Virtual Reality Re-Embodiment of a Hand using simulated Robotics

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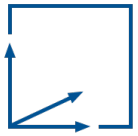
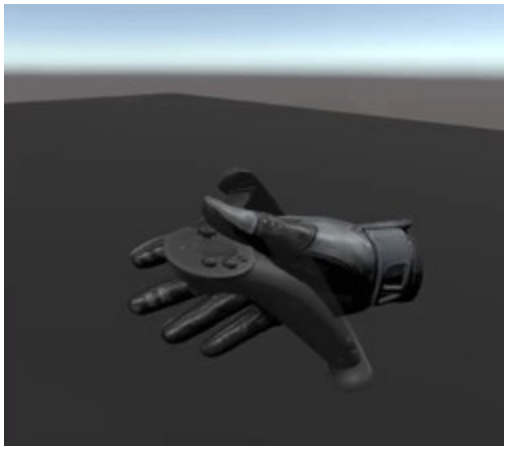


Final: Bachelor Informatics: Games Engineering

Supervisor: Sandro Weber

Introduction / Motivation

- What is Re-Embodiment?
- Rubber Hand Illusion
- Virtual Reality
- Neurorobotics Platform and Unity 3D Client



Source:
https://valvesoftware.github.io/steamvr_unity_plugin/images/skeleton_knuckles_controller.gif

Source:
https://valvesoftware.github.io/steamvr_unity_plugin/images/skeleton_knuckles_withoutcontroller.gif

Problem Description: Issues

- Move the virtual hand with the Index Controller
- Send position and rotation data to the server
- Move the virtual robot hand with PID controller
- Create the sense of Re-Embodiment

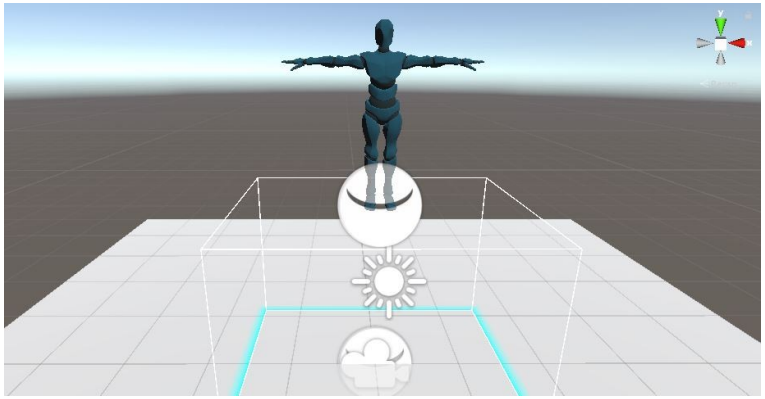
Source: G. Streeter. “Valve Announces Knuckles EV3 And Here Are The Upgrades“. Sept. 2018. url: https://www.vrandfun.com/valveannounces-knuckles-ev3-and-here-are-the-upgrades/.

Existing Solutions / Related Work

- SteamVR Unity Plugin for hand movement
- SteamVR Input System
- VR Re-Embodiment in the Neurorobotics Platform
- Virtual Embodiment of Human Feet in the Neurorobotics Platform
- Virtual Embodiment: Dealing with Discrepancies between the Virtual and the Real Body
- PID-Tuning Framework for Remotely Operated Humanoid Robots
- Is the Rubber Hand Illusion Induced by Immersive Virtual Reality?

Goals of this Thesis

- Expand Unity 3D Client with handtracking using the Index Controller
- Control the virtual robot hand
- Create sense of Hand Re-Embodiment



Critical Research Issues

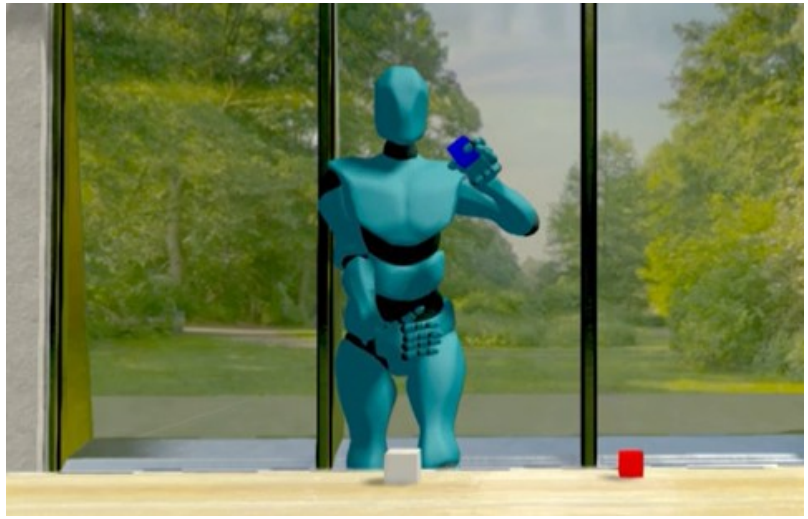
- Accuracy of the Handtracking
- Occuring Re-Embodiment
- Improve the sense of Re-Embodiment

Proposed Work / Approach

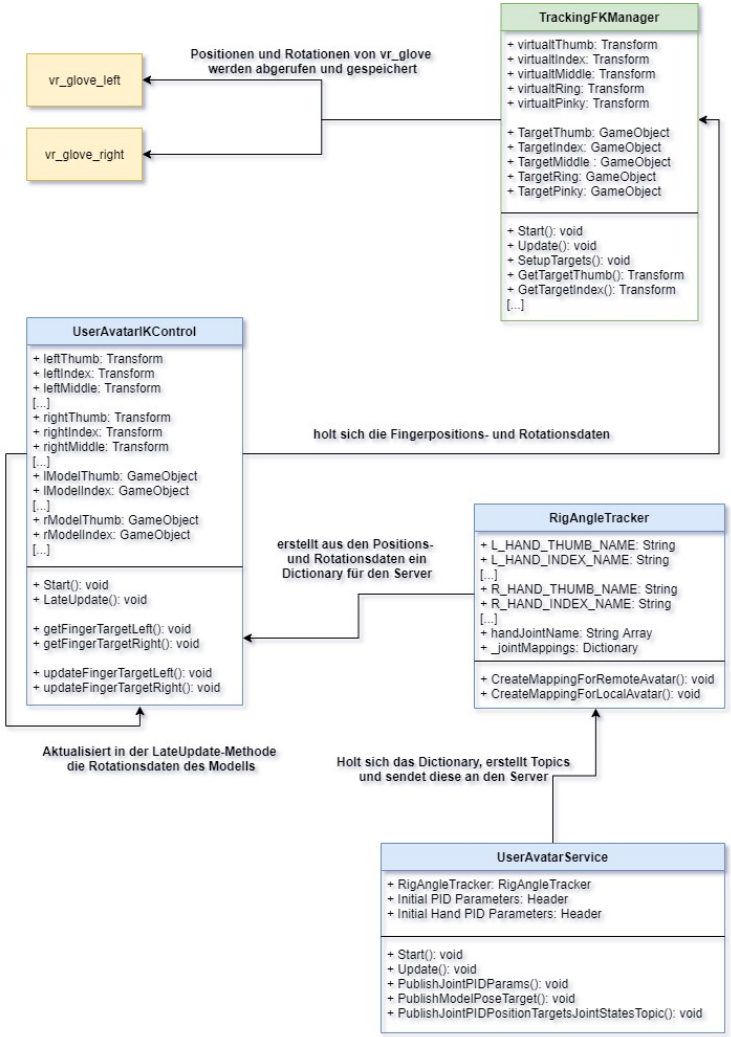
- Install SteamVR Unity Plugin
- Use virtual hand from Plugin with tracking script
- Create targets for finger joints with virtual hand joint positions
- Use targets for user avatar model finger movement
- Make virtual hand invisible
- Send finger joint positions to server
- Use PID-Controller and positions to move robot fingers
- Userstudy for sense of Re-Embodiment

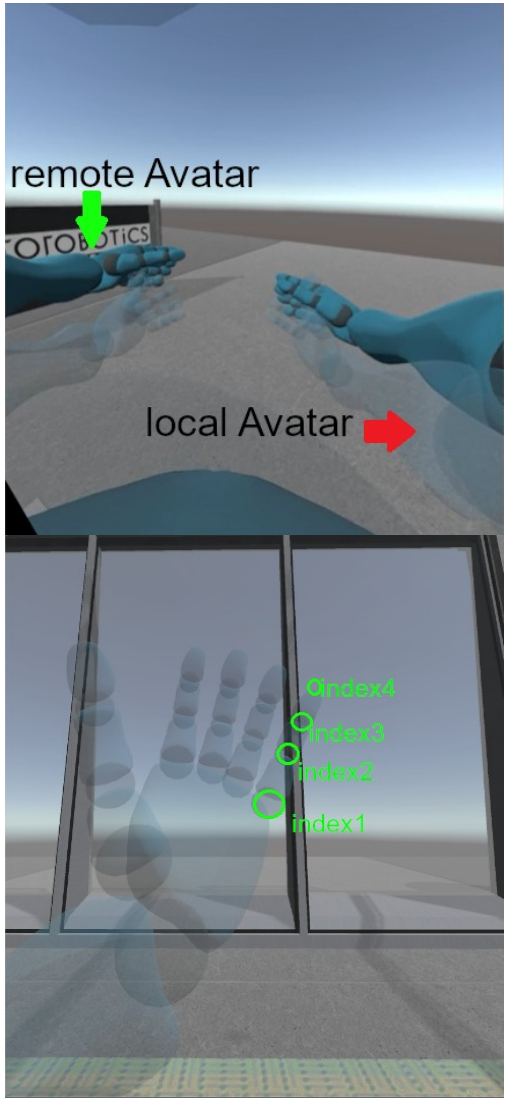
Implementation

- TrackingFKManager for Fingertracking
- UserAvatarIKControl for Model movement
- RigAngleTracker for joint creation
- UserAvatarService for adjusted PID Parameters and publishing joints to server
- Haptic Feedback



Implementation



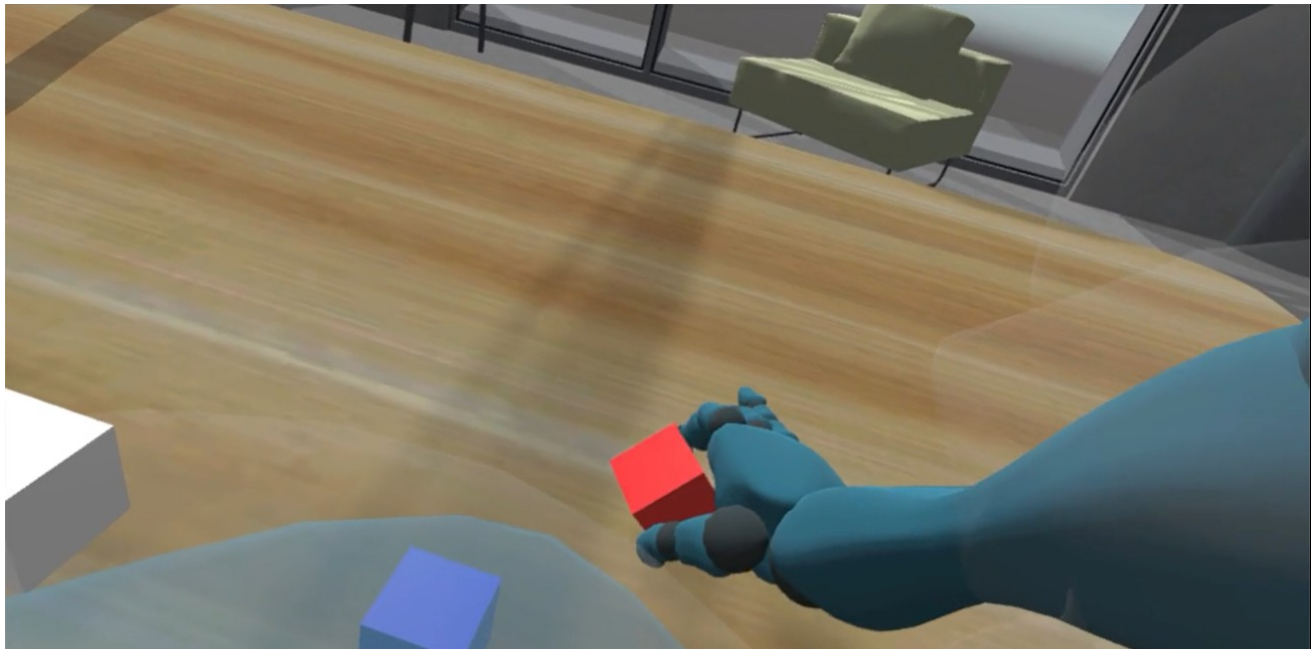


Implementation – Haptic Feedback

- 3 Scripts for Controller Vibration
  - AssignMeshCollider:
    - Assign Colliders to Objects
  - CollisionHandler:
    - Determine, which hand caused the collision
  - HapticsHand
    - Trigger haptic pulse and let controllers vibrate

Implementation – Adjustments

- PID Parameters in UserAvatarService
- Invisible local Avatar
- Transparent Torso of remote Avatar

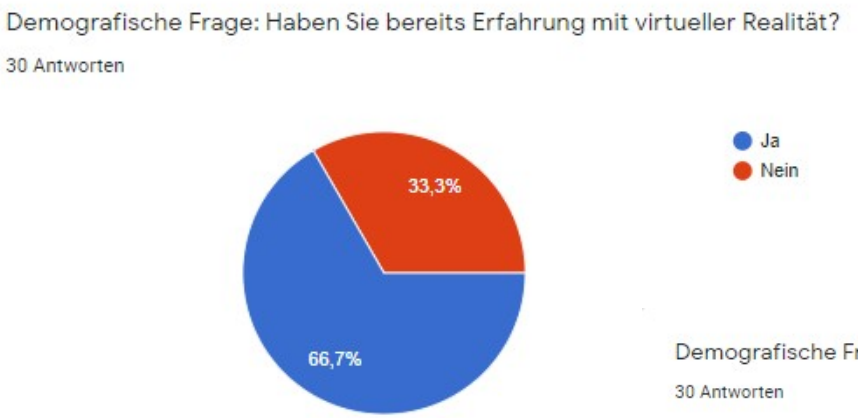


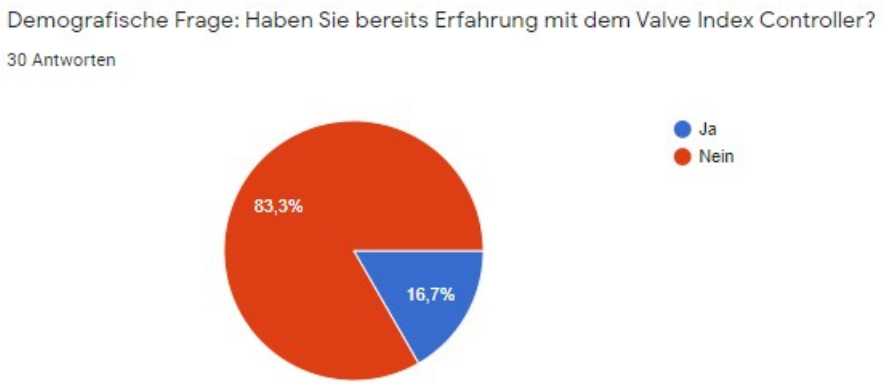
Evaluation (User Studies, Test Runs)

- User Study for Re-Embodiment of the Hand
- 30 Test subjects, 10 female, 20 male
- 6 Phases of the Experiment
- Final Questionnaire containing 22 questions:
  - 5 demographic questions
  - 10 SUS questions
  - 7 special questions about Re-Embodiment
- Time measurements

Evaluation (User Studies, Test Runs)

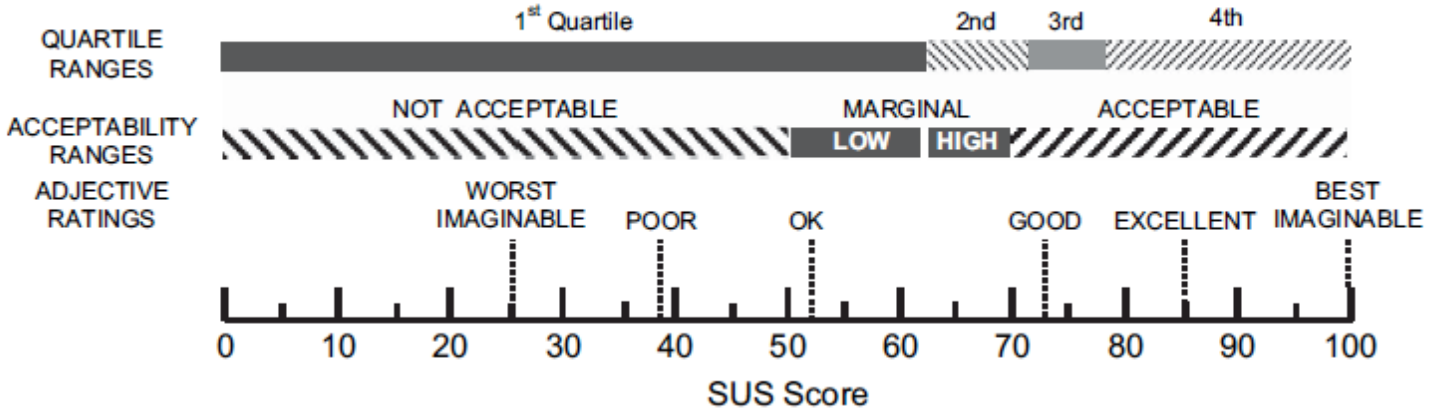
- 20 test persons had experience with virtual reality
- 5 test persons had experience with the index controller





Evaluation (User Studies, Test Runs)

- SUS Score: 63,1667
- Acceptable score
- Programm needs to be optimized in future Projects



Source: A. Bangor, P. Kortum, and J. Miller. “Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale.” In: J. Usability Stud. 4 (Apr. 2009), pp. 114–123

Evaluation (User Studies, Test Runs)

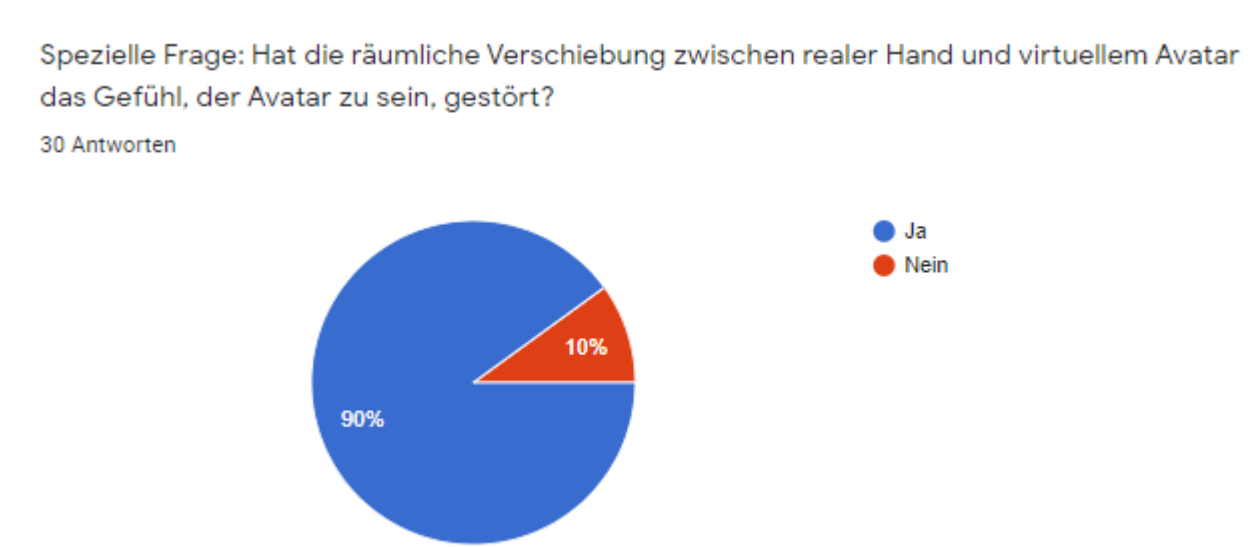
- Mixed answers for special question
- 8 test persons voted for Phase 5 of the Experiment

Evaluation (User Studies, Test Runs)

- Most of the test persons didn‘t have the feeling of Re-Embodiment of the Hands
- 11 test persons did feel the virtual hands as their own

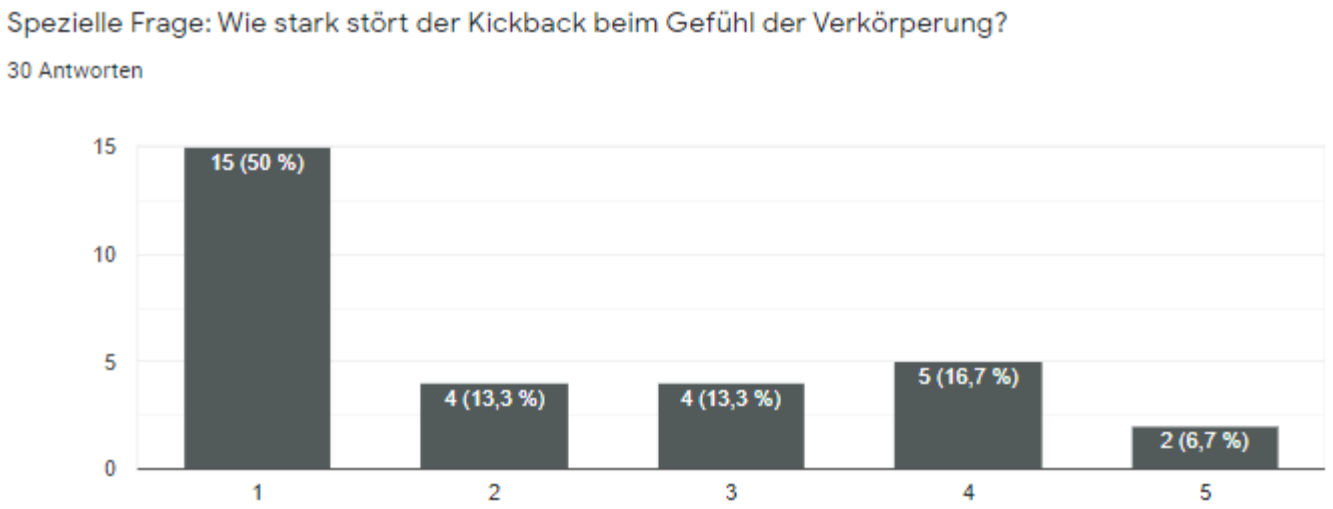
Evaluation (User Studies, Test Runs)

- Reason: the spatial shifting between real and virtual Avatar was too big



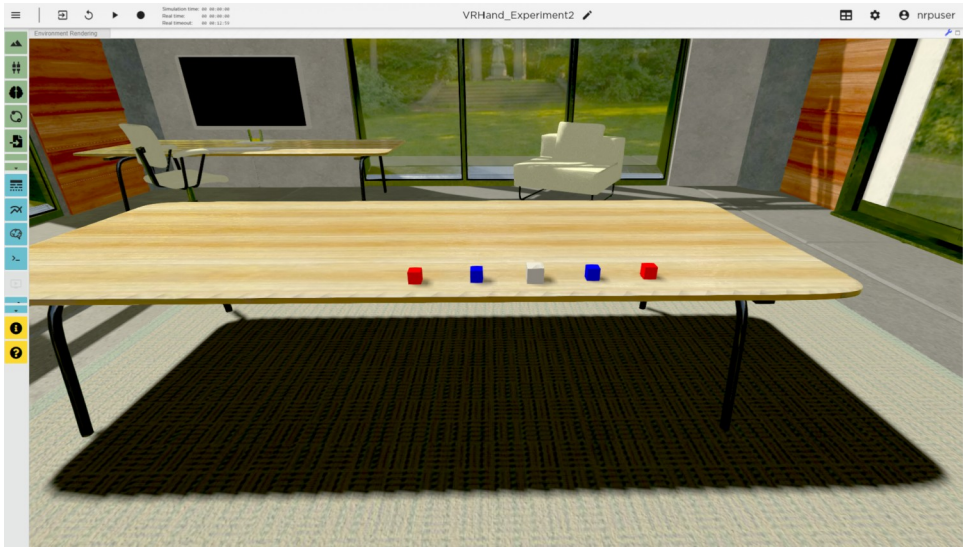
Evaluation (User Studies, Test Runs)

- Most of the test persons didn‘t noticed the Kickback



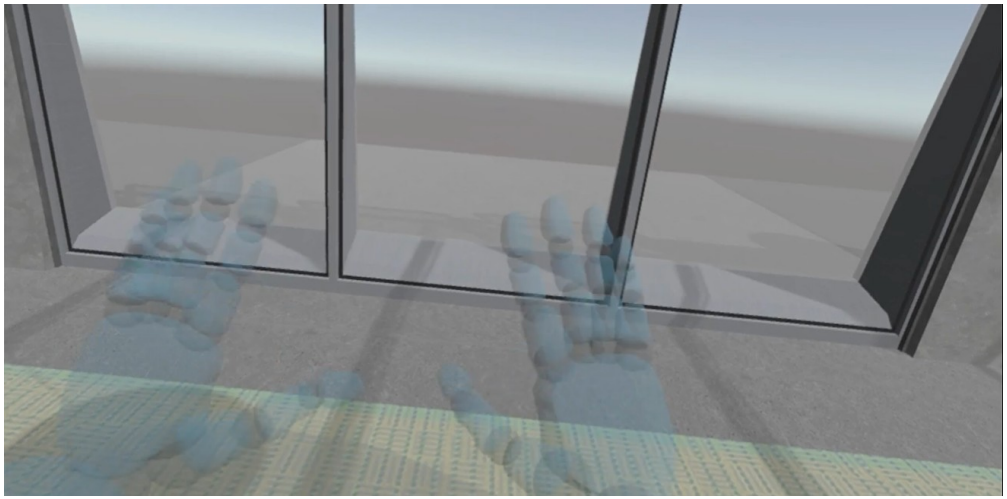
Conclusion

- Hand- and Fingertracking works quite well with this approach
- Re-Embodiment did happen in the User Study but need to be improved



Discussion / Suggested Future Work

- Better tuning of the PID parameters to reduce kickback
- Reduce spacial shifting between remote Avatar and real Hands
- Try with real Robot



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