Toggling Depth Cues in Virtual Reality

An Interactive Demonstration for Experiencing Classical Depth Cues in Isolation

Lennart Küppers
Technische Hochschule Brandenburg
Brandenburg an der Havel, Germany
lennartkueppers@web.de

Thies Pfeiffer
Hochschule Emden/Leer
Emden, Germany
thies.pfeiffer@hs-emden-leer.de

Martin Christof Kindsmüller
Technische Hochschule Brandenburg
Brandenburg an der Havel, Germany
mck@th-brandenburg.de

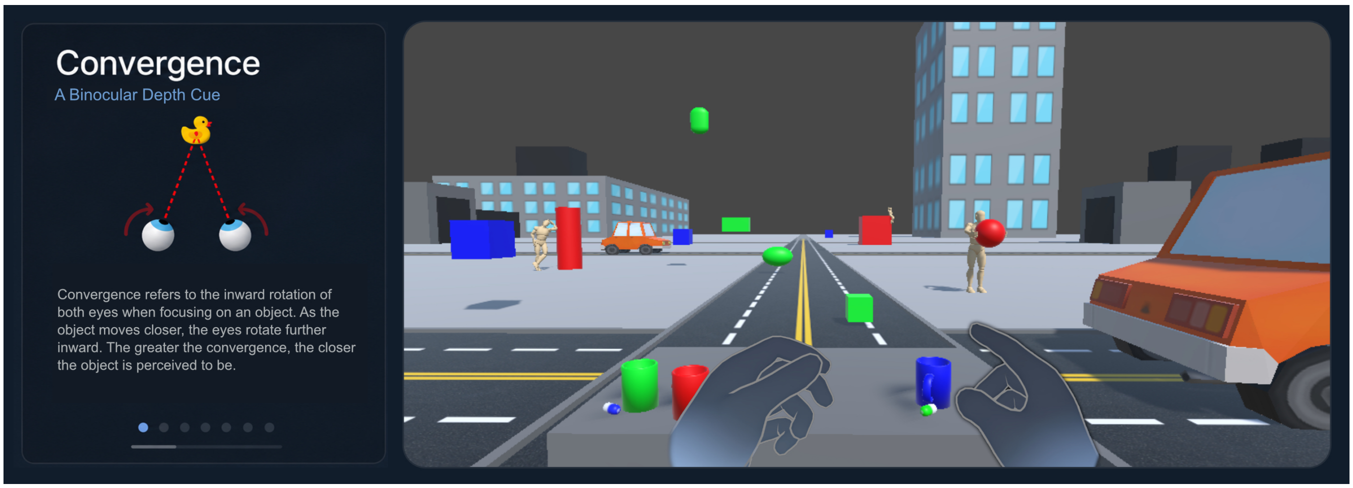

Figure 1: Example of didactic content (e.g. convergence) and screenshot of explorative virtual environment

Abstract

Understanding depth perception in Virtual Reality is challenging because multiple visual depth cues contribute simultaneously to the perception of three-dimensional space. While these cues are well described in literature, their individual influence is difficult to experience directly. We present an interactive Virtual Reality application that enables users to explore classical depth cues by selectively activating, deactivating and combining them in real time. The application provides a guided learning experience in which individual depth cues are explained and immediately visualized inside immersive VR. A modular framework allows each cue to be controlled independently while maintaining a consistent shared virtual environment. The demonstration runs on a Meta Quest 3 headset and invites visitors to interactively investigate how individual cues influence spatial perception and performance during specific tasks. The system is intended as an educational tool for teaching depth perception as well as a flexible framework for future perceptual experiments.

CCS Concepts

• **Computing methodologies** → **Virtual reality; Perception**.

Mensch und Computer 2026 – Tagungsband, Gesellschaft für Informatik e.V., 30. August - 02. September 2026, Duisburg, Germany

https://doi.org/10.18420/muc2026-mci-demo-309

Keywords

Virtual Reality, Human Perception, Visualization, Depth Perception

1 Introduction

Depth perception is one of the key factors that enables users to experience virtual environments as spatially coherent and immersive [2]. Human depth perception results from the combination of numerous binocular, monocular, and motion-based visual cues. Since these cues usually occur simultaneously, it is difficult to examine them in isolation from one another. Due to their complex nature, their individual contribution to depth perception is difficult to understand. To support the teaching and research of these cues, we developed an interactive VR application that allows classical depth cues (shown in Table 1) to be explored and isolated individually. Users can activate, deactivate and combine different cues while immediately observing their influence on a shared virtual scene. Instead of relying on static illustrations alone, the application enables direct perceptual comparison inside an immersive environment. The application was originally developed as part of a master's thesis that also investigated the subjective importance of different visual depth cues in Virtual Reality. The underlying framework served both as an educational tool and as an experimental platform for a user study lasting approximately one hour. For the "Mensch und Computer" demonstration, a demo mode was introduced that condenses the original workflow and allows visitors to freely navigate between three independent sections via

Table 1: Overview of the depth cues implemented in the demonstration. The classification is adapted from Dörner et al. [1].

Depth Cue	Classification	Effective Range
Occlusion	Monocular	Entire scene
Disparity	Binocular	Up to 10 m
Convergence	Binocular	Up to 2 m
Accommodation	Monocular	Up to 2 m
Image Blur	Monocular	Entire scene
Linear Perspective	Monocular	Entire scene
Texture Gradient	Monocular	Entire scene
Relative Size	Monocular	Entire scene
Known Size	Monocular	Entire scene
Height in Visual Field	Monocular	Beyond 30 m
Atmospheric Perspective	Monocular	Beyond 30 m
Shape from Shading	Monocular	Entire scene
Shadow Cast	Monocular	Entire scene
Motion Parallax	Dynamic	Beyond 20 m
Accretion	Dynamic	Entire scene

a central menu, making the application suitable for short conference demonstrations. Visitors can explore each depth cue through guided explanations and interactive animations, manipulate individual depth cues within a shared virtual environment, and directly experience their influence on depth perception and performance during various tasks. The modular implementation also allows new depth cues and demonstration scenes to be integrated with little effort, making the application suitable for future educational and research purposes.

2 Application Overview

The demonstration is organized around a central main menu that provides access to three independent application modules. Unlike the original experimental workflow developed for the accompanying master's thesis, the demonstration mode was specifically designed for short conference sessions and allows visitors to freely switch between all modules at any time. Animated transitions between scenes and user interfaces ensure a consistent and intuitive experience throughout the application.

2.1 Didactic Module

The first module introduces the classical visual depth cues through guided explanations and animated visualizations (as shown in Figure 1 on the left side). Visitors can select individual depth cues from a panel and explore their perceptual principles before interacting with the remaining parts of the application. This introductory section establishes the conceptual background required to correctly interpret the visual effects presented later in the other modules.

2.2 Perceptual Tests Module

The second module contains the central interactive environment (as shown in Figure 1 on the right side). Here, visitors can activate and deactivate individual depth cues while observing their influence within a shared virtual scene. Since all modifications are applied immediately, different combinations of depth cues can be explored without a constant re-design of the scene. This part connects the theoretical knowledge and practical visualization of the depth cues, to enhance the learning experience. During this part, visitors can not only deepen their understanding of individual depth cues, but also explore how disabling one cue influences the effectiveness of others.

2.3 Practical Tests Module

The third module (Figures 2 & 3) contains two interactive tasks that demonstrate practical applications of the framework. The tasks, Precise Positioning and Relative Positioning, allow visitors to freely experiment with different depth cue configurations while solving representative spatial problems at different distances. Missing or degraded depth cues are known to limit spatial task performance in VR [3]. Because some depth cues are more effective at far or short distances, these cues will be highlighted in the panel, so influential changes in depth during a specific task can be efficiently observed by the testers and will not be missed.

3 Modular Depth Cue Framework

The core contribution of the application is a modular framework that enables classical depth cues to be manipulated largely independently within a shared virtual environment. Since many depth cues rely on common rendering techniques or modify identical scene properties, completely independent implementations are generally not possible. The framework therefore manages these dependencies

Figure 2: A task to identify the closest out of 4 cubes. The left image contains all depth information, the right shows the task with some removed cues.

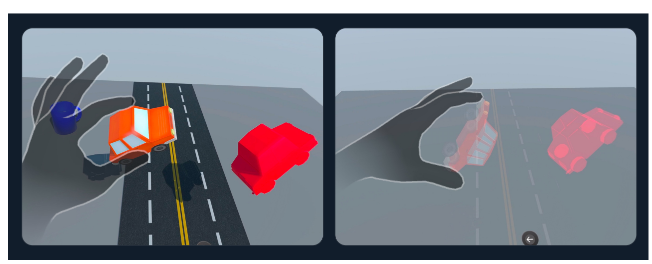

Figure 3: A task to position an object as precise as possible at a target location (red). The left image contains all depth information, the right shows the task with some removed cues.

while preserving a coherent and visually plausible virtual scene, allowing users to freely explore the influence of individual depth cues without manually reconfiguring the environment. Each depth cue is implemented independently and encapsulates all modifications required for its activation and deactivation. A central panel coordinates these controllers, restores the original scene state whenever cues are disabled, and resolves interactions between simultaneously active depth cues. This modular architecture allows most implemented depth cues to be combined dynamically while minimizing conflicts between individual rendering techniques. To maximize reusability, the framework was designed independently of individual demonstration scenes. The depth cue panels can therefore be attached to additional scenes with only minimal configuration, enabling the same interaction interface and depth cue implementations to be reused for future demonstrations or perceptual experiments. Since different depth cues rely on fundamentally different perceptual mechanisms, several specialized implementation strategies were required. Some cues can be manipulated through conventional rendering parameters, whereas others require custom engine-specific solutions. For example, accommodation is simulated by a dynamically controlled depth-of-field effect that adjusts the rendered focal plane to match where the user is currently looking. As the Meta Quest 3 has a fixed optical focal distance, the user's accommodation itself cannot be driven; the rendered defocus blur instead reproduces its retinal effect. On the other hand image blur controls the activation state of the depth-of-field effect by switching it on and off. Linear perspective is manipulated by transitioning between perspective and nearly orthographic camera projections, reducing the characteristic convergence of parallel lines while preserving spatial orientation and navigation. Deactivating binocular disparity, which is usually not possible in Unity/VR, was achieved through a camera-scaling technique: setting the camera scale to 0 also scales the IPD to 0, which is equivalent to presenting two identical images, one per eye [4]. Similar to these approaches, other depth cues including motion parallax, texture gradients, shadow casts, or atmospheric perspective also required individual solutions and techniques, varying in complexity. By encapsulating these implementations within independent modules, the framework provides a flexible foundation for extending the demonstration with additional depth cues, scenes, or interaction concepts while maintaining a consistent software architecture.

4 Interactive Demonstration

Ideally, visitors begin the demonstration in the didactic learning module, where each depth cue is introduced through concise explanations and animated visualizations. This section establishes the perceptual concepts required to understand the subsequent interactive demonstrations. Afterwards, visitors enter the shared scene environment, where all implemented depth cues can be activated, deactivated, and combined. Immediate visual feedback enables direct comparison between different cues and their effects on the environment. Finally, visitors may explore different interactive perceptual tasks. In the "Precise Positioning" task, objects must be positioned as accurately as possible at a target position while experimenting with different combinations of depth cues. The "Relative Positioning" task focuses on judging spatial relationships between multiple objects. Depth cues can also be activated and deactivated freely during this task. Both tasks encourage visitors to actively investigate how individual depth cues contribute to successful spatial perception and task performance rather than only observing isolated visual effects. Depth cues like binocular disparity, accommodation or convergence are much more relevant at short distances, while cues like atmospheric perspective or motion parallax are more important at longer distances. Throughout the demonstration, users can return to the main menu at any time, allowing flexible exploration of all available modules during the limited duration of a conference demonstration.

5 Conclusion

This paper presented an interactive Virtual Reality demonstration for exploring classical visual depth cues through a modular and extensible software framework. Unlike conventional demonstrations, the application enables visitors to manipulate individual depth cues largely independently within a shared virtual environment while preserving a coherent and realistic visual representation. The demonstration combines guided explanations, free exploration, and interactive perceptual tasks to illustrate how different visualization techniques contribute to spatial perception. Owing to its modular architecture, the framework can easily be extended with additional depth cues, demonstration scenes, or educational content, making it suitable both as a teaching application and as a foundation for future perceptual research prototypes.

References

[1] Ralf Dörner, Wolfgang Broll, Paul Grimm, and Bernhard Jung. 2019. *Virtual und Augmented Reality (VR/AR): Grundlagen und Methoden der Virtuellen und Augmentierten Realität* (2 ed.). Springer Vieweg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-58861-1

[2] Fatima El Jamiy and Ronald Marsh. 2019. Survey on depth perception in head mounted displays: distance estimation in virtual reality, augmented reality, and mixed reality. *IET Image Processing* 13, 5 (2019), 707–712. https://doi.org/10.1049/iet-ipr.2018.5920

[3] Nicolas Gerig, Johnathan Mayo, Kilian Baur, Frieder Wittmann, Robert Riener, and Peter Wolf. 2018. Missing depth cues in virtual reality limit performance and quality of three dimensional reaching movements. *PLOS ONE* 13, 1 (2018), e0189275. https://doi.org/10.1371/journal.pone.0189275

[4] Abdeldjallil Naceri and Ryad Chellali. 2012. The effect of isolated disparity on depth perception in real and virtual environments. In *2012 IEEE Virtual Reality Workshops (VRW)*. IEEE, Costa Mesa, CA, USA, 107–108. https://doi.org/10.1109/VR.2012.6180905