Worker Performance and Adaptability in Remote Welding Operations under Network Delays

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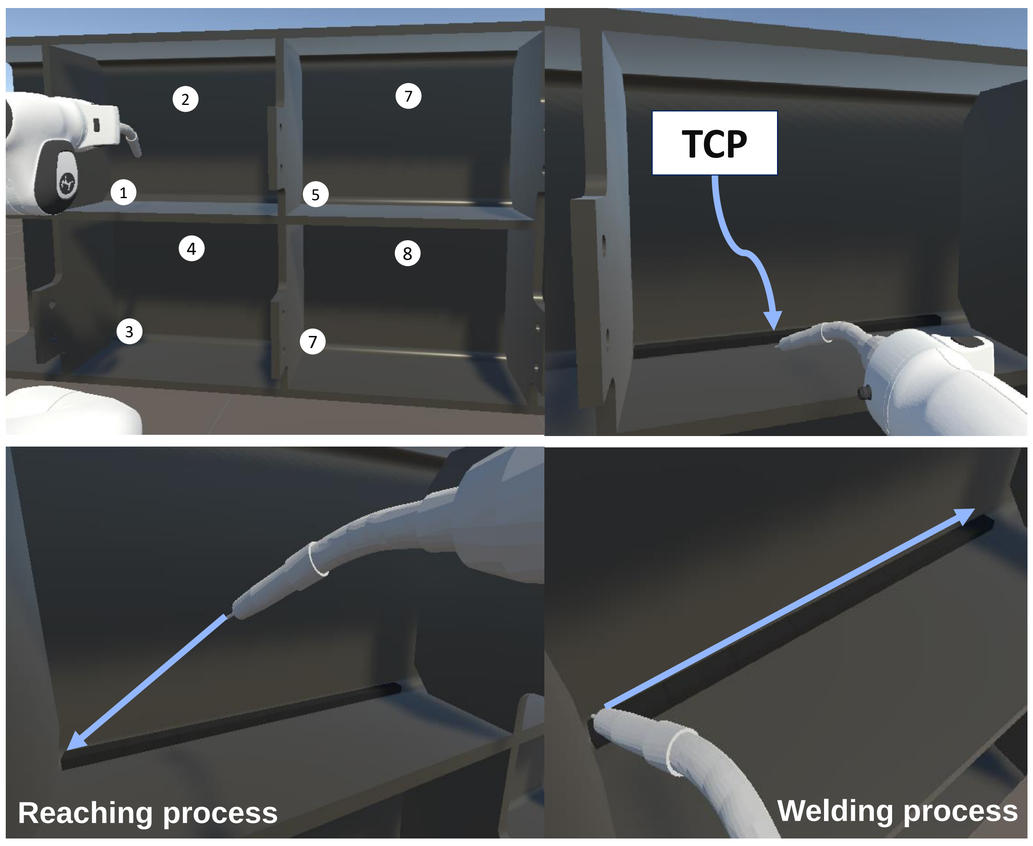
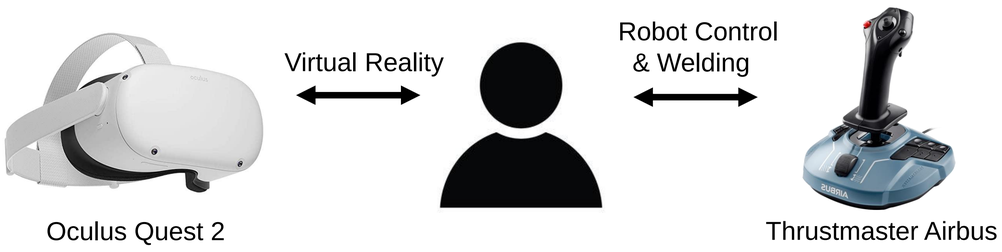
Research Introduction

Automation in construction, particularly through the remote-controlled robotic welding, is seen as a potential solution to enhance safety and productivity in the construction industry. However, network delays in remote welding can introduce adverse affects such as low-quality welds or loss of operation time. This study investigates how remote workers handle disruptions caused by network delays using VR experiments and proposes a novel metric which can be used as an indicator of workers' adaptability to network delays.

Methods





Oculus Quest 2

Thrustmaster Airbus

1) Establish a **VR environment for remote welding** work using a robot.

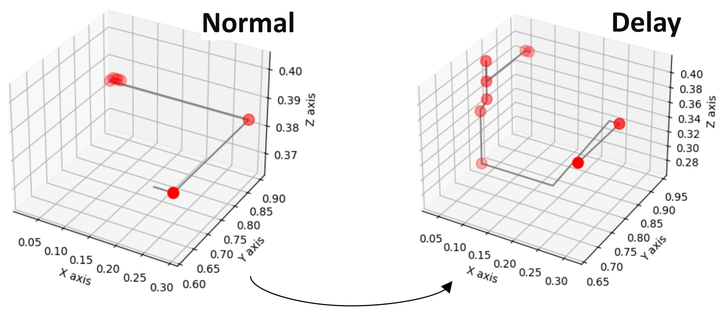
2) Simulate **network *delay* states twice** in the VR environment.
(First one returns to *normal state*, second one remains throughout the experiment)

3) Conduct experiment. (32 VR welding task, 16 times for horizontal and vertical each, N = 12)

4) **Record 3D coordinates of TCP** (Tool Center Point) during the experiment.

Sample results

The series of 3D coordinates of TCP recorded (Participant 1)

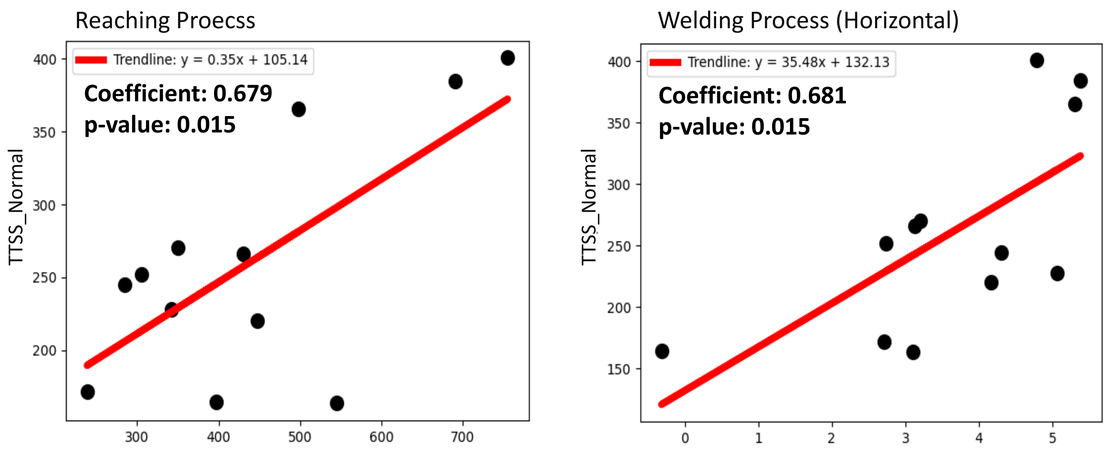


Participant's reaching process at the same location during *normal* and *delay states*.
As shown, the *delay state* shows a less smooth trajectory compared to the *normal state*.

Line : The route traveled by TCP.
Red points : The positions where TCP was stationary for more than 0.1 seconds.

Result

Pearson correlation : TTSS_Normal vs. TTSS_Delay & EWA_Delay



Measures

Required Time (RT) : Elapsed time for each process
Total Time Spent Stopped (TTSS) : Sum of the time TCP stopped for 0.1 seconds or more for each reaching process
Excess Welding Amount (EWA) : The distance TCP moved beyond the weld end point for each welding process

TTSS_Normal : TTSS measured during *normal state*
TTSS_Delay : TTSS measured during *delay state*
EWA_Delay : EWA measured during *delay state*

Research Question

" Would workers who smoothly handle remote work in *normal state* also handle work relatively smoothly in *delay state*? "

In the Second Delay :
The lower the TTSS at *normal state*,
the lower the TTSS at *delay state*, and the lower the EWA at *delay* state.
Workers who smoothly handle remote weld work in *normal state* showed higher adaptability to *delay state*.

But in the First Delay :
Such correlation has not been found.
Workers who smoothly handle remote weld work in *normal state* do not necessarily exhibit differences in work performance from the early stages of *delay state* onset.

Conclusion & Future works

This study has discovered a novel metric (TTSS) indicating adaptability of remote welding workers to network delay. It was found that
" lower TTSS in normal remote welding correlates with higher adaptability to network delay. "

Out further researchs aim to analyze remote welders' adaptation to network delays and develop technologies to improve this adaptation.

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