Interactive Impossible Objects: Designing Physical Interaction with Impossible Objects Using Binocular Disparity Adjustment and Redirection

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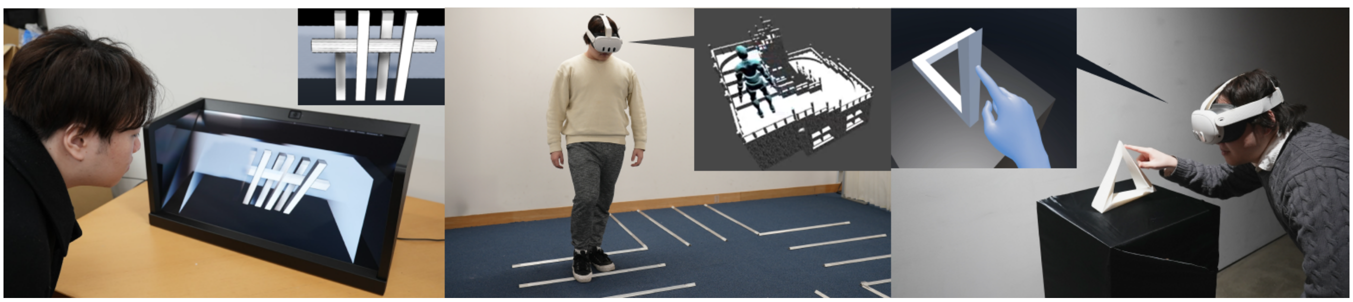

Figure 1: (Left) Observing an impossible object of the wrong depth using a stereoscopic display. (Center) A user ascending the stairs is seen from the outside. The tactile feedback on their feet enhances the illusion of continuous ascending. (Right) The user can interact with an impossible object in VR by touching the corresponding planes in physical space.

Abstract

We present *Interactive Impossible Objects*, a system that transforms classic impossible objects into walkable and touchable experiences in Virtual Reality (VR). While impossible objects have been extensively studied for their visual illusions, limited research has examined physical interaction with such objects. Our approach solves two core challenges: preserving the illusion of binocular disparity and maintaining interactivity. We achieve this by rendering distinct 3D models for each eye to preserve the visual illusion and applying redirection techniques that map a single continuous physical object onto a seemingly discontinuous or distorted virtual shape. In our demonstrations, users successfully navigate an "endless" staircase and interact with impossible objects in VR while engaging with corresponding real-world counterparts, maintaining a seamless illusion throughout the experience.

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CCS Concepts

• **Human-centered computing → Virtual reality**.

Keywords

impossible object, binocular-disparity adjustment, redirection techniques, multimodal interaction

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1 Introduction

Impossible objects–such as the Penrose triangle or staircase–are famous optical illusions that appear structurally plausible from specific perspectives but cannot exist in Euclidean 3D space [Kulpa 1983]. Artists like M. C. Escher popularized these motifs for their provocative blend of geometry and perception. Computer graphics researchers have extended these illusions to animated 3D models [Alexeev 2024; Sugihara 2008]. However, most of these efforts focus on specific viewpoint representations rather than allowing user-driven physical exploration. When viewed in stereoscopic environments, structural inconsistencies of impossible objects often become apparent. Furthermore, when impossible objects are rendered in three dimensions, they often become distorted or discontinuous, making them unsuitable for haptic interaction or physical navigation. As a result, physical contact with impossible objects remains unexplored despite their rich artistic and perceptual implications.

In this paper, we apply *binocular-disparity adjustment* and *redirection* techniques to the field of impossible objects, allowing impossible objects to be viewed in VR with natural stereopsis and to touch them. Specifically, we address:

- **Binocular Disparity:** By modeling each eye's viewpoint independently, the user perceives a consistent illusion in both eyes, preserving the impossible shape.
- **Physical Interaction:** Through *redirection techniques* [Azmandian et al. 2016; Nagao et al. 2018], we align a single continuous physical surface (or limited physical steps) with a discontinuous or warped virtual geometry object.

In our demonstration, users can experience three interactions: observing impossible objects that transform interactively according to the viewpoint to create a natural 3D effect, ascending "endless" staircases, and touching a Penrose triangle with realistic haptic feedback. These experiences bridge the gap between visual illusions and physically embodied interactions.

2 Implementation

2.1 Binocular Rendering of Distinct Models

To create a seamless illusion, we generate different 3D models for each eye, ensuring each viewpoint perceives a continuous object. For instance, in an "endless" staircase, the bottom and top edges are warped for each eye so that both appear to meet seamlessly from the respective vantage points. Additionally, to ensure that the illusion persists while observing or interacting with the impossible structure, The user is warped away from the discontinuity relative to the approaching discontinuity, as shown in Figure 2.

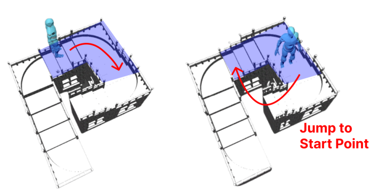

Figure 2: The user warps to the edge opposite the discontinuity when the discontinuity is approached so that the discontinuity of the object is located away from the user and the user's point of view.

2.2 Redirecting Physical Interaction

We map the warped virtual geometry onto real-world objects through redirection techniques. For walking, based on Nagao et al.'s method [Nagao et al. 2018], we let users step onto a small set of physical steps while continuously manipulating their virtual viewpoint to simulate an endless ascent or descent. Similarly, for touching, based on the body-warping technique [Azmandian et al. 2016], we developed an algorithm that maps the faces of different solids to each other. Specifically, the faces were divided into micro-rectangles, and the corresponding positions after redirection were determined (see Figure 3 top). These walking and touching redirection techniques ensure that users feel a consistent haptic response even when the virtual geometry is non-Euclidean, thus preserving the illusion during active exploration.

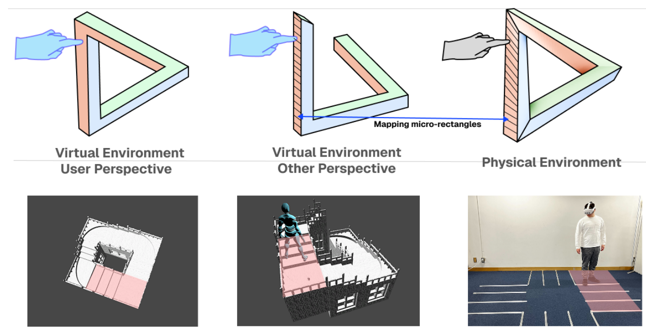

Figure 3: Mapping impossible geometries to real surfaces. Regions of the same color indicate planes or steps matched through redirection.

3 Demonstration

Using either an ELF-SR2 autostereoscopic display or a Meta Quest 3 headset, participants experience three impossible-object illusions: face-tracking reverses a column's depth (Figure 1, left); Redirected Walking turns a few floor bumps into an endless staircase; and haptic retargeting lets users trace a seamless Penrose triangle while touching a warped physical proxy (Figure 1, right).

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References

Vlad Alexeev. 2024. Impossible World: Impossible Figures. https://im-possible.info/english/index.html Accessed: 2024-09-17.

Mahdi Azmandian, Mark Hancock, Hrvoje Benko, Eyal Ofek, and Andrew D. Wilson. 2016. Haptic Retargeting: Dynamic Repurposing of Passive Haptics for Enhanced Virtual Reality Experiences. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 1968–1979. doi:10.1145/2858036.2858226

Zenon Kulpa. 1983. Are impossible figures possible? *Signal Processing* 5, 3 (1983), 201–220. doi:10.1016/0165-1684(83)90069-5

Ryohei Nagao, Keigo Matsumoto, Takuji Narumi, Tomohiro Tanikawa, and Michitaka Hirose. 2018. Ascending and descending in virtual reality: Simple and safe system using passive haptics. *IEEE transactions on visualization and computer graphics* 24, 4 (2018), 1584–1593.

Kokichi Sugihara. 2008. Computer-Aided Creation of Impossible Objects and Impossible Motions. In *Computational Geometry and Graph Theory*, Hiro Ito, Mikio Kano, Naoki Katoh, and Yushi Uno (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 201–212.