Mind the GAP:
Geometry Aware Passthrough Mitigates Cybersickness

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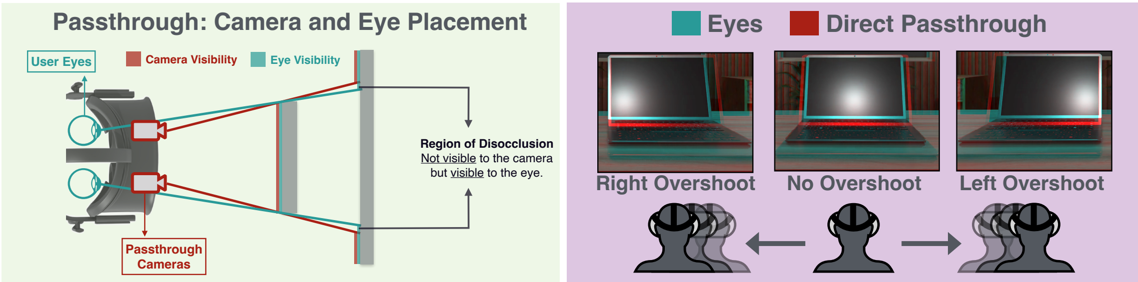
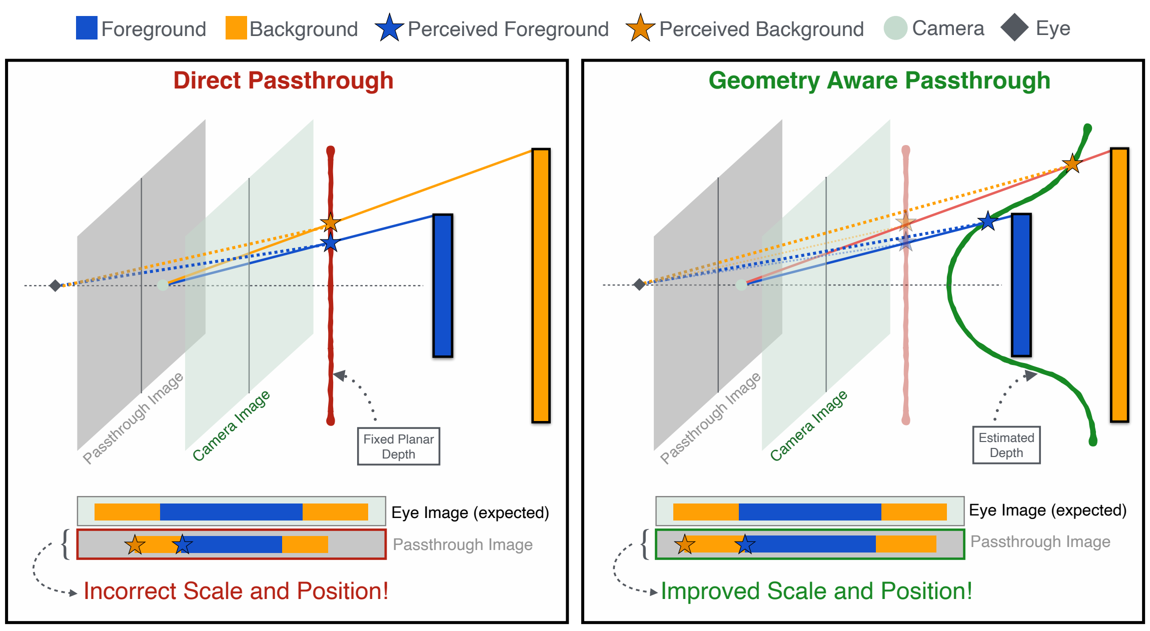
Introduction



1a. Difference in viewpoints causes disocclusion *1b. Passthrough exaggerates the user head motion*

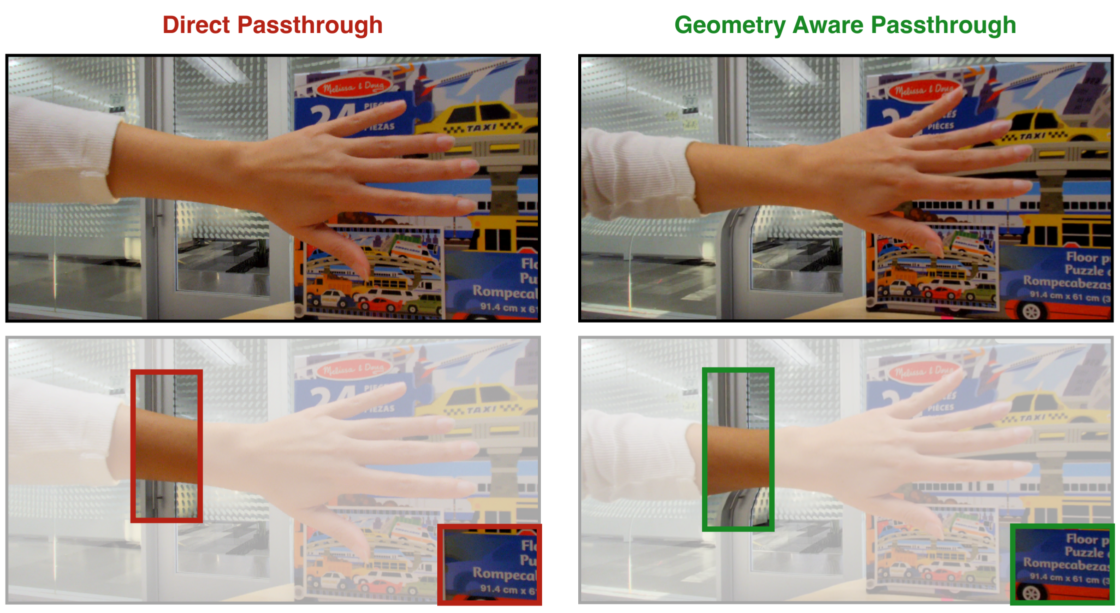
Video See-Through (VST) headsets utilize world-facing cameras to create Augmented Reality (AR) experiences. Due toinherent hardware limitations, the camera's perspective deviates from the user's natural viewpoint. Hence, directly displaying camera feeds can cause visual discomfort and cybersickness due to the inaccurate perception of scale and exaggerated motion parallax. This paper presents initial findings on the potential of geometry aware passthrough systems to mitigate cybersickness through enhanced depth perception. We introduce a promising protocol for quantitatively measuring cybersickness experienced by users in VST headsets. Using this protocol, we conduct a user study to compare direct passthrough and geometry aware passthrough systems.

Passthrough Modes



Direct Passthrough (DP)
DP directly displays unprocessed video feedsfrom external cameras, forgoing any form of view correction. It can be interpreted as a simplified form of planar reprojection. We set the projection plane 2 meters from the cameras.

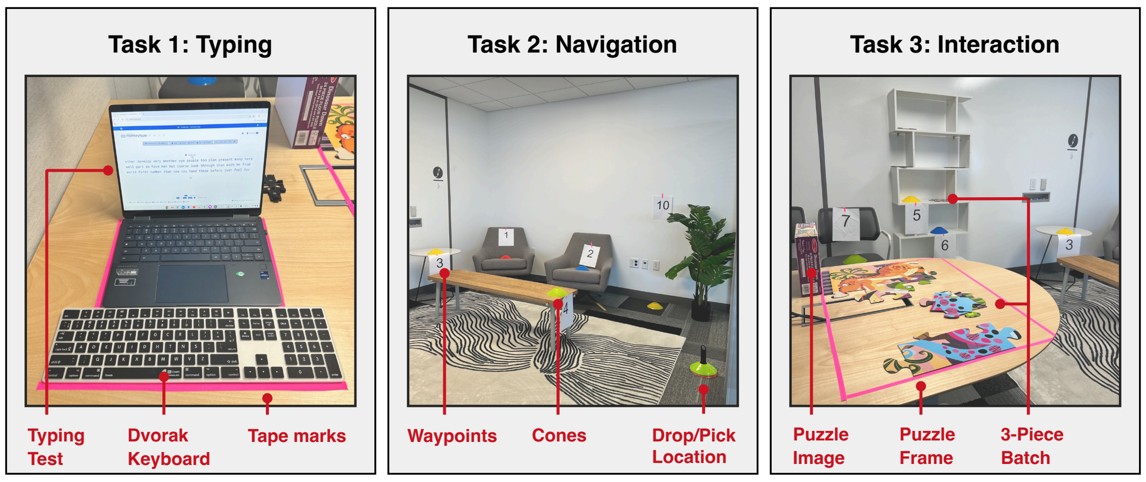
Geometry Aware Passthrough (GAP)
GAP employs novel view synthesis techniques or reprojection to align external camera images with the user's viewpoint. We follow Chaurasia et al. as our approach is similar to their passthrough implementation — Passthrough+.



DP introduces visual discrepancies in object positions and scales. The camera-eye disparity manifests as an exaggerated perception of motion parallax, particularly pronounced with objects in close proximity.

GAP mitigates the camera-eye disparity but may result in holes in the rendered imagery due to depth disocclusion. Thus, GAP is susceptible to warping that results from filling holes via stretching.

User Study



We introduce a protocol specifically tailored to quantify cybersickness in the context of VST HMD use cases. 25 participants with varied VR experience completed the study under 3 conditions: Natural Vision (NV), DP, and GAP (∼15 min per condition).

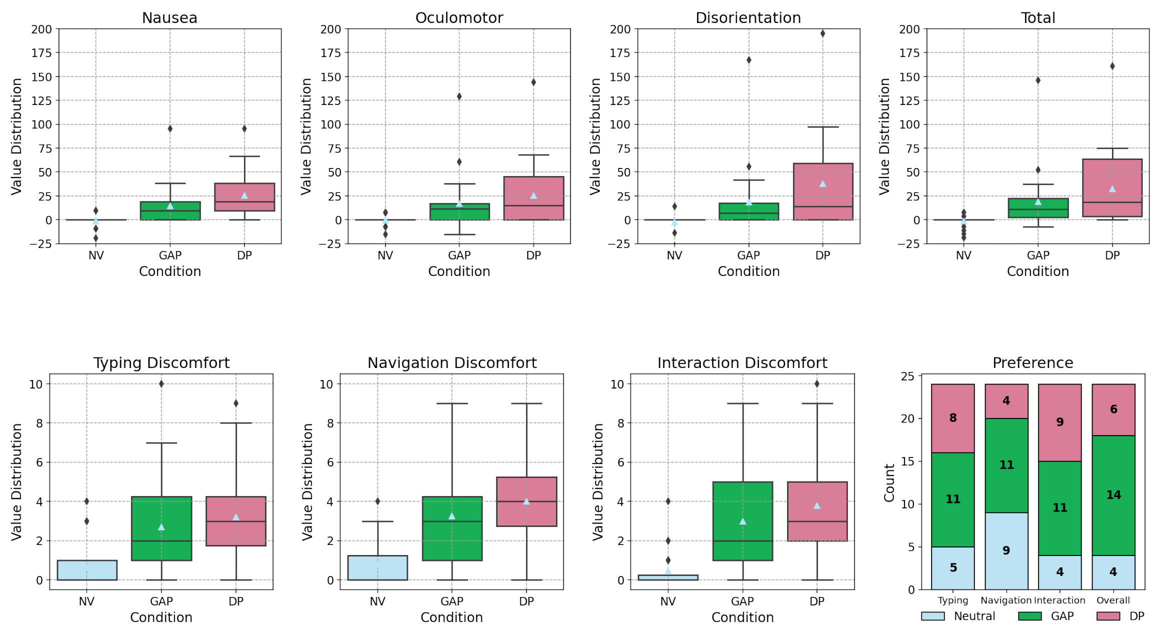
Tasks

- **Typing:** 6-minute task on a physical Dvorak keyboard to simulate productivity use cases requiring frequent gaze shifts.
- **Navigation:** Moving numbered cones across a room, requiring head/body motion, depth perception, and spatial awareness.
- **Interaction:** Completing a 24-piece jigsaw puzzle in batches, encouraging locomotion and visual-motor engagement.

Measures

- **SSQ:** Simulator Sickness Questionnaire scores before and after each condition.
- **Discomfort:** Real-time self-reported discomfort (0–10 scale) after each task.
- **Qualitative Feedback:** Preferences and open-ended responses.

Results



GAP Mitigates Cybersickness. GAP significantly reduced Nausea, Disorientation, and Total Severity SSQ scores as well as discomfort scores compared to DP.

Sensory Conflict in DP Causes Discomfort. "What I see does not match what is happening... Do you trust what you see or how you move?"

Geometry Enhances Spatial Awareness. "Depth perception was worse with [DP]... With [GAP], I could toss the cone and not miss; with [DP], I had to be more careful."

Conclusion

We presented a promising protocol aimed at evaluating visually-induced discomfort and cybersickness in VST HMDs through key use cases. To the best of our knowledge, our study is the first one to reveal reduced nausea, disorientation, and total scores of cybersickness with geometry aware passthrough. We believe this work provides an initial step toward refining these systems and enhancing user comfort in VST technologies.