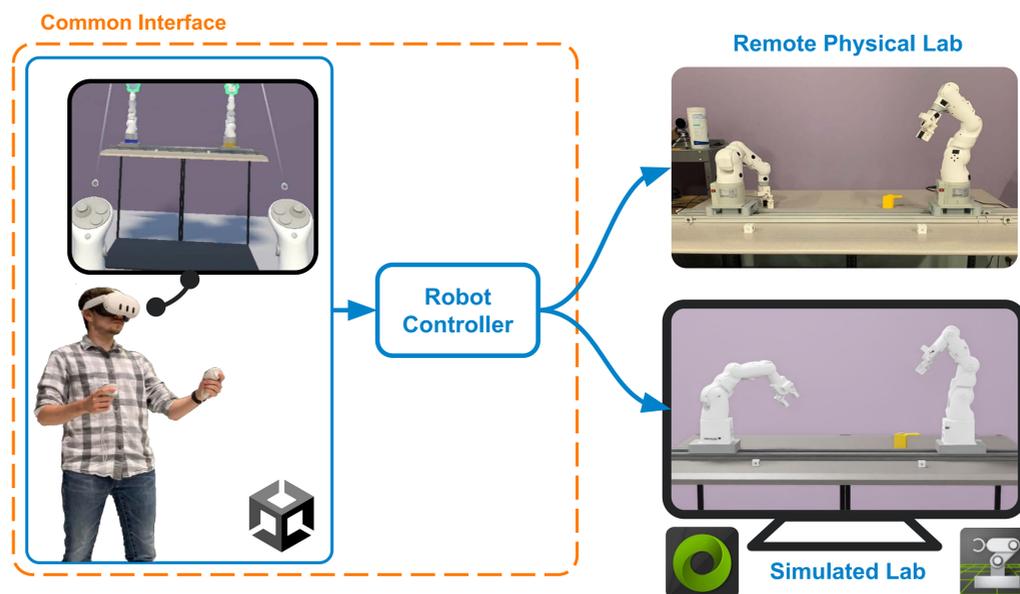


Using Virtual Reality for Remote Dexterous Manipulation: An Exploration of Methods

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Abstract

In situations where it is difficult to perform robotic laboratory tasks with physical hardware—such as handling radioactive materials, or collecting imitation learning demonstrations at scale—it is useful to be able to simulate the robotic laboratory environment. Mixed Reality interfaces enable operators to interact with these simulations in an intuitive and immersive format. In order to achieve quality, accurate control from the operator, it is important that the simulated hardware, environment, and interaction paradigms are as good as they can be. In this work, we perform a survey of existing techniques for robot simulation, robot control, 3D scene reconstruction, and VR user interaction, and propose methodology for examining the most effective combination of methods for remote teleoperation. Further, we examine how to address user-perceived differences between the simulation interface and the physical control interface.



As shown above, our goal is to create a VR-enabled User Interface that communicates with a robot controller to provide a common method for interacting with remote and simulated robotic laboratories.

Motivation

Due to its hazardous nature, isotope production must be conducted within a remote environment through a machine interface known as a “hot cell”. By creating an interactive simulation of the hot cell that doubles as the operator interface, new operators can be trained without needing access to the hardware, lab procedures can be tested for potential safety risks, and task demonstrations can be collected for robot learning.



Methods

Use Unity3D and NVIDIA Isaac Sim to implement several variations of the above diagram with different **scene generation** and **interaction paradigms**.

Scene Generation

The simulated lab environment must be modeled, either by hand in a CAD software, or using 3D reconstruction methods.

Shown below is an example of a RGB point cloud captured with an Intel RealSense D455 stereo camera, which can be used to generate a 3D mesh.



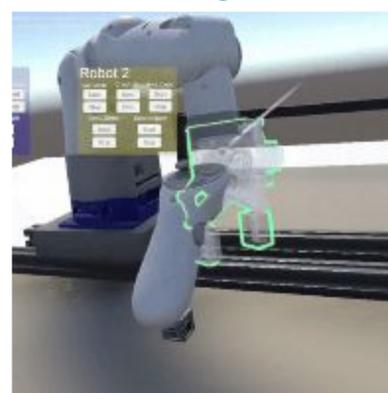
Interaction Paradigms

Mirroring



Send **joint-space commands** based on the pose of a virtual “leader” robot

Absolute Target Position



Send **target-space commands** to the robot controller to solve the inverse kinematics

Jogging



Apply incremental change to the robot in either **joint or target space**.

Results

Pros

Cons

Mirroring

Intuitive User control

Developer intensive to simulate

Absolute Target Position

User can focus on task-space objects

Highly dependent on robot hardware accuracy/calibration

Jogging

User has low-level control of hardware

Slower operation

Conclusions

- Different interaction paradigms will suit different levels of sensing ability, robot hardware accuracy, and user preference.
- A common interface in Omniverse Isaac Sim and Unity 3D allows for easily switching robot arm hardware and VR hardware without much developer effort.
- In the future, automatic methods of extracting objects (such as the beaker) from the scene with sensors will allow for faster, automated task completion.

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