# Hand-Tracking and Extended Reality Interface - Collaborative Robots

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## Introduction

This research project is centered around testing and expanding the capabilities of collaborative robot arms, also known as cobots. Robotic arms are used in many industrial settings, from simple pick-and-place operations to complex human-robot interaction. The main goal was to explore new ways to control a cobot effectively and safely using extended reality (XR). We implemented and documented a variety of control methods progressing from basic input devices to full hand-tracking interaction.

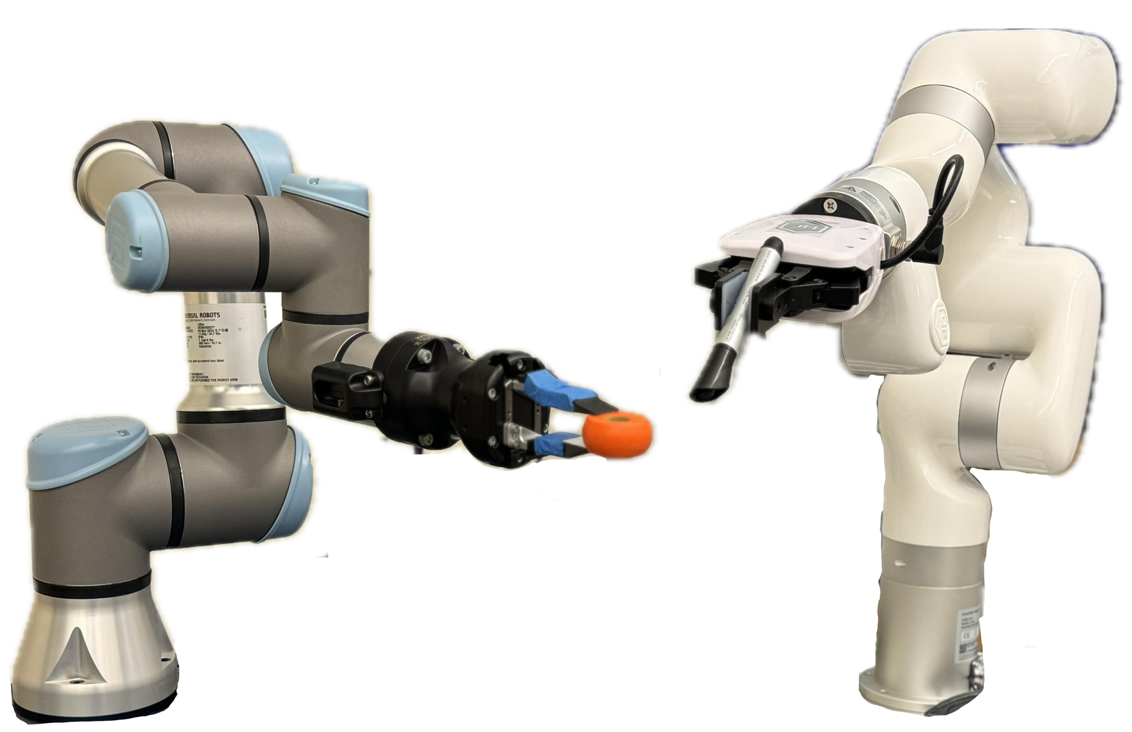

Fig 1: UR3e and xArm 5 cobots

## Materials and Equipment

We used two collaborative robots to test different control methods with a Meta Quest 3:

- **UR3e (Universal Robots):** lightweight, compact, industrial cobot which works effectively in tight spaces. We paired it with the Robotiq 2F-85 adaptive gripper, which provided reliable grasping for a range of object sizes.
- **XArm5 (UFactory):** A five axis cobot, proficient at simple pick and place operations. It was equipped with the xArm Gripper, allowing for reliable grasping and manipulation of objects.
- **Meta Quest 3:** An XR headset to track a person's hands.

## Extended Reality Interface

The team's key achievement was implementing a virtual reality hand-tracking system using a Meta Quest 3 headset. Pose data from the headset was streamed to the computer via MQTT protocol, providing a reliable and efficient way to transmit real-time position data. The computer application then processed this data and translated the tracked hand positions into both Cartesian velocity commands and Cartesian position commands.

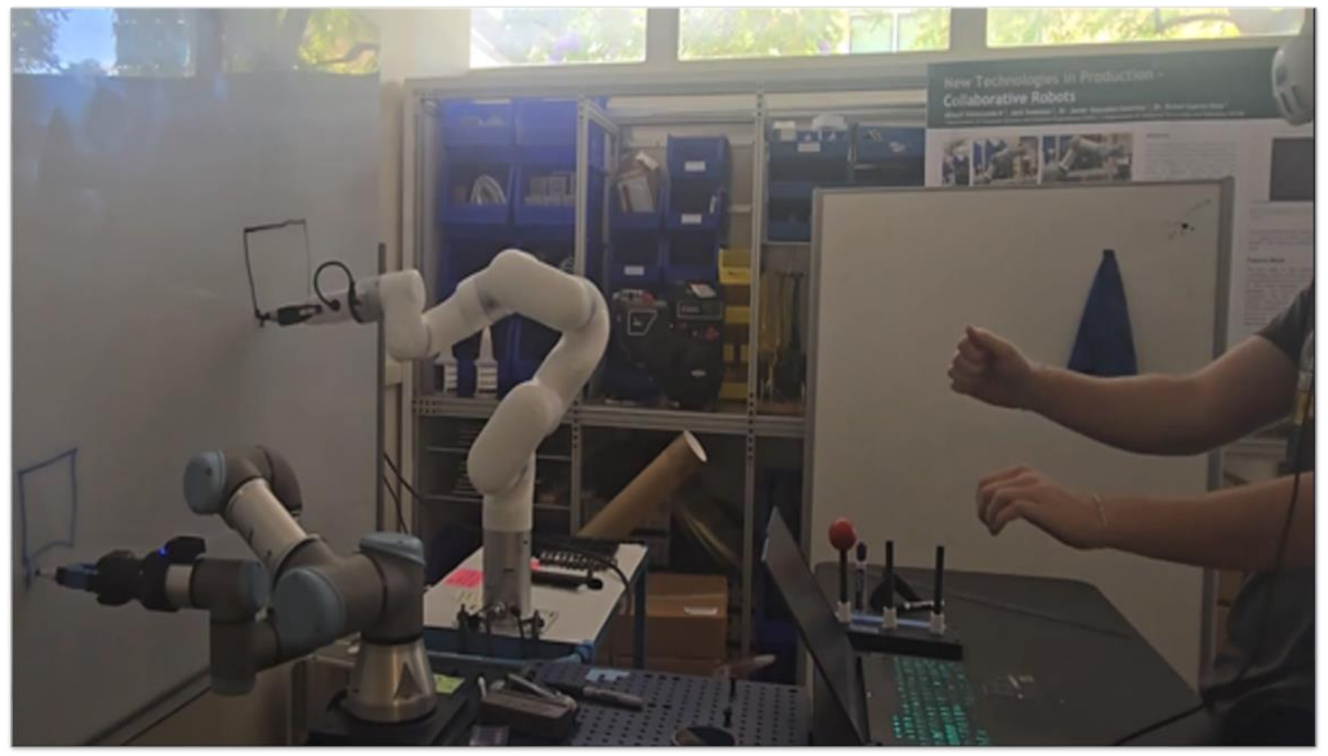

Fig. 2: Robots controlled by hands using Meta Quest side view

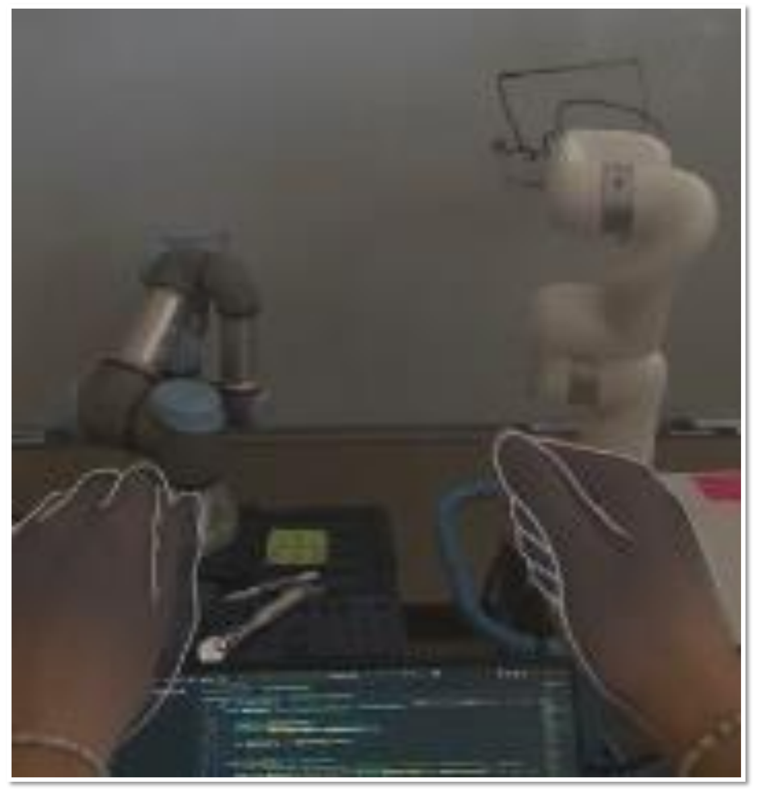

Fig. 3: User's perspective of control using meta quest

## Mouse Control

As a baseline, the team first tested keyboard and mouse input. For mouse tracking, both Cartesian velocity commands (smooth continuous motion) and Cartesian position commands (precise movements) were implemented. These provided a reliable foundation for testing responsiveness and precision before transitioning to XR control.

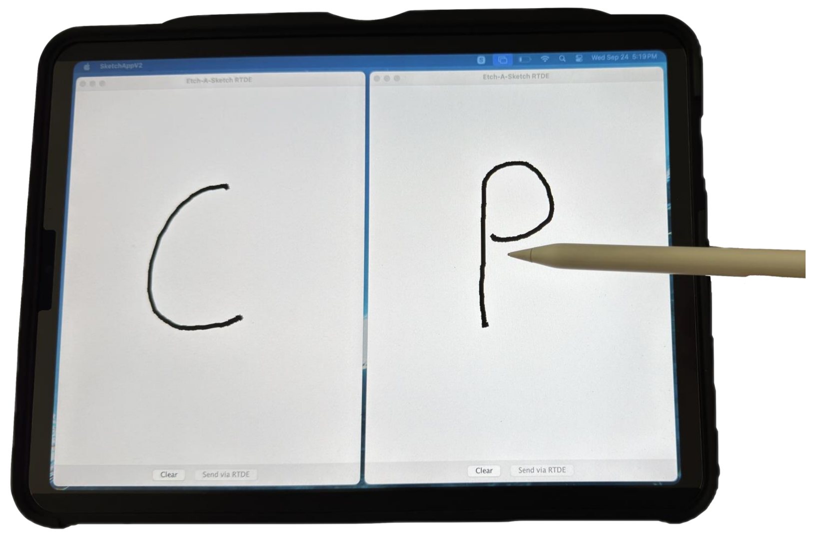

Fig. 4: UI of Cobots writing by following mouse

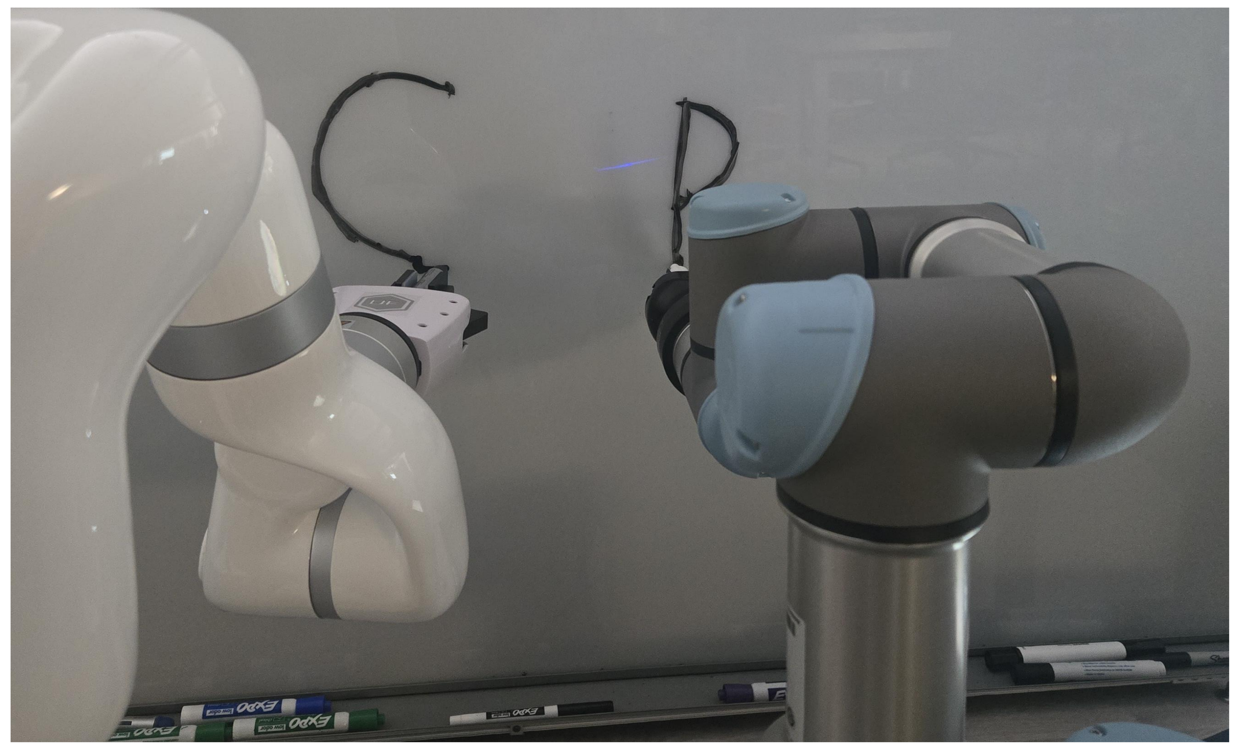

Fig. 5: UR3e and xArm 5 cobots write by following mouse front view

## Challenges

The major challenge was achieving stable and accurate hand-tracking, as inconsistent MQTT data could cause for sudden jumps. Because of this, the team tested using both velocity and position control and implemented several strategies including data filtering, velocity clamping, and dead-zone thresholds in order to ensure smooth movement.

## Future Work

The next steps for the research team include expanding and improving the hand tracking control system. One possibility would be to map the user's hand gestures directly to the cobot's gripper, enabling the robot to emulate the opening and closing hand gestures of the . Another direction is the refinement of data tracking to achieve smoother and more precise motion as well as reducing jitter.

## References

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Scan to watch video of robots following hands