MoVRI: The Museum of Virtual Reality Illusions

Martin Feick
martin.feick@dfki.de
DFKI and Saarland University,
Saarland Informatics Campus
Saarbrücken, Germany

André Zenner
andre.zenner@dfki.de
Saarland University and DFKI,
Saarland Informatics Campus
Saarbrücken, Germany

Simon Seibert
s8siseib@stud.uni-saarland.de
Saarland University, Saarland
Informatics Campus
Saarbrücken, Germany

Oscar Javier Ariza Nuñez
oscar.javier.ariza.nunez@uni-hamburg.de
University of Hamburg
Hamburg, Germany

David Wagmann
s8dawagm@stud.uni-saarland.de
Saarland University, Saarland
Informatics Campus
Saarbrücken, Germany

Juliana Helena Keller
s8jukell@stud.uni-saarland.de
Saarland University, Saarland
Informatics Campus
Saarbrücken, Germany

Anton Wittig
s8anwitt@stud.uni-saarland.de
Saarland University, Saarland
Informatics Campus
Saarbrücken, Germany

Antonio Krüger
antonio.krueger@dfki.de
DFKI and Saarland University,
Saarland Informatics Campus
Saarbrücken, Germany

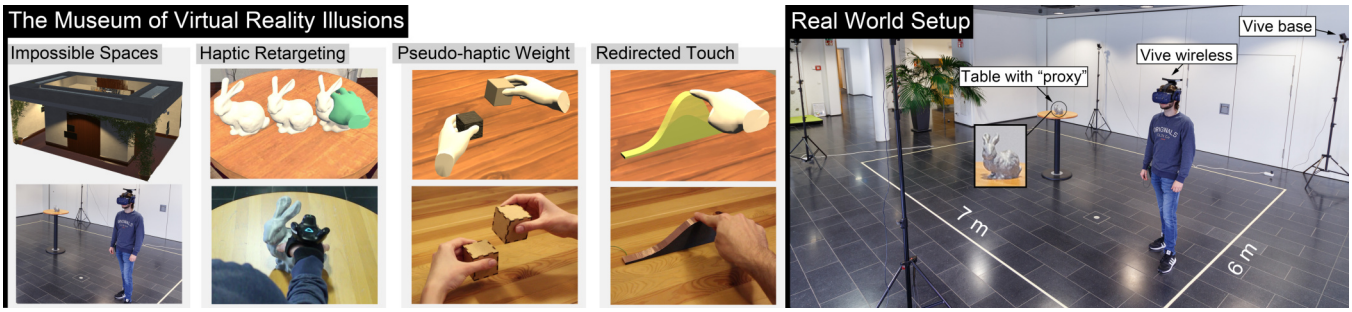

Figure 1: MoVRI showcases four illusion techniques that can be experienced in different exhibition rooms. The system can be calibrated to the physical space available, with larger spaces allow for more realistic museum tours.

ABSTRACT

We demonstrate the Museum of Virtual Reality Illusions (MoVRI). In contrast to a physical museum, the MoVRI is not a real world building, but an interactive VR application. Moreover, the museum does not exhibit pieces of art, but famous "pieces" of scientific VR research: a collection of VR illusion techniques. In the last decades, many different kinds of illusions have been presented in the VR research field; yet, how these illusions feel, mostly remains abstract for the reader. Therefore, we designed and implemented MoVRI, allowing visitors to experience various illusions displayed in exhibition rooms. Visitors can explore the museum by natural locomotion and enter the exhibition rooms they are most interested in. As a result, MoVRI empowers novices and VR experts to experience VR illusions at first hand, that would otherwise remain inaccessible.

DFKI Tech Report, 2023, Saarbrücken, Germany

CCS CONCEPTS

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

KEYWORDS

Virtual Reality, Illusions, Haptic Retargeting, Pseudo-Haptic, Impossible Spaces, Redirected Touch

ACM Reference Format:
Martin Feick, André Zenner, Simon Seibert, Oscar Javier Ariza Nuñez, David Wagmann, Juliana Helena Keller, Anton Wittig, and Antonio Krüger. 2023. MoVRI: The Museum of Virtual Reality Illusions. In *DFKI Tech Report*. Saarbrücken, Germany, 4 pages.

1 INTRODUCTION

The main goal of VR systems is to simulate an immersive virtual environment for training, education, entertainment, or other purposes. However, a range of different challenges makes implementing VR applications difficult—for example, the tracking space in which the user can move around in the real world might be limited, users might reach out to touch virtual objects but only find thin air, or properties of virtual objects interacted with could not be perceived

(e.g. objects might feel weight-less). One way to address some of these limitation is the use of VR illusion techniques that play with the user's perception, often without users even noticing it. Examples of such VR illusion techniques are Redirected Walking [8], Impossible Spaces [14], Change Blindness Redirection [6, 13], Redirected Touching [2, 5], Haptic Retargeting [1, 3], or Pseudo-Haptic Feedback [10, 11].

While all these techniques have been documented and published in research papers, it is often difficult and cumbersome for people, in particular those new to VR, to understand and imagine how the techniques work and how the effects feel. An easy way to try out famous VR illusion techniques does not exist today and existing demos are usually specialized on only a single technique. It is this gap that MoVRI fits in by allowing users interested in VR illusion techniques to explore different virtual "exhibition rooms", each demonstrating and explaining a different VR illusion technique.

To achieve this, each illusion technique is implemented in two ways, *experience* and *explanation* mode, because often, the purpose of VR illusions is to remain unnoticeable for users. In experience mode, a users performs interactions by playing a mini game with for instance, an unnoticeable hand redirection illusion, while in explanation mode, the real and the warped virtual hand position alongside a textual (and audio) explanation is displayed in the VR environment (see Figure 3).

In this demo, we present the MoVRI, showcasing the four illusions techniques: Impossible Spaces, Redirected Touching, Haptic Retargeting and Pseudo-Haptic Feedback. The clue about MoVRI is, that exploring the museum works with an illusion, suggesting a much larger virtual space than physically available—which will be revealed to the visitor at the very end of the museum tour.

2 MOVRI - DESIGN AND IMPLEMENTATION

The museum consists of exhibition rooms and an elevator to travel to different floors (or levels). An aisle around the room can be used to access-up to three exhibition rooms at one floor. The MoVRI uses a modular approach, i.e., we offer a template room that can be used when including a new illusion technique. MoVRI can be tailored to the physical space available by running through a calibration routine; however, the setup works best if more physical space is available—smaller setups prevent compelling illusions and may trigger claustrophobia. To this end, we provide three different types of rooms: (1) the foyer, where each visitor starts, (2) placeholder rooms that can be filled with any content and (3) exhibition rooms that showcase VR illusions. To demonstrate many of the well-established hand-based illusion techniques proxies are needed [9]; these are often placed on furniture. To prevent visitors from bumping into such requisites, which are only relevant for specific illusions, MoVRI uses placeholders such as virtual fountains, plants or couches [12]. They are automatically scaled to the required size during calibration. MoVRI is customizable with respect to physical constrains and room layout and therefore, uses config *.toml* files[1]. Exhibition rooms are implemented in different scenes and can be easily included by adding them to the config file.

[1]https://toml.io/en/

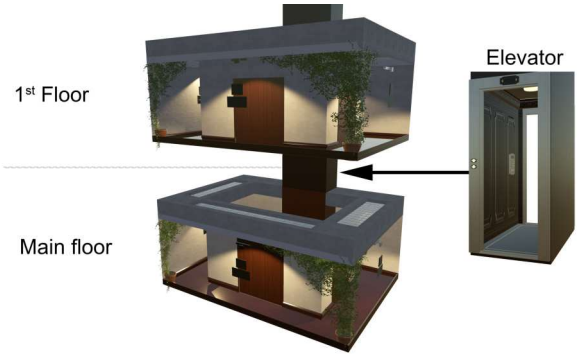

Figure 2: MoVRI's level design enables "endless" scalability.

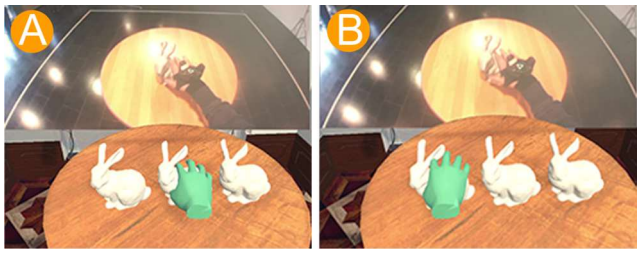

Figure 3: Haptic retargeting explanation mode shows real and warped virtual hand by using the HMD's front camera.

MoVRI comes as a Unity3d package, and was developed with Unity3d v. 2019.4.32f1[2]. It uses SteamVR[3] and an HTC Vive setup[4], consisting of four base 2.0 stations mounted on tripods, a Vive Pro headset and Vive trackers. In order to create a more compelling and immersive experience, we opted for an untethered setup using Vive wireless adapter[5]. Hand-based illusion techniques were realized using the HaRT-Toolkit [15]. Below we outline both, *experience* and *explanation* mode.

Experience. In experience mode visitors navigate through the museum and enter different exhibition rooms. Each room offers a unique experience for instance, a mini game that can be played while being exposed to an unnoticeable illusion. Once a visitor finishes the game the explanation mode starts.

Explanation. In explanation mode, the illusion techniques get revealed. How this happens depends on the experienced illusion. For example, since many of our exhibited techniques utilize real/virtual hand offsets, we implemented a live-streaming of the HMD's front facing camera into the virtual environment. This allows visitors to compare their real hand position with the warped virtual hand position (see Figure 3). In addition, the illusion techniques are then explained by a museum guide through text and audio. Explanations can be skipped, replayed, rewinded and muted on demand.

[2]https://unity.com/
[3]https://www.steamvr.com/
[4]https://www.vive.com/
[5]https://www.vive.com/us/accessory/wireless-adapter/

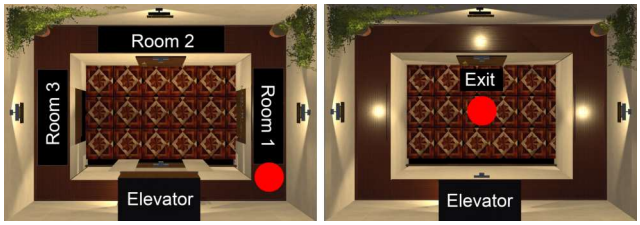

Figure 4: Remapped layout. Red sphere shows position of a visitor and the perspective difference between being inside a room and the aisle. Left: Room 1 is loaded, because the user enters the segment area of room 1. Right: Visitor stands in room 2.

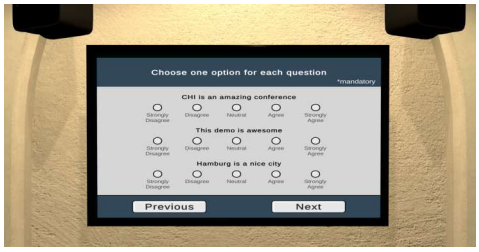

Figure 5: LCD can be used to display explanations or to collect feedback inside MoVRI [4].

3 VR ILLUSION TECHNIQUES

In the following, we describe the four illusion techniques: Impossible Spaces, Redirected Touching, Haptic Retargeting, and Pseudo-Haptic Weight which will be presented (see Figure 1).

Impossible Spaces is a design mechanic for virtual environments that aims to maximize the perceived size of a virtual environment while using a smaller physical space [14]. This can be achieved by overlapping architectural layouts as depicted in Figure 4. MoVRI makes use of two different impossible spaces techniques, an elevator and dynamic loading of exhibition rooms, to create the illusion of a larger virtual space. The elevator is a standard mechanic, allowing visitors to travel to different floors, entering "new and unkown" territory. Additionally, it enables sheer endless possibilities to expand MoVRI in the future, adding more illusion or interaction techniques if desired. The dynamic loading effectively exploits MoVRI's layout, consisting of the elevator, an aisle and a central room in the middle, shown in Figure 2. Alongside the aisle, there exist three doors that lead to different exhibition rooms, which are dynamically loaded when users (marked with a red sphere in Figure 4) enters the corresponding segment of the aisle. Once inside the room, a visitor only sees a single exit door depicted in Figure 4 right. To ease navigation and to create a stronger space illusion, way signs are installed.

Haptic Retargeting is a hand-based illusion techniques that offsets the position of the virtual hand from the hand position in the real world when reaching for a target [1]. As a result, a user compensates for the offset, allowing her, for example, to touch three virtual bunnies while being redirected to the same physical 3D printed bunny (i.e. a proxy object as in Figure 1). This can be achieved by manipulating the Control-Display (CD) ratio, effectively scaling-up or down users' movements by introducing a gain factor g [1]. Ultimately, this method aims to reduce the number of proxies needed while still enabling realistic haptic sensations for various virtual objects.

Redirected Touching is a visuo-haptic illusion, utilizing a similar technique as described above, but while the user's hand is in contact with a physical physical proxy object [2]. Figure 1 shows an example, a user explores a Gaussian-shaped virtual object embodied by a physical proxy with her index finger. By using redirected touch, we may alter the length, height or incline of the virtual object while rendering the important tactile cues such as the apex atop correctly (indicated in yellow). This can be used to remap tactile features of different geometries [2, 5].

Pseudo-Haptic Weight uses virtual-to-real hand offsets to suggest objects of different weights, even though they weigh the same. This can be achieved by applying a gain factor $g < 1.0$ i.e., users' virtual movements become slower than their real movements. This has been demonstrated to increase the perceived weight of an object [11]. Moreover, differences in colour and texture may result in an even stronger weight illusion [7].

4 DEMONSTRATION OF MOVRI

4.1 Demonstration

To showcase MoVRI, our demo will be executed by two people. One introducing groups of up to 10 people to the MoVRI, explaining its concept and purpose while waiting. Since only one participant at a time can experience MoVRI, we plan to have a larger LCD screen, sharing the HMD perspective or our demonstration video that can be used to support explanations and foster discussions. The second demo person ensures the safety of visitors in VR and further, assists them with the HMD, makes sure that they feel comfortable, and engages directly with them in case of questions. The length of the museum tour is highly flexible, depending on how many exhibition rooms the visitor wants to explore, how quickly explanations will be understood and how many exhibition rooms are available to visit. Thus, we can easily cope with high traffic fluctuations at our demo booth by limiting the number of rooms an individual may experience.

Through informal pilot testing, we determined that a $7m \times 6m$ workspace is ideal to provide compelling VR space illusions. This way, rooms, aisles and the elevator are large enough, and will not be perceived as restrictive. Moreover, we also welcome audiences that rely on wheelchairs or crunches.

4.2 Collecting Visitor's Feedback

As outlined above, engaging with VR illusions is mostly restricted to reading about them, watching videos or, if possible, participating in lab studies. Therefore, we plan to use this opportunity to open this space up to a wider audience. Thus, we would like to collect visitor's feedback about the illusions and the explanations inside MoVRI using the VRQuestionnaireToolkit [4]. Responding to the displayed questions is completely voluntary and can be skipped if desired. It will also be possible to experience MoVRI without participating in the data collection procedure.

ACKNOWLEDGMENTS

This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – project number 450247716.

REFERENCES

[1] 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*. ACM, San Jose California USA, 1968–1979. https://doi.org/10.1145/2858036.2858226

[2] Yuki Ban, Takuji Narumi, Tomohiro Tanikawa, and Michitaka Hirose. 2014. Displaying Shapes with Various Types of Surfaces using Visuo-haptic Interaction. In *Proceedings of the 20th ACM Symposium on Virtual Reality Software and Technology (VRST '14)*. Association for Computing Machinery, Edinburgh, Scotland, 191–196. https://doi.org/10.1145/2671015.2671028

[3] Lung-Pan Cheng, Eyal Ofek, Christian Holz, Hrvoje Benko, and Andrew D. Wilson. 2017. Sparse Haptic Proxy: Touch Feedback in Virtual Environments Using a General Passive Prop. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. Association for Computing Machinery, Denver, Colorado, USA, 3718–3728. https://doi.org/10.1145/3025453.3025753

[4] Martin Feick, Niko Kleer, Anthony Tang, and Antonio Krüger. 2020. The Virtual Reality Questionnaire Toolkit. In *Adjunct Publication of the 33rd Annual ACM Symposium on User Interface Software and Technology (UIST '20 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 68–69. https://doi.org/10.1145/3379350.3416188 event-place: Virtual Event, USA.

[5] Luv Kohli. 2010. Redirected Touching: Warping Space to Remap Passive Haptics. In *2010 IEEE Symposium on 3D User Interfaces (3DUI)*. 129–130. https://doi.org/10.1109/3DUI.2010.5444703

[6] Eike Langbehn, Paul Lubos, and Frank Steinicke. 2018. Redirected Spaces: Going Beyond Borders. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Reutlingen, 767–768. https://doi.org/10.1109/VR.2018.8446167

[7] Akihiro Maehigashi, Akira Sasada, Miki Matsumuro, Fumihisa Shibata, Asako Kimura, and Sumaru Niida. 2021. Virtual Weight Illusion: Weight Perception of Virtual Objects Using Weight Illusions. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (CHI EA '21)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3411763.3451842 event-place: Yokohama, Japan.

[8] Niels Christian Nilsson, Tabitha Peck, Gerd Bruder, Eri Hodgson, Stefania Serafin, Mary Whitton, Frank Steinicke, and Evan Suma Rosenberg. 2018. 15 Years of Research on Redirected Walking in Immersive Virtual Environments. *IEEE Computer Graphics and Applications* 38, 2 (March 2018), 44–56. https://doi.org/10.1109/MCG.2018.111125628

[9] Niels Christian Nilsson, André Zenner, and Adalberto L. Simeone. 2021. Propping Up Virtual Reality With Haptic Proxies. *IEEE Computer Graphics and Applications* 41, 05 (Sept. 2021), 104–112. https://doi.org/10.1109/MCG.2021.3097671 Publisher: IEEE.

[10] Andreas Pusch and Anatole Lécuyer. 2011. Pseudo-haptics: From the Theoretical Foundations to Practical System Design Guidelines. In *Proceedings of the 13th international conference on multimodal interfaces - ICMI '11*. ACM Press, Alicante, Spain, 57. https://doi.org/10.1145/2070481.2070494

[11] Majed Samad, Elia Gatti, Anne Hermes, Hrvoje Benko, and Cesare Parise. 2019. Pseudo-Haptic Weight: Changing the Perceived Weight of Virtual Objects By Manipulating Control-Display Ratio. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, Glasgow, Scotland Uk, 1–13. https://doi.org/10.1145/3290605.3300550

[12] Adalberto L. Simeone, Eduardo Velloso, and Hans Gellersen. 2015. Substitutional Reality: Using the Physical Environment to Design Virtual Reality Experiences. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'15)*. ACM, 3307–3316. https://doi.org/10.1145/2702123.2702389

[13] Evan A. Suma, Seth Clark, David Krum, Samantha Finkelstein, Mark Bolas, and Zachary Warte. 2011. Leveraging Change Blindness for Redirection in Virtual Environments. In *2011 IEEE Virtual Reality Conference*. 159–166. https://doi.org/10.1109/VR.2011.5759455 ISSN: 2375-5334.

[14] Evan A. Suma, Zachary Lipps, Samantha Finkelstein, David M. Krum, and Mark Bolas. 2012. Impossible Spaces: Maximizing Natural Walking in Virtual Environments with Self-Overlapping Architecture. *IEEE Transactions on Visualization and Computer Graphics* 18, 4 (April 2012), 555–564. https://doi.org/10.1109/TVCG.2012.47 Conference Name: IEEE Transactions on Visualization and Computer Graphics.

[15] André Zenner, Hannah Maria Kriegler, and Antonio Krüger. 2021. HaRT - The Virtual Reality Hand Redirection Toolkit. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (CHI EA '21)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3411763.3451814 event-place: Yokohama, Japan.