Development of an XR-Based Training System for Laboratory Device Operation and Safety Instruction

Training new students and employees in laboratory environments such as the COSES Lab is resource-intensive and often requires repeated 1:1 supervision by experienced staff. Traditional approaches—written manuals, videos, or in-person demonstrations—struggle to scale, may lead to inconsistent knowledge transfer, and are limited in their ability to convey safety-critical information interactively. Extended Reality (XR) technologies open the door to a new generation of immersive, standardized, and highly engaging training experiences. By capturing expert demonstrations and embedding them in interactive VR/MR environments, we can create autonomous training modules that fully immerse users in laboratory procedures without exposing them to real-world risks. These modules can preserve procedural fidelity, provide real-time feedback, and highlight dangerous or incorrect actions in ways that are impossible with conventional training methods. This thesis offers students the opportunity to work hands-on with state-of-the-art XR headsets (VR/MR), develop an interactive training system, and explore cutting-edge interaction concepts within a real laboratory context.

Project expectations

The goal of this thesis is to design, implement, and evaluate an XR training framework that teaches new lab users how to operate laboratory equipment safely and correctly. You will gain direct access to cutting-edge XR hardware and lab equipment, practical experience building an end-to-end XR application, insights into safety-critical instructional design, and the opportunity to work on a highly interdisciplinary topic at the intersection of XR and laboratory training—ultimately contributing to the development of next-generation autonomous training systems. The system should:

- Integrate expert-recorded demonstrations
- Support step-by-step training in an immersive environment
- Visualize hazards and safety-critical mistakes
- Provide interactive guidance and feedback
- Enable autonomous, repeatable, and intuitive learning sessions

The final prototype should demonstrate how XR can improve both operational safety and learning efficiency.

- Review XR-based training solutions, multimodal interaction concepts, and safety-instruction methodologies.
- Record expert demonstrations using video or XR capture tools and prepare the material for integration into XR experiences.
- Design the training workflow, feedback logic, and user guidance and define how users interact (controllers, hand-tracking, gaze, etc.).
- Build a functional XR-prototype using Unity or Unreal Engine and deploy on VR/MR headsets (e.g., Meta Quest, HTC Vive, or similar).
- Conduct a user study comparing XR-based training to conventional training to measure usability, workload, learning outcomes and safety awareness. Analyze results using qualitative and quantitative methods.
- Document all design choices, methods, implementation steps, and evaluation results.
- Prepare a high quality manuscript to publish at an international conference.

Student Profile

We are looking for a motivated student who:

- Is excited about working hands-on with VR/MR headsets and XR technologies
- Has basic programming skills (C#, C++, or similar)
- Is interested in human–computer interaction, visualization, training systems, or immersive technologies
- Is motivated to conduct user studies and empirical evaluations
- (Optional but beneficial) Has experience with 3D modelling tools or UX/UI design principles

Co-supervision

This work will be conducted in close association with the Chair of Power Transmission and Distribution at TUM and the company H&S Hard- & Software Technologie GmbH & Co. KG, Dortmund

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