# Designing a Virtual Reality Interface for Teleoperation of Welding Robots in Construction

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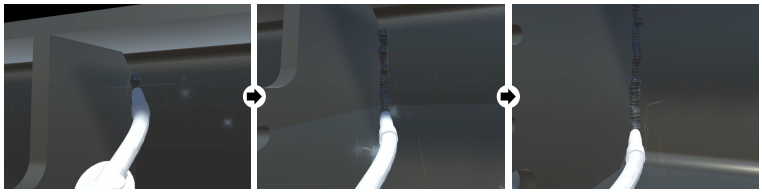
ICRA2024 YOKOHAMA | JAPAN

## Overview

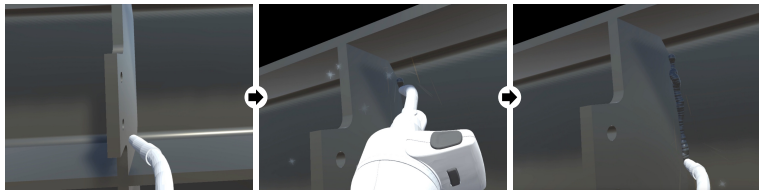
- In this study, we explore the effect of viewpoint control technique in VR (*coupled* vs. *decoupled* viewpoint) on task performance, perceived workload, and perceived usability in the context of teleoperating welding robots in construction.
- Our comparative study with 10 participants demonstrated that under the *coupled* condition, participants completed the welding tasks significantly faster and with greater consistency across different locations when compared to the *decoupled* condition.

### Coupled Viewpoint



Coupled viewpoint provides a fixed perspective for detailed observation and control. The camera is coupled to the robot's end-effector at a certain distance, aligning the user's viewpoint with the tool tip and allowing viewpoint control through head rotations tracked by the HMD.

### Decoupled Viewpoint



Decoupled viewpoint offers a broader understanding of the remote workspace. The camera movements are independent of the robot's end-effector, allowing orientation control via the HMD while employing an extra VR controller for positional changes along the X, Y, and Z axes.

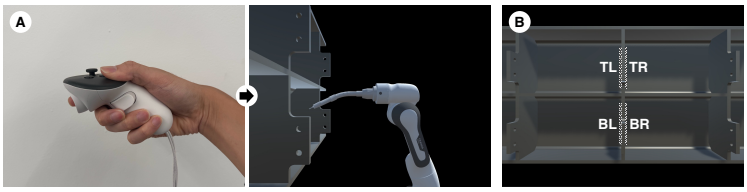
## Background

This study presents our exploration of a VR interface in assisting construction workers to teleoperate construction welding robots. Specifically, we aim to answer the following questions:

- Which of the two viewpoint control techniques (coupled and decoupled viewpoint) better supports teleoperation in VR?
- (Future work) How does switching between viewpoints during operation affect welding performance?
- (Future work) What are the design considerations for tele-welding in construction and its interfaces?

## User Study: Coupled vs. Decoupled

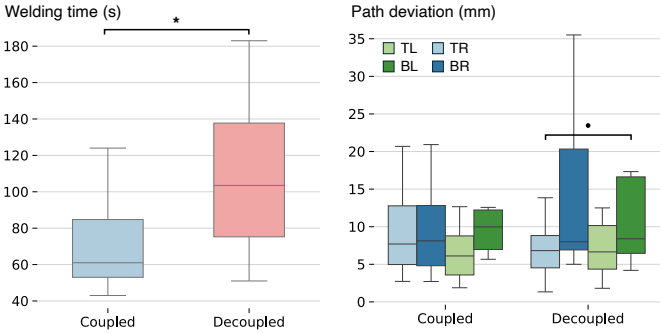
- 10 university students (9 male, 1 female, all right-handed)
- MIG-welding to attach stiffeners on two W-beams (W400 × 197)
- Coupled vs. decoupled camera viewpoint
- 2 VIEWPOINTS × 4 SEAMS = 8 data points per participants
- Experimenter demonstrated interface techniques; participants familiarized themselves before starting trials seated



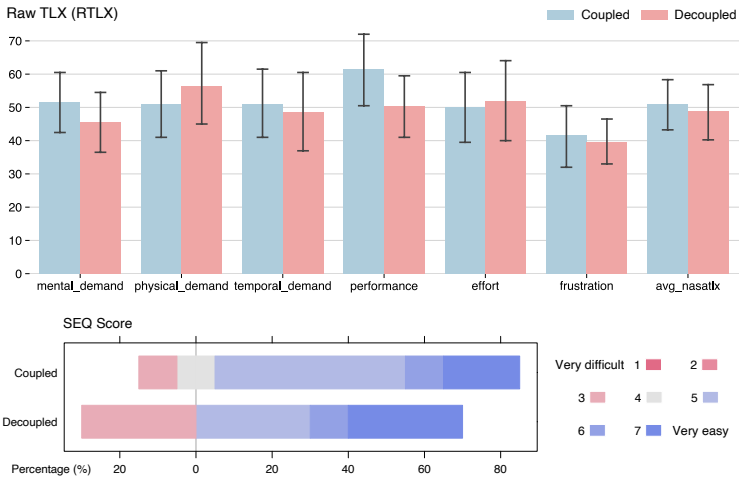

(A) Side view of the VR controller held in a user's hand (Left) and its direct mapping to the robot's end effector in the VR interface (Right).
(B) Four welding seam locations in the virtual task scenario.
TL = Top left, TR = Top right, BL = Bottom left, and BR = Bottom right.

## Results

### (1) Task Performance




### (2) Subjective Measures




## Conclusion

- Our results suggest that the coupled viewpoint led to improved task efficiency, with participants completing welding tasks 33.5% faster than when using the decoupled viewpoint. The coupled viewpoint also demonstrated greater consistency across different locations, though no significant differences were observed in mean welding errors and path deviations across all welding locations.
- Future research should expand our work by evaluating our interface with larger, professionally experienced groups in welding.