

MULTI-LAYER ROBOTICS TELEOPERATION FOR FRANKA EMIKA PANDA

Ruby Blaney
Supervisor David Russell

Research in the modern robotics field is an end product of both simulation and hardware environments that bridge automatic motion execution with task planning. However, this combination is notoriously tricky and causes technical friction for developers due to the multiple disconnected software platforms, and is often a steep learning curve to overcome.

My project aimed to develop an efficient framework that connected robot control , realistic physics environments, and virtual reality so that robotic arms, such as the Franka Emika Panda, are much simpler to program and test.

To build this framework, the project combined the Robot Operating System (ROS) for device communication, MuJoCo for real-time physics, and Unity with Meta Quest for immersive visualisation. The research looked at combing these different robotic tools into a single pipeline without causing major delays or lag.

Testing showed that this unified multi-layer approach successfully enables real-time tracking and interactive control. These findings make multi-platform robotics development much more accessible. Ultimately, this framework provides a foundation for future academic research to progress the field of robotic manipulation regarding teleoperation techniques. This, if progressed, can also be pushed from research into industry as with the techniques developed can be used in remote-operating surgical environments or used in the space industry, where physical human exploration may be difficult.



INTRODUCTION

Modern robotics research relies heavily on combining simulation and hardware to bridge task planning with automated motion execution. However, working with multiple disconnected software platforms creates a steep learning curve and high technical friction for developers. This project addresses these barriers by developing a streamlined, multi-layer framework designed to make programming and testing robotic arms significantly more efficient.



RESULT

- Experimental Outcomes:**
- **Performance & Latency:** The unified multi-layer architecture successfully achieved stable, low-latency data transmission between ROS, MuJoCo, and Unity/Meta Quest, avoiding major synchronization bottlenecks during runtime.
 - **Tracking & Control:** Real-time tracking of the Franka Emika Panda was reliably maintained within the immersive virtual environment, demonstrating that smooth teleoperation across disconnected platforms is achievable.
 - **Framework Usability:** Testing indicated that bridging these tools into a single pipeline significantly reduced the technical friction typically encountered when setting up multi-platform robotic simulations.



OBJECTIVE

- Primary Objective: To design and implement a unified, multi-layer framework that seamlessly connects robot control, realistic physics simulation, and virtual reality.
- Key Aims:
- Simplify the programming and testing workflow for robotic arms like the Franka Emika Panda.
 - Bridge the gap between disparate software tools (ROS, MuJoCo, Unity/Meta Quest) into a single, cohesive pipeline.
 - Minimise lag and synchronisation bottlenecks to enable reliable real-time tracking and interactive control.



ANALYSIS

- Data & Performance Analysis:**
- **Interoperability & Communication:** Evaluating the data streams across ROS, MuJoCo, and Unity revealed that overhead can be effectively managed with optimized message passing, preventing critical lag during active teleoperation.
 - **Platform Bottlenecks:** The analysis indicates that simulation fidelity and real-time visualization can coexist without sacrificing control frequency, though network stability remains a primary factor for headset deployment.
 - **Implications:** These insights validate that multi-platform modular frameworks are viable alternatives to monolithic software, offering a flexible foundation for future robotics development.



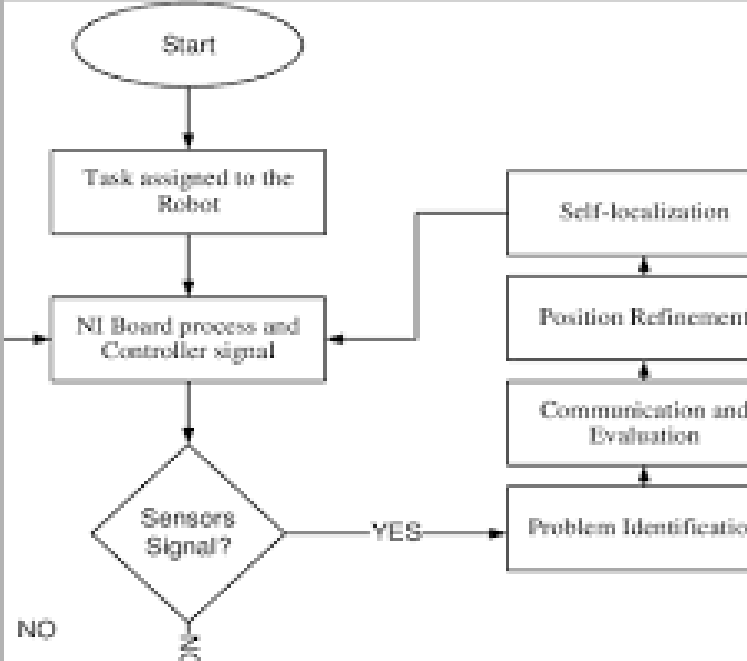
METHODOLOGY

- System Architecture & Approach:
- **Robot Control (ROS):** Utilised the Robot Operating System for reliable device communication and managing data flow for the Franka Emika Panda.
 - **Physics Simulation (MuJoCo):** Integrated MuJoCo to handle real-time, high-fidelity physics calculations and environmental interactions.
 - **Visualisation & Teleoperation (Unity / Meta Quest):** Built an immersive virtual environment using Unity deployed to a Meta Quest headset for intuitive user visualisation and remote control.
 - **Pipeline Integration:** Developed a synchronised multi-layer architecture to bridge these platforms, ensuring low-latency data exchange between simulation physics and physical execution.

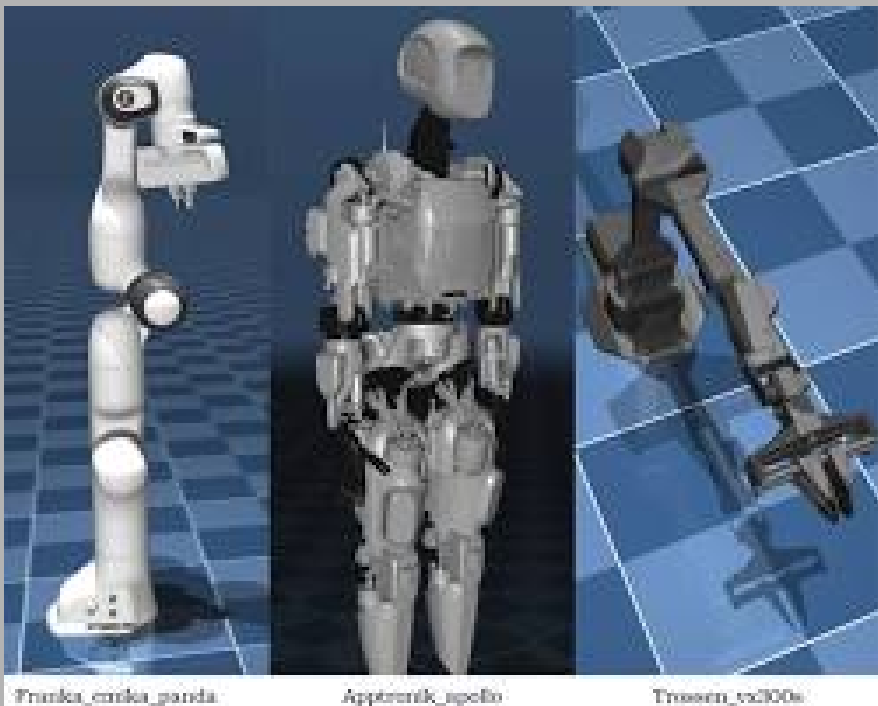
Franka Emika Panda Arm



System Architecture



Physics Simulation



CONCLUSION

In conclusion, this project successfully demonstrates that integrating ROS, MuJoCo, and Unity/Meta Quest into a unified multi-layer framework provides a stable and efficient pipeline for robotic arm teleoperation. By bridging these platforms, the system reduces technical friction and enables real-time tracking for the Franka Emika Panda. Future work will expand on these adaptive methodologies to advance complex manipulations, opening pathways for remote-operating applications in demanding environments such as space exploration and specialized surgery.

References:



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