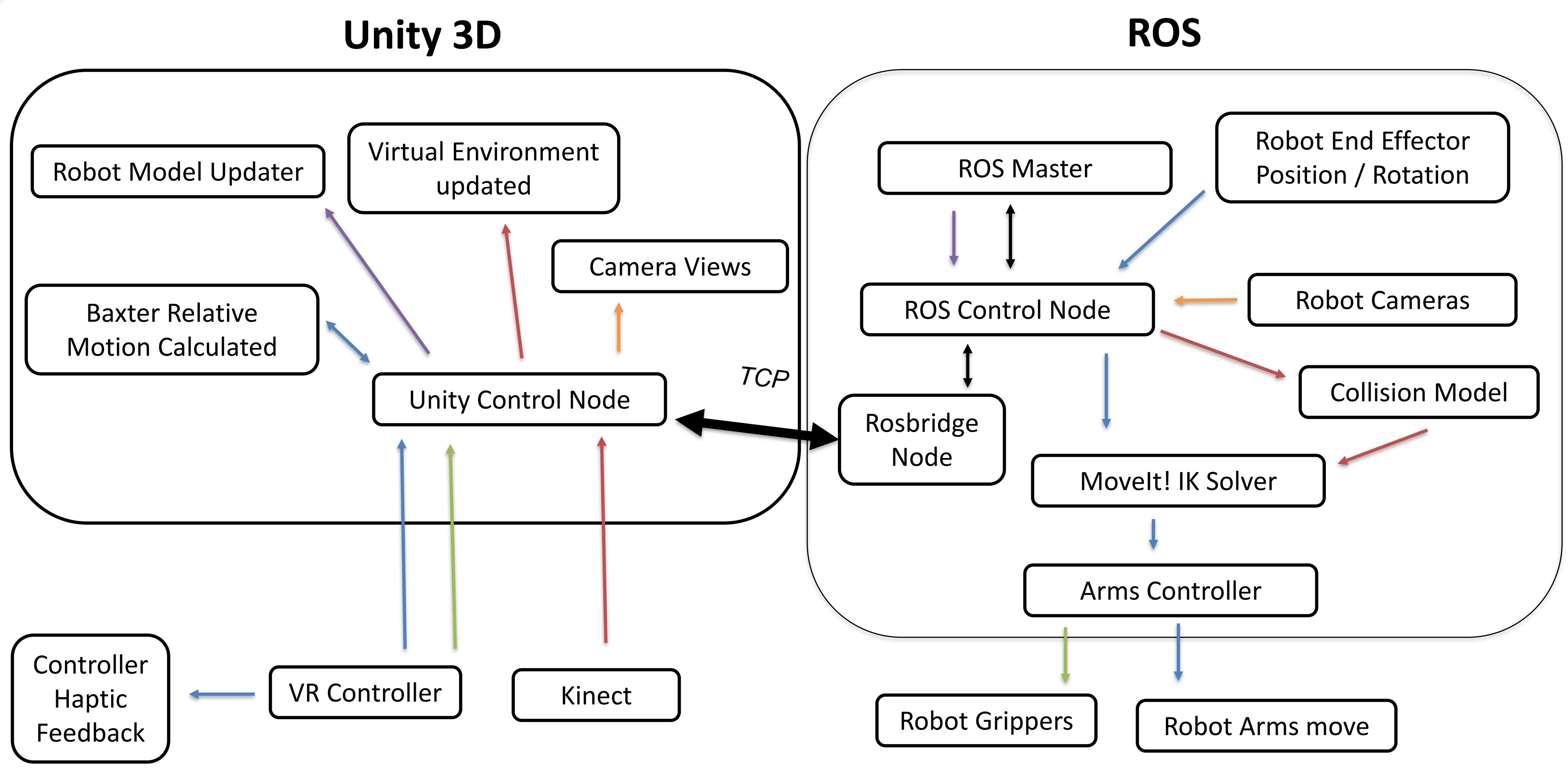
Existing Solutions

Recent research by J. I. Lipton et al [1] at the Massachusetts Institute of Technology (MIT) led to the creation of a homunculus model for VR teleoperation of a robot. They demonstrated capabilities and needs for a VR teleoperation model.

The proposed system will incorporate the following additional features:

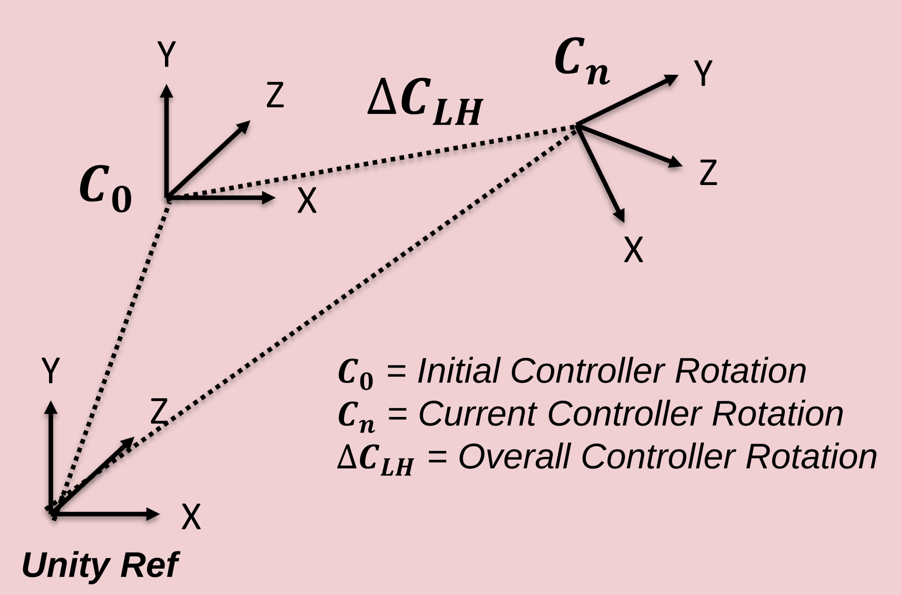
- A real time updating virtual representation of the work scene.
- Perspective view allowing user different viewpoints.
- Haptic feedback of Inverse Kinematic (IK) constraints.
- Relative motion control from 6-DoF controllers for robot arm manipulation.
- Enhanced safety through addition of detected objects to robot collision avoidance model.

Work In Progress Concept Implementation



VR to Robot Manipulation using Quaternion Rotations

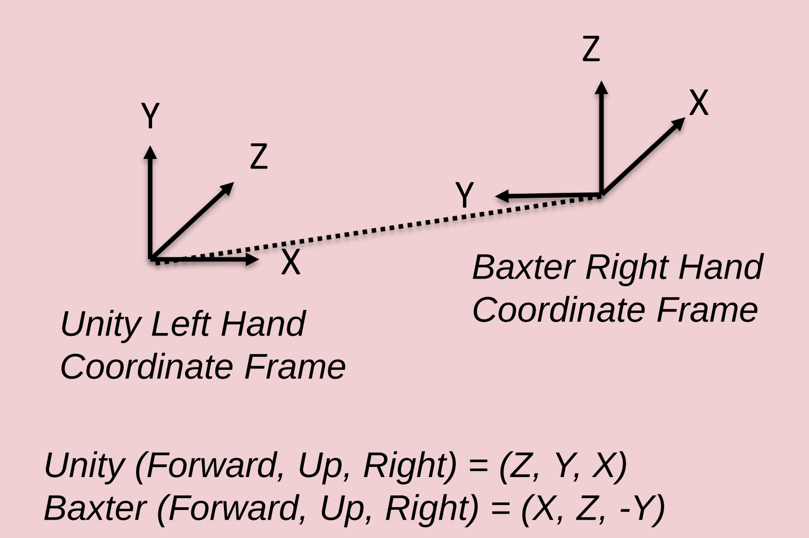
Step 1



$$\Delta C_{LH} = C_0^{-1} * C_n$$

Controller trigger is pulled resulting in C_0 being recorded. Each subsequent Unity frame overall rotation ΔC_{LH} is calculated in the above equation. C_0 and C_n are quaternion rotations relative to Unity's world reference frame

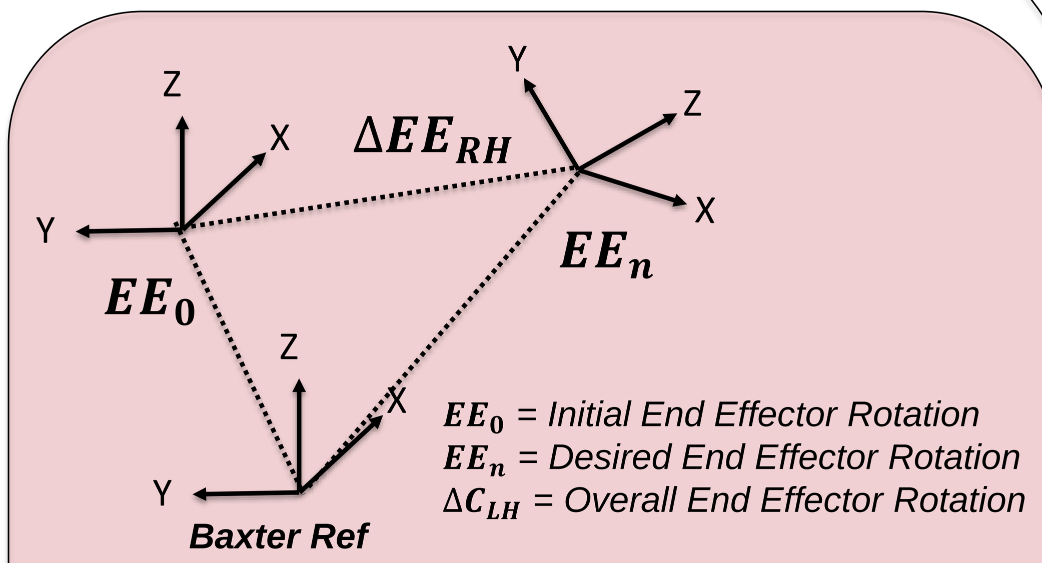
Step 2



$$\Delta EE_{RH}(x, y, z, w) = \Delta C_{LH}\ (y, x, -z, w)$$

The quaternion ΔEE_{RH} , describing the overall rotation in the Baxter robot's End Effector right-handed frame, is attained through manipulation, shown above, of the quaternion ΔC_{LH} from the left-handed overall rotation of the controller.

Step 3



$$EE_n = EE_0 * \Delta EE_{RH}$$

The desired quaternion EE_n , describing rotation from Baxter reference frame to the desired position, is calculated using the above equation. EE_n and EE_0 are quaternion rotations relative to Baxter's Base reference. This is used in an IK solver to find joint angles for robot arm

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References

[1] J. I. Lipton, A. J. Fay and D. Rus, "Baxter's Homunculus: Virtual Reality Spaces for Teleoperation in Manufacturing," in IEEE Robotics and Automation Letters, vol. 3, no. 1, pp. 179-186, Jan. 2018.

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