

Quality and User Experience for Teleoperation

Remote Controlled 3D Positioning in Augmented Telepresence: User and Quality of Experience

Shirin Rafiei

PhD student at Mittuniversitetet and RISE - Research Institutes of Sweden

Supervisors: Prof. Mårten Sjöström, Prof. Kjell Brunnström, Dr. Jonas Andersson

Research centre (MIUN): Sensible Things that Communicate (STC)

Unit (RISE): Collaborative Autonomous Systems

Remote Control System



<https://www.cyngn.com/blog/teleoperations-and-remotely-operated-robotics>



Remote Control systems (RCS) Domains:



- **Scope:** Mining, Construction and Airport Safety

Monitoring

Control

Assistance



Teleoperation



Teleoperation in Industrial Applications

Advantages

Enhances safety and efficiency



Inclusiveness



Reduce commute to sites



Challenges

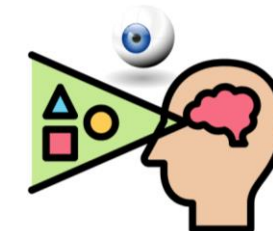
Maintaining Situational awareness



Audio



Haptic



Visual



Delivering *visual information* to operators

Van Damme, S., et al (2022)

Arevalo Arboleda, S., et al (2021)

Real world use cases

Scaling in Mining



Boliden AB

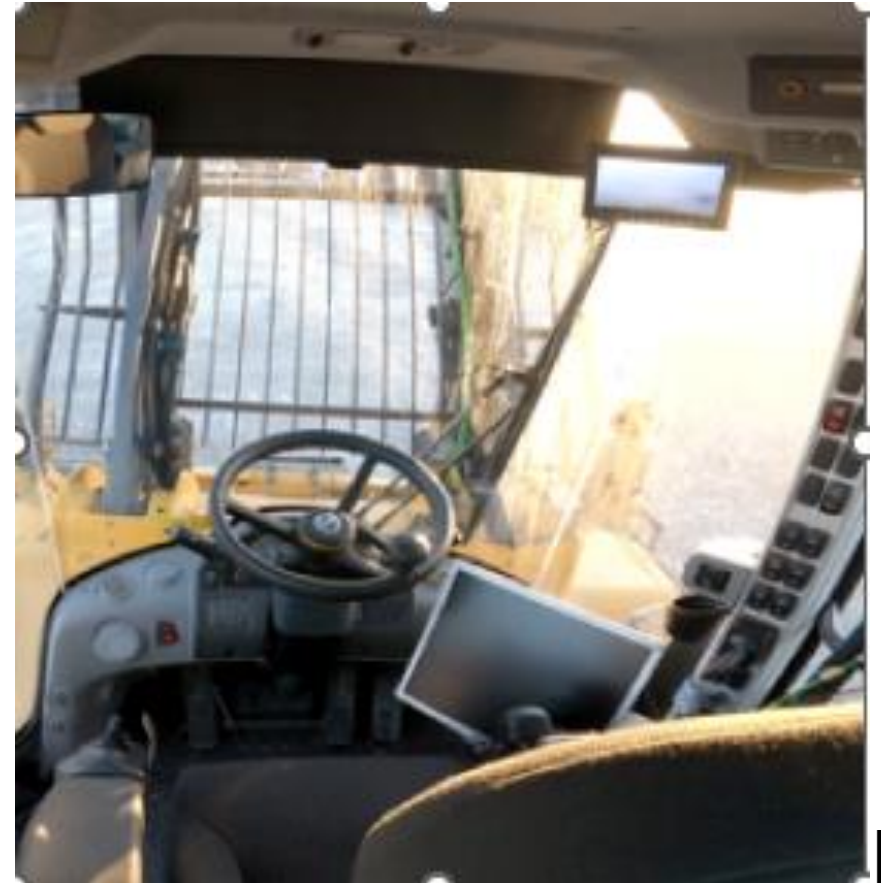


Examples of real-world use cases

Construction Machinery



Volvo Construction Equipment



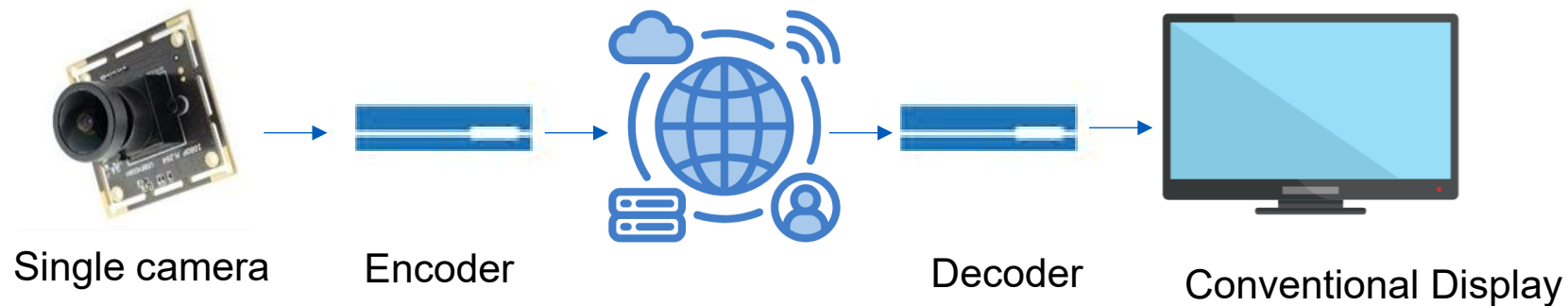
Visual presentation in Teleoperation

- Capturing view with multi camera and presenting Stereoscopic view



Dima, E., et al (2020)

- Capturing view with single-camera and presenting view on conventional display



<https://tunnelingonline.com/epiroc-launches-mobius-for-drills/>

Focus of research in prior art and research gaps

Technology Aspects and Engineering Insights

- Technical Performance and System Metrics

Taufik, S., et al (2020)

Visual Interface impacts

- Augmented Telepresence (AT)

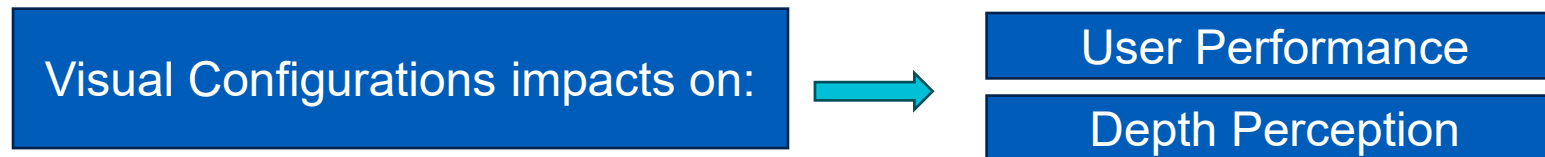


Quality of Experience and User Experience were treated separately

- Quality of Experience (QoE) aspects in Teleoperation
- User Experience (UX) aspects in Teleoperation

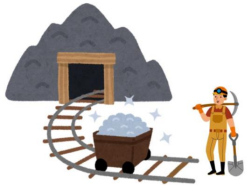
Research purposes

- ➔ Purpose 1: Get an improved understanding of how **view augmentation**, **video degradation**, and **remote scene presentation** impact **user performance** and **depth perception** in Teleoperation systems.



- Purpose 2: Increasing the knowledge of how a **mixed-methods approach (QoE and UX)** enhances the understanding of the **Quality of User Experience** in Teleoperation system





Study 1: Impacts of applied visual interfaces in mining context

Study 1: Augmented Remote Operating System for Scaling in mining (AROSS)

Visual interface configurations: Novel perspective, LiDAR view, Disocclusion augmentation, Original views

Sender (on-site)

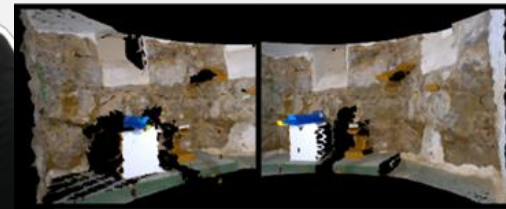


Receiver (Remote-site)



(a)

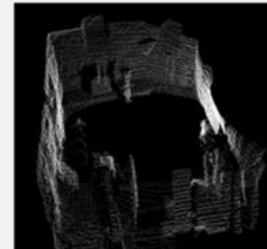
(b)



(c)



(d)



(e)

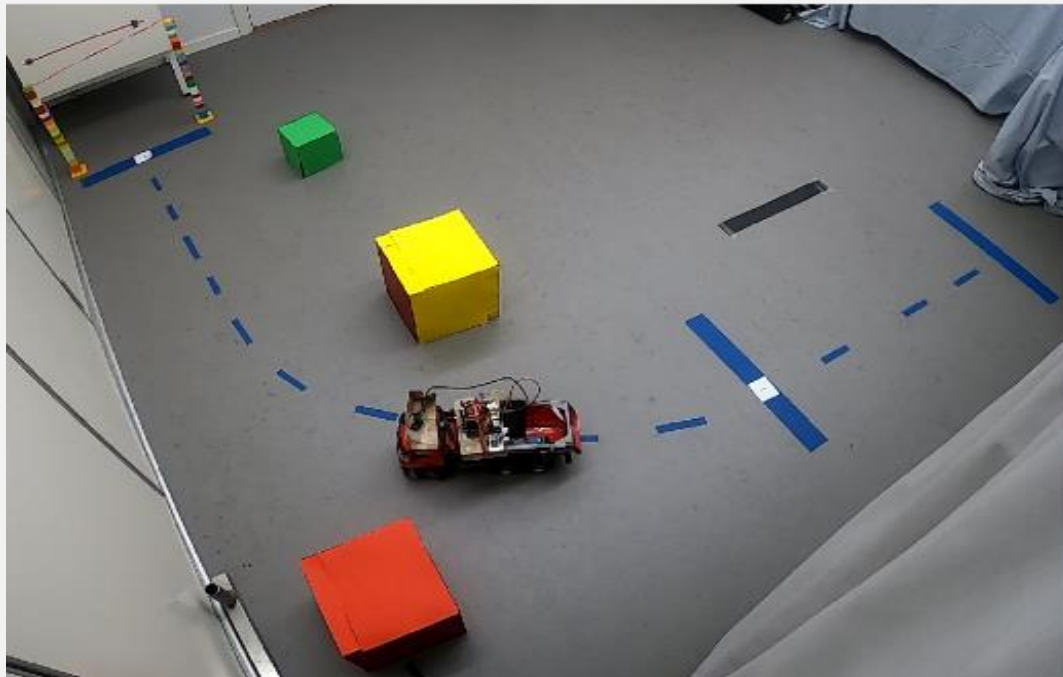
Study 2:

Impacts of applied visual interfaces in construction context

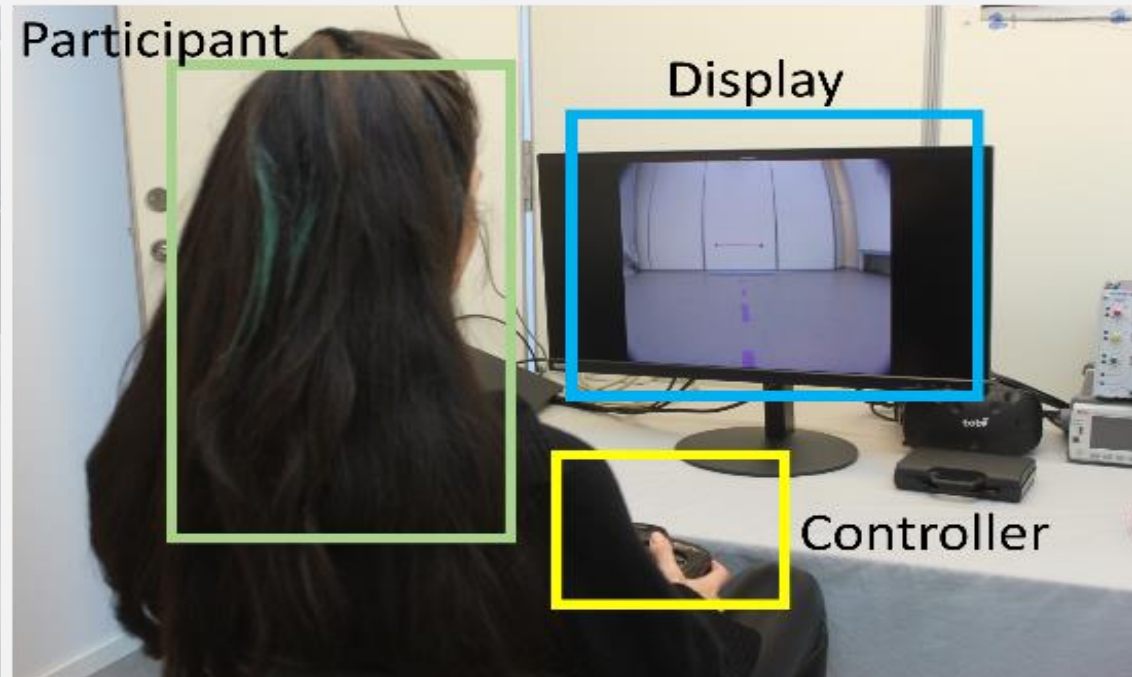
Study 2: Impacts of applied visual interfaces in construction context

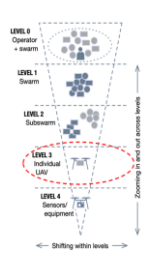
Visual interface configurations: Spatial video resolution (3 levels) , Field of View (2 levels) , Latency (3 levels)

Sender (on-site)



Receiver (Remote-site)





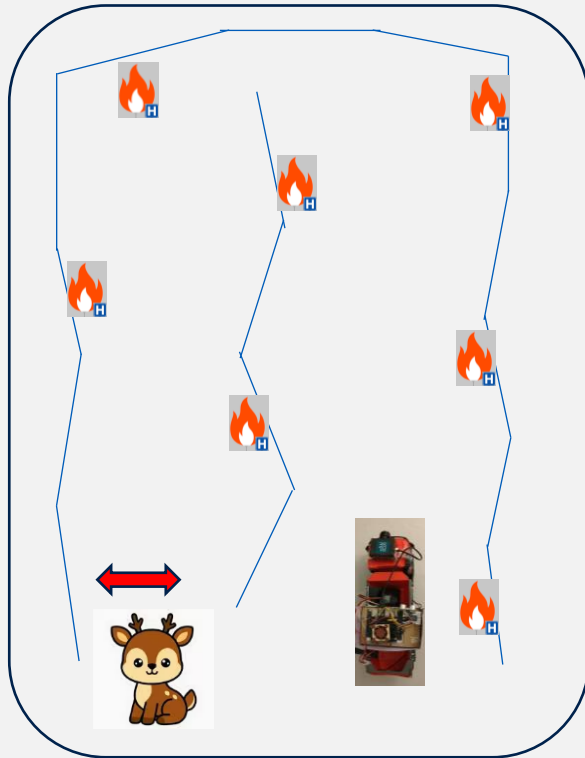
Airport Safety management

Study 3:

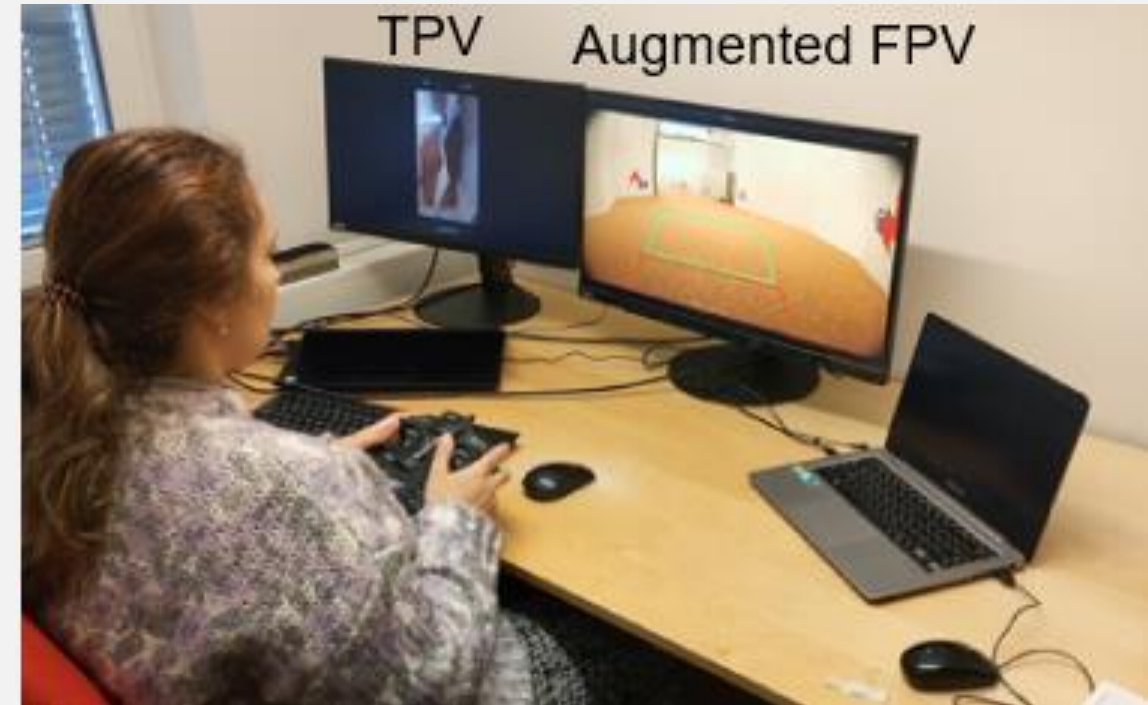
Study 3: Impacts of applied visual interfaces in finding debris at Airports

Five different enabled visual interface configurations: FPV, TPV, Augmented FPV, Augmented FPV+TPV, FPV+TPV

Sender (on-site)



Receiver (Remote-site)



Study 1: Impacts of applied visual interfaces in mining context

Augmented Remote Operating System for Scaling in mining (AROSS)

Visual interface configurations: Novel perspective, LiDAR view, Disocclusion augmentation, Original views

Sender (on-site)

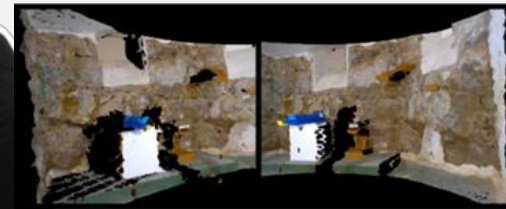


Receiver (Remote-site)



(a)

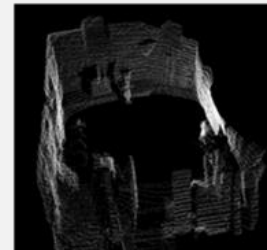
(b)



(c)



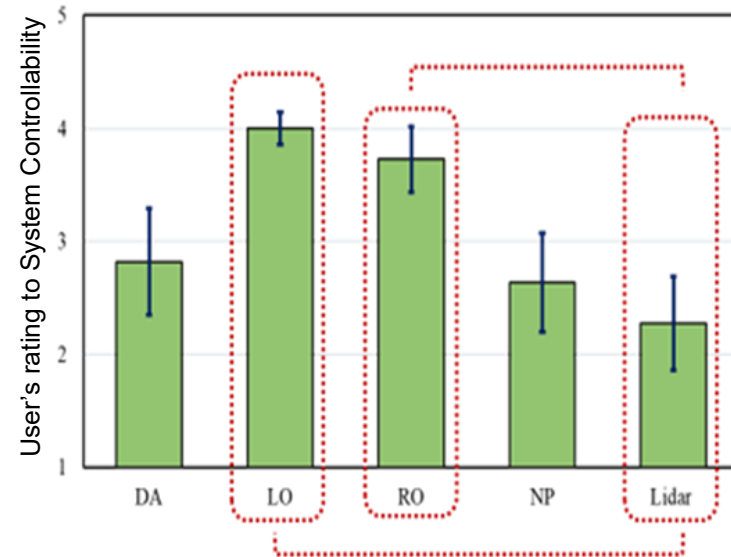
(d)



(e)



Key Results - Performance & Depth Perception (AROSS)



- AROSS for Mining:
 - Original views (LO, RO) → higher task accuracy and control.
 - DA & LiDAR views showed mixed results—useful as supporting views but less effective alone.
 - Depth confidence improved with Novel Perspective and LiDAR.

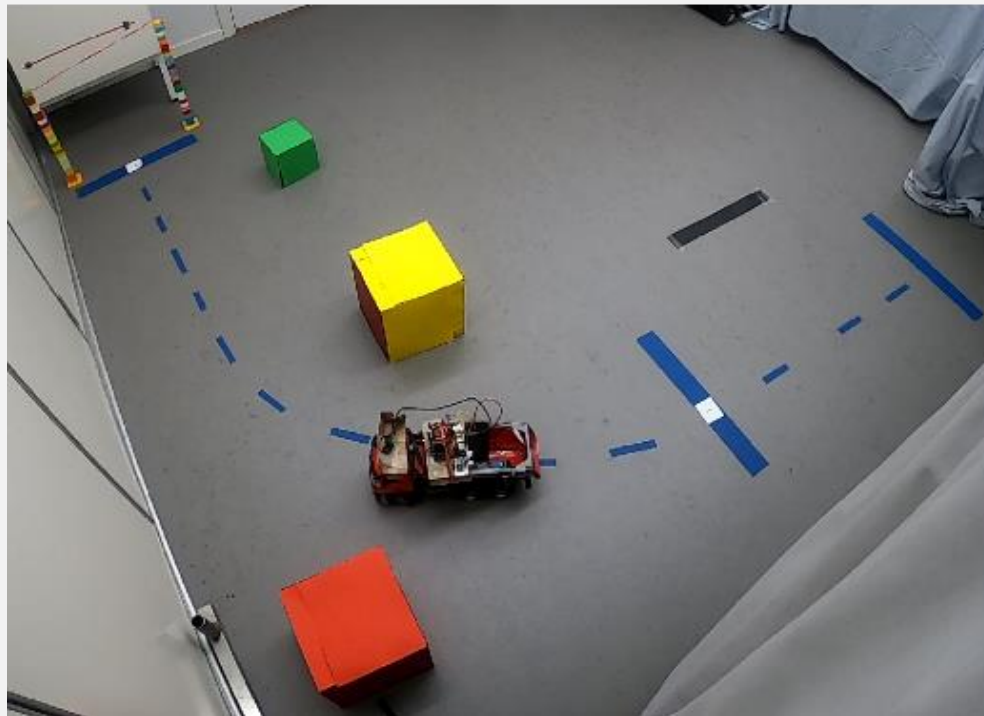
Rafiei, S., Brunnström, K., Andersson, J. et al. Investigation of human interaction with an augmented remote operating system for scaling in mining applications. Qual User Exp 9, 5 (2024). <https://doi.org/10.1007/s41233-024-00068-9>

Impacts of applied visual interfaces in construction context

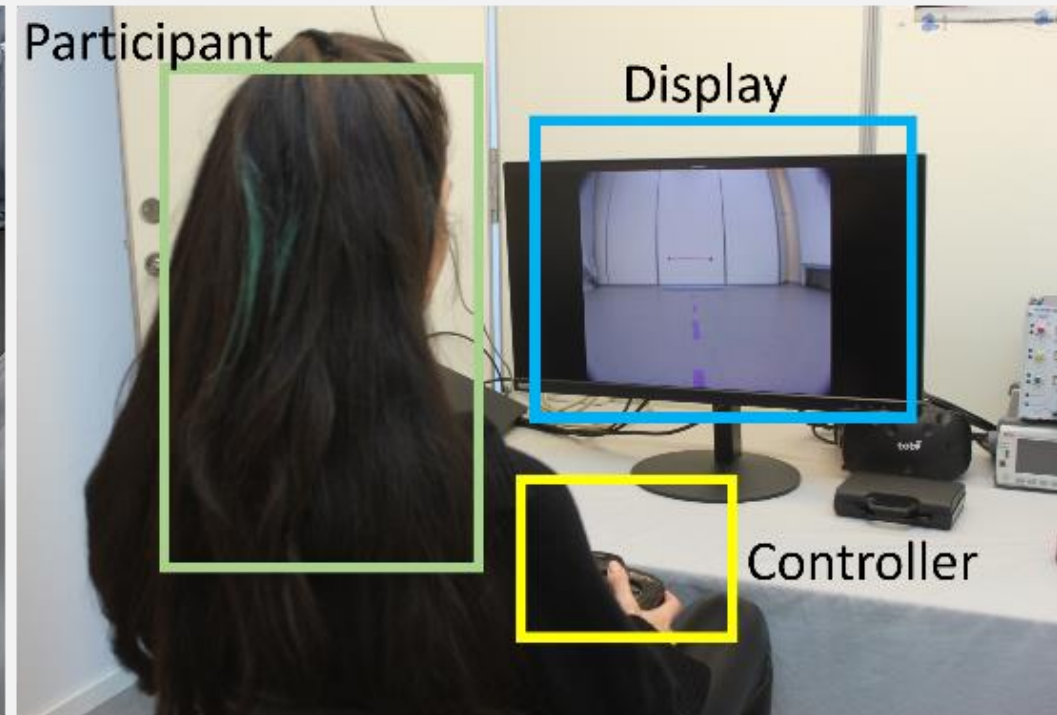
Laboratory Remote Control Platform (LRCP)

Visual interface configurations: Spatial video resolution (3 levels) , Field of View (2 levels) , Latency (3 levels)

Sender (on-site)



Receiver (Remote-site)

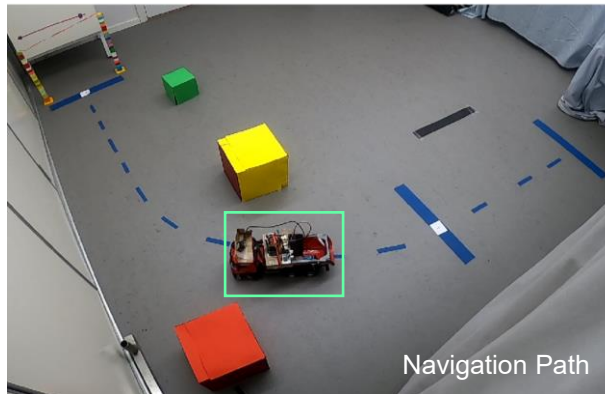
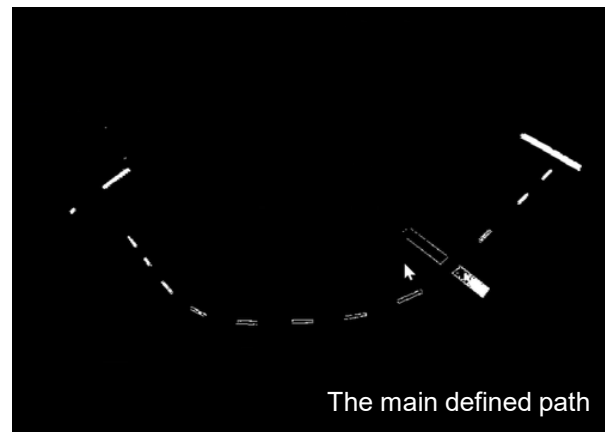
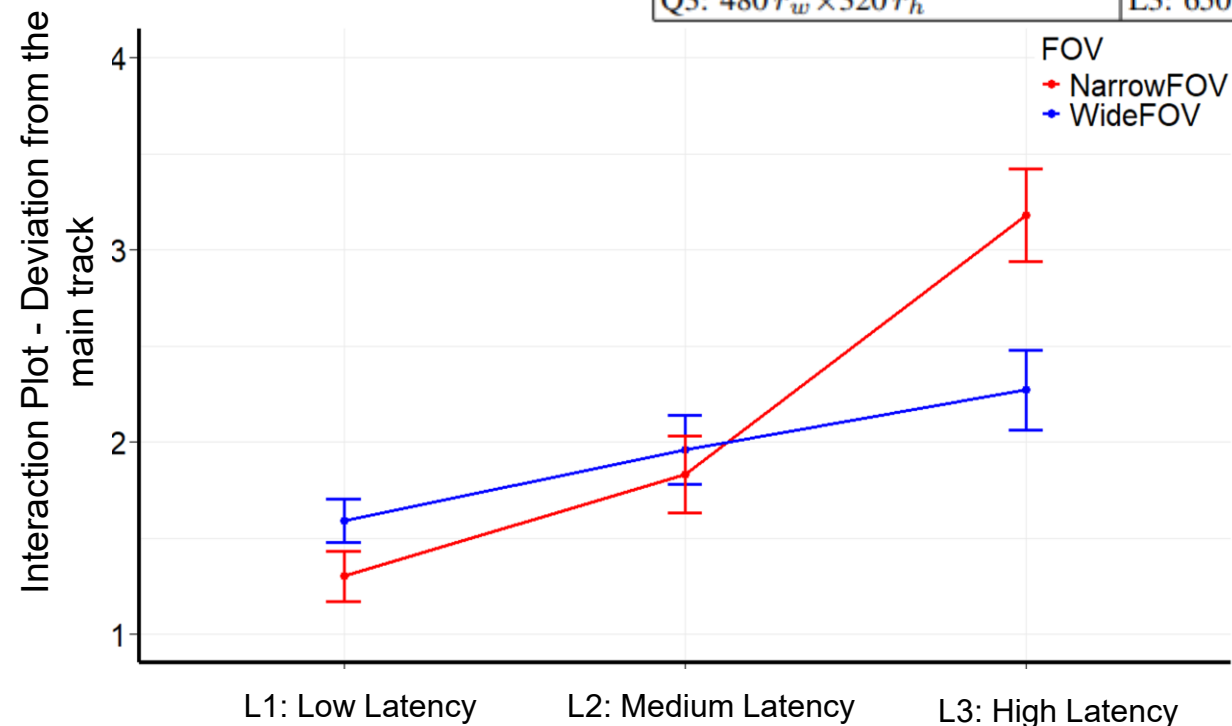


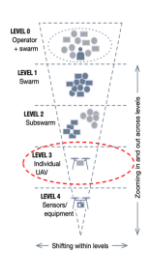
Key Results - Performance & Depth Perception (LRCP)

- Wide FOV makes Teleoperation more robust against latency, compared to a Narrow FOV

DIFFERENT CONDITIONS APPLIED AS TEST CONFIGURATION (VQ - L - FOV)

Quality levels (Frame rate 30 fps)	Latency (ms)	FoV(degrees)
Q1: $720 r_w \times 640 r_h$	L1: 150	F1:120
Q2: $640 r_w \times 480 r_h$	L2: 400	F2:105
Q3: $480 r_w \times 320 r_h$	L3: 650	-



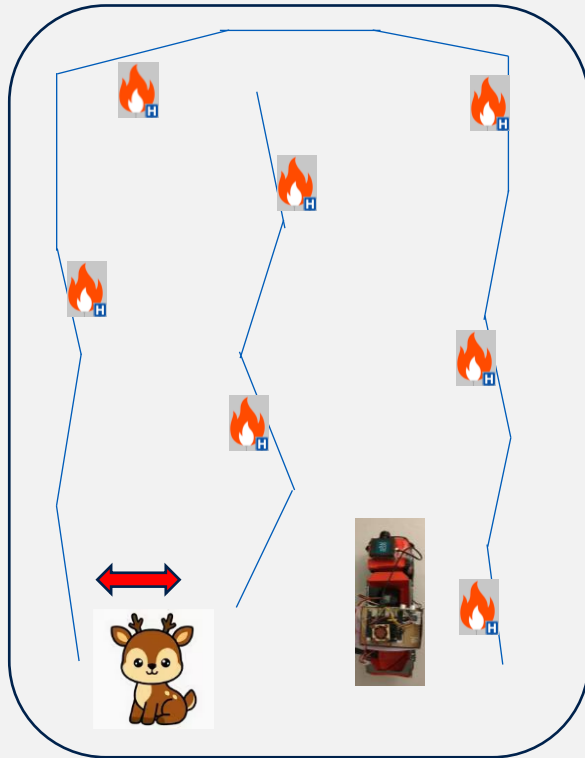


Airport Safety management

Study 3: Impacts of applied visual interfaces in finding debris at Airports

Five different enabled visual interface configurations: FPV, TPV, Augmented FPV, Augmented FPV+TPV, FPV+TPV

Sender (on-site)

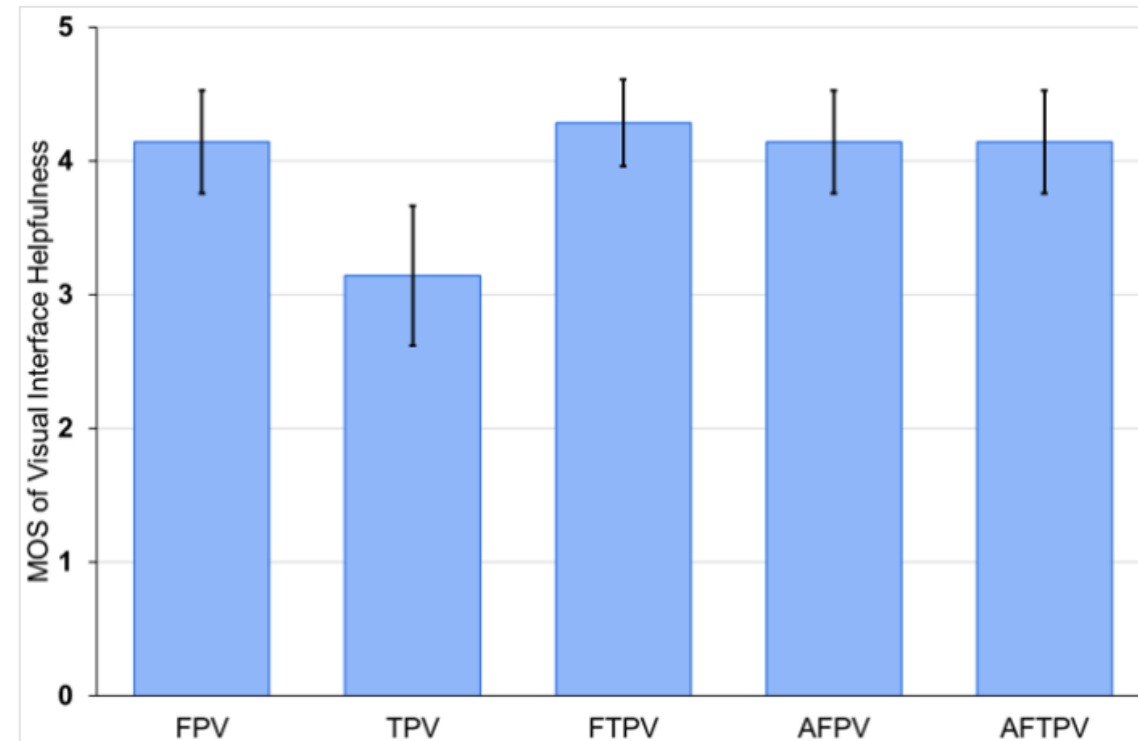


Receiver (Remote-site)





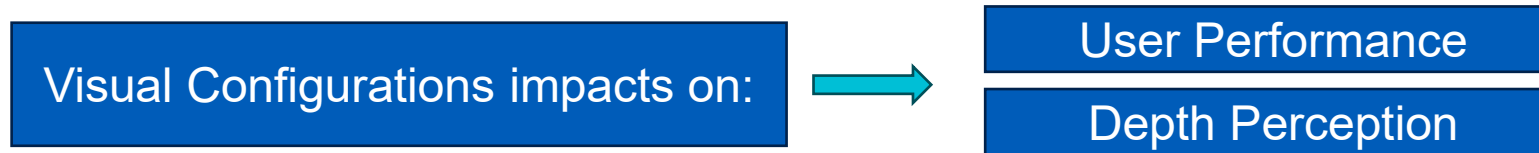
Test run	FPV	AFPV	TPV
Trial 1	Active	Active	Active
Trial 2	Active	Not Active	Not Active
Trial 3	Active	Active	Not Active
Trial 4	Active	Not Active	Active
Trial 5	Not Active	Not Active	Active



Rafiei S, Brunnström K, Pifferi G, Schenkman B, Djupsjöbacka A, Andérn B, et al. User Study on Visual Interface Helpfulness in Remote Inspection Tasks Using Teleoperation. In: 2025 17th International Conference on Quality of Multimedia Experience (QoMEX) [Internet]. IEEE conference proceedings; 2025. p. 1–4. Available from: <https://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-56256>

Enhance the understanding of Quality of User Experience

- What visual interface enhancements support users' perception of depth and spatial layout?
 - Interface simplification
 - Reduced Latency
 - Enhanced Spatial cues
 - Multi-sensory augmentation
- How **video degradation, view augmentation and remote scene presentation** influence the *Quality of User Experience*?
 - *High Latency → Frustration, Visual strain and Problem in precisely control the system*
 - *Video Quality → System remained usable but appreciated stability in Video Quality*
 - *View augmentation → Specific visual and perceptual limitations (Blurriness and misalignment)*



- **Visual Configurations on Performance** : Conventional views (LO/RO) offered greater clarity and reduced cognitive load. FPV was better than TPV in navigation tasks
- **Visual Degradation on Performance**: Low quality, high latency, and Narrow FOV impaired control, responsiveness, and interaction strategies.
- **Depth Perception Insights**: Conventional layouts supported clearer spatial understanding; Lidar and NP aided depth perception in some contexts but added complexity.
- **Depth Perception Insights**: Wide FOV improved navigation and spatial awareness but introduced fish-eye distortion, while Narrow FOV limited context. TPV assisted FPV in depth perception.

Practical Impact

- Direct relevance for **mining and construction teleoperation, and airport safety management.**
- Broader application in **drone operations and automotive industries (Volvo Cars, Volvo Trucks, Scania).**
- Useful for **standards development (ITU)** in immersive media and XR systems.



Further investigations for study III:

- **Biometric measures:** Eye-tracking could have deepened insight into attention, scanning, and workload.
- **Limited UX methods:** Interview instead of experiential feedback to defined questions.
- **Cognitive load not explicitly measured:** Tools like NASA-TLX could have provided clearer mental effort data.

Thank you!

E-mail

Shirin.rafiee@ri.se

Web <https://www.ri.se/en/person/shirin-rafiee>