# I Am a Robot: First-person Robotic Arm Control with Hand Motions in Virtual Reality


Emory Meursing*
emeursi@ostatemail.okstate.edu
Oklahoma State University
Stillwater, Oklahoma, USA

Zeyu Deng*
zdeng6@lsu.edu
Louisiana State University
Baton Rouge, Louisiana, USA

Jordan Fogg
jordan.fogg@okstate.edu
Oklahoma State University
Stillwater, Oklahoma, USA

Long Huang
lhuan45@lsu.edu
Louisiana State University
Baton Rouge, Louisiana, USA

Huaxia Wang
huaxia.wang@okstate.edu
Oklahoma State University
Stillwater, Oklahoma, USA

Chen Wang
chenwang1@lsu.edu
Louisiana State University
Baton Rouge, Louisiana, USA



## ABSTRACT

With the rapidly growing virtual reality (VR) technologies, maturing motion tracking applications, and the advancement in robotics, physically interacting with the remote world via a robot while the user is observing the scene through a VR headset seems to be one solution to the substantial need for telepresence. This work presents a first-person viewing hand motion controlled robotic arm framework that provides an immersive robot control experience. In particular, we developed a platform with an off-the-shelf 360° camera, a robotic arm, and a VR headset to allow for live 360° video streaming, hand tracking, and robotic arm control. Demo activities with three types of robot operation tasks (i.e., in-air drawing, object collection, and line tracing) show that our platform enables an enhanced first-person vision presence and a smooth robot teleoperation.



## CCS CONCEPTS

• **Human-centered computing → Ubiquitous computing**; • **Computer systems organization** → *Robotic control*; *Embedded and cyber-physical systems.*

## KEYWORDS

Human-robot Interaction; Motion Control; Virtual Reality

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*Both authors contributed equally to this research.



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## 1 INTRODUCTION

As society progresses through the years, it advances in many different fields: businesses develop new ideas on ways to market their products to consumers, new medicine is created to help increase the longevity of human life and cure multitudes of diseases, and engineers are developing new processes to upgrade current technologies or invent new ones. One such technology is virtual reality (VR), available in commercial devices like the Meta Quest 2 [2]. As Meta states: "*VR uses cutting-edge graphics, best-in-class hardware, and artistically rendered experiences to create a computer-simulated environment where you aren't just a passive participant, but a co-conspirator.*" [1]

With the integration of virtual reality into different fields of the working environment, many have looked into VR to see if there is some way to integrate it into their job. Within the robotics field, one way to implement this technology is the remote operation of a robot to allow a user to work from a controlled environment instead of a hazardous one. There have been technologies to enable a robot to follow VR controllers [3], allow a robot in the real world to mimic a simulation of itself [5], and let users view information from a robot in augmented reality (AR) [4]. However, there is still no commercial or open sourced applications that integrate live VR streaming with robot control.

In this demo, we implement a platform that allows a 360° camera to stream a video feed directly into a VR headset to allow users to quickly manipulate a robotic arm like using their own hand. In particular we use the stereoscopic lenses of VR headsets to replicate the 3D field of depth that are captured by a 360° camera, allowing the user to see the surrounding environment to avoid obstacles or dangers near the robot. VR can also add additional quality of life features that makes human-robot interaction feel more natural. We further use the motion capture device to allow user to control the robotic arm with simple hand movements. Preliminary studies comparing the proposed platform with the traditional 2D video streaming are conducted.

Our contributions are summarized as follows:

- We studied the immersive telepresence achieved by combining a VR headset and a 360° camera's footage.
- This work developed a low cost, off-the-shelf platform that uses a VR headset to allow a user to manipulate a robotic arm from a distance.

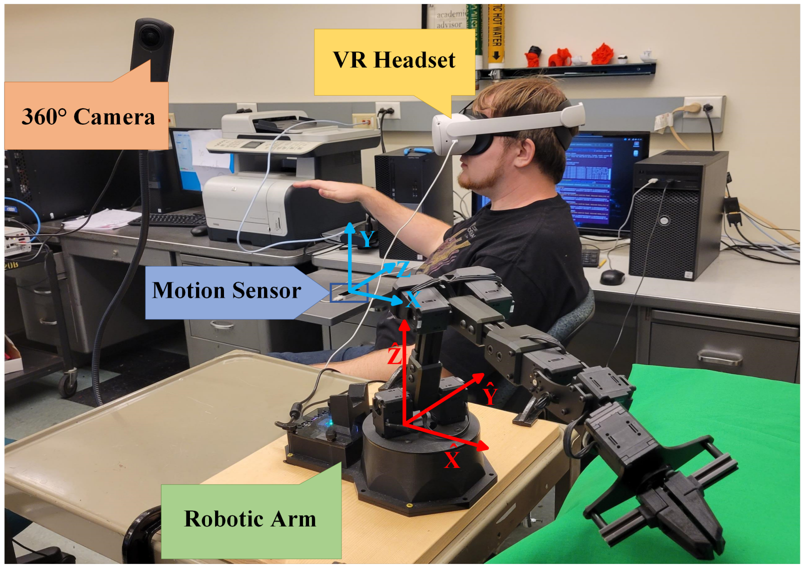


**Figure 1: Illustration of VR enabled robotic arm control platform.**

- The proposed demo activities include three different types of robot operation tasks, in-air drawing, object collection, and line tracing, which allow participants to experience the immersed robot control when the robot is vision-blocked or remote.

## 2 DEMO PLATFORM DESIGN

The overview of our system and the set up environment is shown in Figure 1. To track user's hand motion and control a robotic arm in real-time, a Leap Motion camera [6] with hand recognition API provided by Ultraleap is used to reconstruct palm center positions in a 3D coordinate, obtain hand orientation, and gripping behaviors. Then the hand trajectory is optimized for robot planning with scaling and offset to overcome limitations from both camera sensing range and robotic arm work envelope. Moreover, we lower the motion control latency with Last-In-First-Out buffering which speeds up computation time and smooths the robotic arm execution with PID controllers. The optimized trajectory is sent to a PX-150 robotic arm through a web socket and then the Interbotix run-time environment. The user observes the environment around the robotic arm through a 360° live streaming camera featured by our Unity program and a Ricoh THETA Z1 360° camera in a Meta Quest 2 VR headset. An alternative observation method is the 2D video shown on a monitor, which is compared in Section 3.

## 3 PROPOSED DEMO AND PRELIMINARY RESULTS

The demo is designed with three robot operation tasks. The first task is a in-air gesture, such as writing a letter "*W*" in the air. The second task is objection-collection, such as picking up and moving a block to a new position. A circle is drawn at this new position and each participant will attempt to pick up the block from one circle and move it into the other circle. The circles were measured so their center distance was 6 inches apart and drawn dark enough to be seen in the camera feed. The third task is line-tracing, such as tracing the letter "*N*" on a sheet of paper. Before the third task, a writing utensil would be added to the end effector of the robot arm to allow participants to trace the letter.

This preliminary study was established under the following criteria: 1) each participant would undergo three specific tasks that can be done originally by hand, 2) each participant would do two sets of testing in order to establish the control and testing populations, and 3) each participant would give an assessment on the satisfaction of the task on a scale of 1 to 10. When the two participants first tested out the VR headsets, they were allowed trial runs of their current task. After each of the three above tasks, the time it took for completing the task and user's rating of the task were recorded. In order to prevent collision, the robotic arm was placed far enough from the participant to ensure they would not come into contact with it during the testing period. Once the user feels acquainted with the testing set up, then they can begin their current task.

Figure 2 shows that our platform is very efficient for objection-collection tasks, as the user has a better perception of the space. The other two tasks have lower requirements of perceiving the spatial information, and thus the two platforms have similar performance. Figure 3 further confirms the participants' better experience with our platform.

## 4 CONCLUSION AND FUTURE WORK

This work implements a first-person robot control platform by integrating 360° camera, live VR streaming, motion capture device and robotic arm. We gathered and compared results from participants preforming three types of tasks with the proposed platform and the traditional 2D video-streaming environment. Results show that the proposed platform is more efficient for object collection tasks as it took less time to complete. Moreover, users appear to

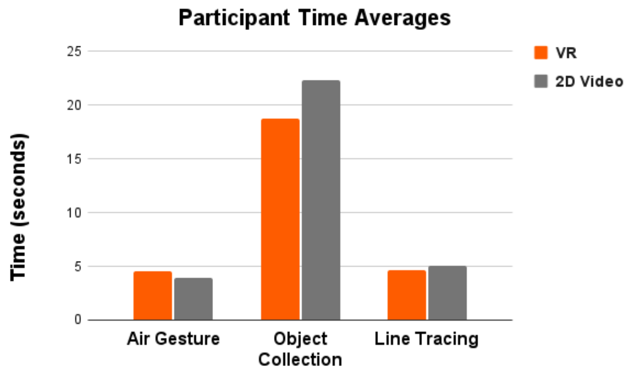


**Figure 2: Participant's average completion times.**

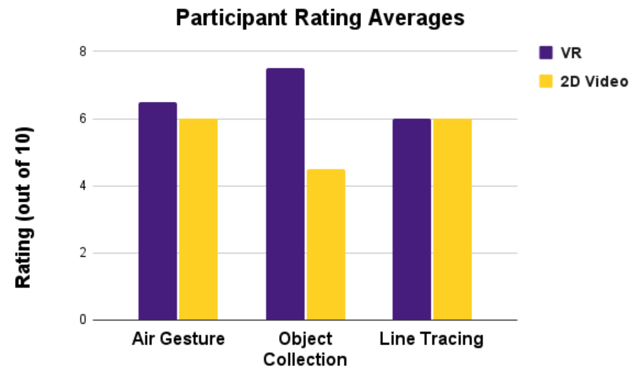


**Figure 3: Average satisfaction rating (scored from 1 to 10).**

be more receptive of completing tasks inside VR rather than with a 2D camera. For the future work, an increase in participants and tasks will allow for more comprehensive experiments. In addition, the implementation of AI algorithms to improve robotic control as well as increasing the connection range between the robot and the camera can further improve this study.

## ACKNOWLEDGMENTS

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