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Digital Twin for UR5 Robot using AR Phase II

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Abstract

This project presents the development of a Digital Twin and Augmented Reality (AR) system for the real-time remote control and monitoring of a UR5 collaborative robot. The principal objective is to create a safe and efficient mixed-reality interface for robotic teleoperation. The methodology involves utilizing the Unity engine to construct the virtual environment and simulate physics, computing robot kinematics, and establishing a low-latency network communication bridge between the ROS2 controller and Unity. Preliminary results demonstrate the successful establishment of a stable connection, achieving highly accurate and synchronized movement between the physical robot and its virtual counterpart. In conclusion, this system significantly enhances operational safety and remote control efficiency, providing a robust foundation for future smart factory applications.

Advisor(s): Asst. Prof. Dr.Sudchai Boonto

1. Introduction

In the modern industrial era, "Digital Twin" technology—creating virtual replicas of physical systems—has gained significant attention for remote equipment analysis and control. This project aims to integrate Digital Twin technology with Virtual Reality (VR/AR) to develop a Mixed Reality (Twin Reality) system for controlling a UR5 robotic arm. Users can monitor the robot's status and control it in real-time via a VR headset (Valve Index). This approach reduces operational errors, enhances safety, and creates a more efficient human-robot collaborative work environment.

2. Methods

The system's methodology integrates a low-latency Star Topology network via a Gateway Router , using the TCP/IP protocol to seamlessly connect ROS 2 on Ubuntu with the Unity engine on Windows.

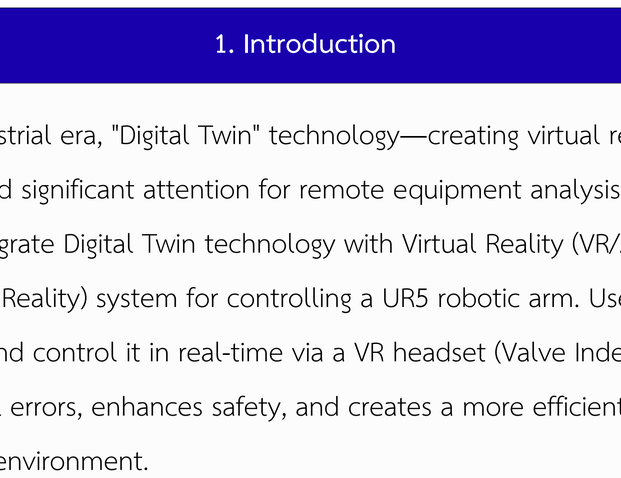


Figure 1. Control robot by controller

the UR5 robot's physics and kinematic chain. For real-time operation, movements from a VR controller are computed into 6D Twist commands and converted into precise joint velocities using an Inverse Jacobian Matrix. Concurrently, a RealSense D455 Depth Camera mounted on the robot's gripper generates real-time 3D models of physical workspace objects directly within the virtual environment, ensuring an accurate and synchronized mixed-reality interface

Within Unity, the NVIDIA PhysX engine and ArticulationBody components are utilized to accurately simulate

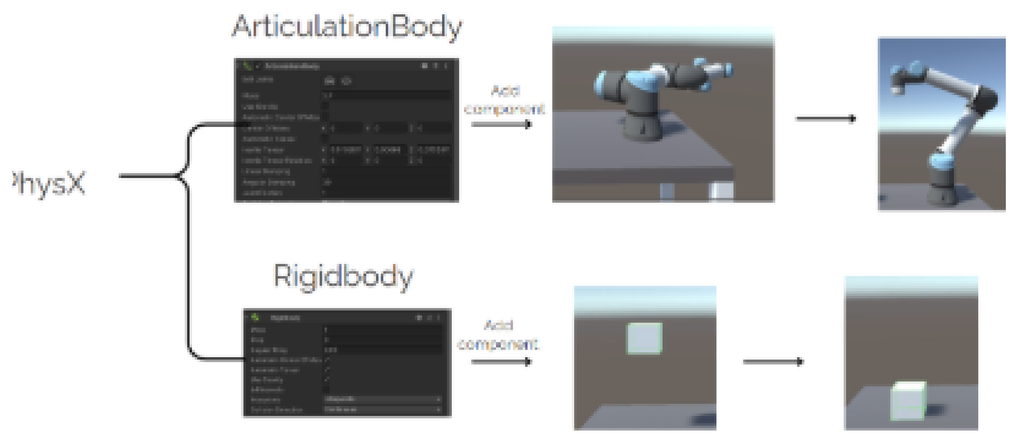


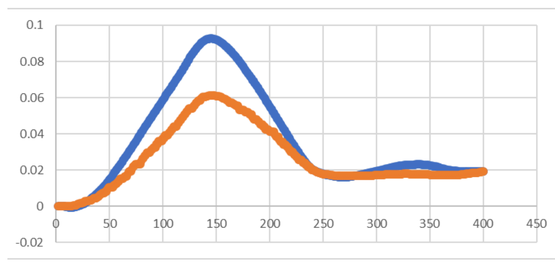
Figure 2. Physics engine in Unity

3. Conclusion

This project successfully developed a remote control system for a UR5 robotic arm utilizing a Twin Reality environment. The communication between ROS 2 and Unity is highly stable, enabling precise real-time operation. Furthermore, the system efficiently virtualizes the physical workspace, making it highly suitable for advanced Smart Factory applications.

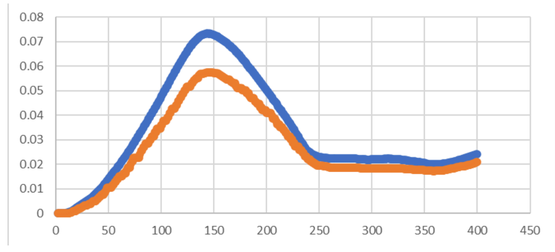
4. Results

Visual output testing confirmed that the Twin Reality environment was successfully and stably rendered onto the Valve Index VR headset. Test accuracy between Real world UR5 and Virtual world UR5 by set twist.



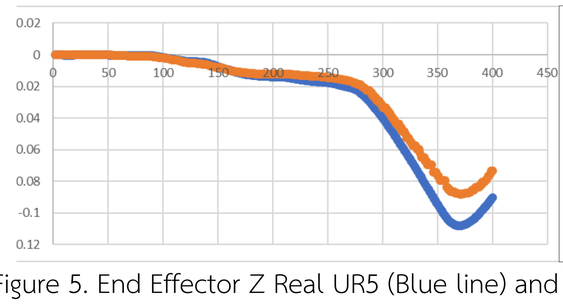
Mean Square Error of X
Real UR5 0.002352
Virtual UR5 0.001174

Figure 3. End Effector X Real UR5 (Blue line) and Virtual UR5 (Orange line)



Mean Square Error of Y
Real UR5 0.017215
Virtual UR5 0.015201

Figure 4. End Effector Y Real UR5 (Blue line) and Virtual UR5 (Orange line)



Mean Square Error of Z
Real UR5 0.014798
Virtual UR5 0.016756

Figure 5. End Effector Z Real UR5 (Blue line) and Virtual UR5 (Orange line)

References

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[2] M. Macklin et al., "Small Steps in Physics Simulation.

[3]Unity Documentation, "Articulation Body component reference”