Spherical Objects as an Opportunity to Investigate Physical Embodiment in Mixed Reality Environments

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ABSTRACT

In this work, we introduce our approach of using current VR and AR technology to explore fully tangible spherical user interfaces. We present three prototypes utilizing this technique. We briefly outline possible challenges, advantages, and fields of application for the presented concepts. Accordingly, we discuss why VR is an interesting tool to investigate interaction with Tangible User Interfaces (TUIs) that are currently not feasible in real world applications such as tangible holographic interfaces or lightweight handheld non-planar displays. This allows for studying various levels of tangible feedback on established use cases such as spherical visualizations. Subsequently, a tangible sphere, due to its natural shape enables an investigation of interaction techniques transferred from the real to the virtual world. Building on these prospects we represent the position that such objects could play a leading role not only in research but in future Virtual Reality (VR) and Augmented Reality (AR) applications that rely on natural interaction based on realistic physical feedback.

CCS CONCEPTS

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

KEYWORDS

Tangible Interaction, Spherical Objects, Virtual Reality, Spherical Displays

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1 INTRODUCTION

As described in the vision [5] of Ishii and Ullmer physical objects play a key role in bridging the gap between real and physical world. Current VR technology allows for precise tracking of controllers and Head Mounted Displays (HMDs) but lacks the possibility to efficiently transfer custom objects to the virtual world without significantly altering their topological features. Tracked spherical objects, however, grant the opportunity to investigate an unobstructed surface in VR since it is possible to use tracking devices mounted to the inside of a sphere. This enables to create rigid, completely round tracked objects that can represent any kind of virtual content on and around their surface. Although it is not inevitably necessary for these objects to be virtually augmented current technology provides this possibility enabling responsive interfaces that are also visually convincing and therefore can accommodate use cases that rely on tangible objects also acting as a display. It is often the consensus that tangible interaction provides benefits in VR and AR, yet it is unclear to what degree physicality can enhance interaction with virtual content. Therefore we see spherical objects as a tool to prototype tangible interfaces and to investigate the necessity of such for concrete use cases.

2 RELATED WORK

Spherical devices and objects have a long history in human computer interaction mainly in the form of trackballs. Since our concepts rely on the possibility of VR and AR to project virtual content onto the sphere we will shortly discuss the fields of tangible interaction and spherical displays. Ware et al. have shown that virtually embodied objects can be used to control [7] content shown on a 2D screen. Concepts for spherical displays in a three-dimensional space either rely on projecting content from the outside or the inside. The first method allows for movable spheres but suffers from projection issues such as limited operation area or shadowing caused by the users' hands [2, 6]. The second method, when implemented in movable fashion, needs a stand to which the projectors are mounted [1] distorting the shape, while a fixed sphere obviously lacks haptic feedback from real rotation and needs to compensate this by simulating rotation by detecting multi-touch input.

3 RESEARCH OBJECTIVES

This paper presents three fields of application in which we used or plan to use tracked spherical objects to investigate the impact of their physical form on interaction: handheld spherical displays, spherical displays in general and sphere-shaped controllers. The latter does represent a hybrid of the first two areas due to the capability to display content on the surface of the controller. In all three areas our main goals of investigation are: the effect a fully embodied object [4] has on the perception of information, if possible, a performance comparison to a real-world version of our simulated approach (e.g. a real spherical display) and the influence a complete unobstructed spherical shape has on basic types of interaction such as rotation and selection. The main motivation behind these investigations is the transfer of natural types of interaction derived from the real world to virtual environments. Hence, we additionally put the focus on the time users would need to learn the specific type of interaction in comparison to more commonly used approaches.

Therefore, our research seeks to provide evidence for the importance of the physical representation of virtual objects regarding spherical devices while exploring novel types of displays that can hardly be realized in reality as well as novel interaction techniques that can be provided by handheld and especially completely round spheres in a room scale VR environment.

4 HARDWARE CONCEPT

The main hardware concept is based on the ability of the HTC Vive Tracker[1] to work when placed behind infrared transparent material such as acrylic glass. The spherical shape additionally benefits this effect since it does prevent disturbing reflections that occur on objects with defined edges. We have implemented this concept using spheres with a diameter of 12, 25, 40 and 60 centimeters. Even for the smallest diameter, it was not possible for users to obstruct the sensors of the tracker using both hands. Therefore, we could not recognize any difference regarding performance and could track the objects in a room scale environment at a constant refresh rate of 90 Hz enabling believable natural interaction with the respective virtual content.

5 PROTOTYPES

We used VR to simulate two kinds of spherical displays: handheld displays and displays mounted to a stand that can be freely rotated on bearings. However, the latter type also allows itself to be picked up by the users which enables an interesting alternative to mere rotational interaction, especially for the smaller sphere sizes.

[1] Vive Tracker:https://www.vive.com/de/vive-tracker/

VR Simulated Spherical Displays

The goal for this project was to recreate a large commercial spherical display (60cm diameter) using VR simulation. The used acrylic glass sphere required a custom build inner frame to withstand rotational forces while it sat on three ball bearings mounted to a slim stand. In contrast to the real world variant, actual rotation of the display provided a novel form of interaction that yet cannot be realized for inside-projected displays. We ran two studies to at first evaluate the feasibility of accurately simulating a spherical multi-touch display and to further investigate if real rotation would result in lower task times and better accuracy. While the first study showed that a VR simulated display performed within a close margin to the real display the second study clearly supported our claim of real rotation and real tangible feedback enhancing task performance significantly.

In a follow-up project, we evaluated the capabilities of our setup being able to provide a tangible interface for large scale simulated displays such as CAVE or dome-shaped environments under the consideration of different user perspectives. In our implementation, we placed a tangible, rotatable sphere in the center of such a large simulated VR display and investigated an alignment and selection task. First results indicate that the small tangible display should rotate in the same direction as the larger one while it was beneficial if the content on the smaller display was shown on the inside of the sphere rather than on the outside.

VR Simulated Handheld Spherical Displays

We see handheld spherical displays as an opportunity to gain insights about the impact the actual shape could have on interaction in comparison to a more abstract physical object. Our evaluation consisted of a study testing three use cases: a virtual globe, a spherical graph, and a 360°video. On the first two use cases, we ran a comparative study with two test groups: one using the handheld spheres and one using Vive-VR-Controllers. Our results [3] showed that especially for the spherical graph users had a 28% higher detection rate in recognizing a pattern hidden in the graph. We achieved comparable performance in the globe tasks that required subjects to find and select a distinct marker on the surface using rotation and selection. Although the spheres overall were slightly superior, it is not clear if this is a result of the different rotational behavior or if the sensation of a fully embodied object is responsible for this effect.

We plan to issue further research on trying to detect the impact weight, mass, surface-characteristics and the forces felt from rotation may have on the perception of information. Since the graph task resulted in the clearest result we see potential in tasks requiring users to detect patterns in visual structures. We also noted that in comparison to the controller method the handheld spheres needed significantly less introduction time for users due to well-known shape. Qualitative results in form of a questionnaire also spoke in favor of the spheres concerning user preference and self proprioception even if the users were not able to see their hand but just the controllers.

Spherical Controllers for VR

While the previous prototypes mainly were focused on detecting the effect of the spherical shape regarding perception and task performance (selection and rotation) we also work on more unconventional applications for the spherical tracked objects in VR while considering the core concepts of natural interaction and high learnability. Thus, we are developing a locomotion concept for navigation in virtual environments that is based on rotating a spherical handheld controller that is also capable of showing visual content such as a miniature variant of the environment. This prototype offers the prospect to gain insights on the impact of the shape and the constant tangible feedback provided by continuous rotation and its influence on risks such as cybersickness. We expect to gain part of these results by issuing a comparison to movement concepts utilizing standard VR controllers.

While the concept in a first version is solely focused on movement further extensions could regard selection and other types of interaction concepts such as tilting or even tossing the controller. In comparison to a classic trackball, the idea offers a full spherical shape, the capability to display content and the utilization of full six-degree-of-freedom interaction. Positive results could point in the direction of application in the fields of public HMD usage where high learning times and long introduction for rather basic types of interaction (movement) are to be avoided.

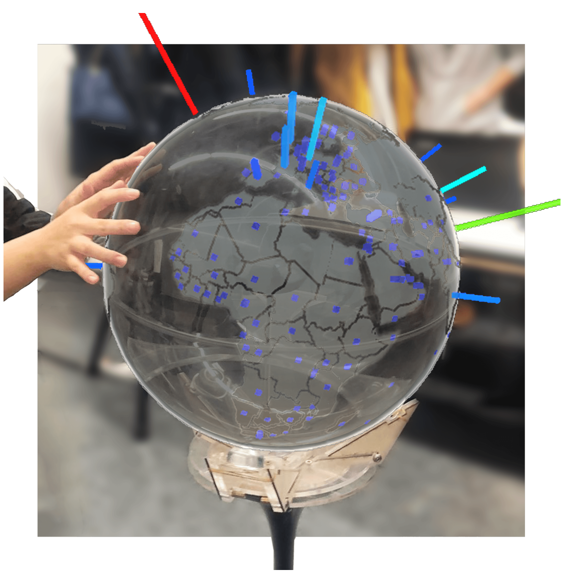

Figure 1: Our prototypes allow for the exploration of novel display technology such as this holographic visualization utilizing the space around the fully tangible object.

6 CONCLUSION AND OUTLOOK

The outlined projects acknowledge the general assumption that full tangible embodiment provides an advantage above simulated or absent haptic feedback. The possibility of VR and AR to realize displays that are not possible in reality while still generating an accurate tangible sensation from a similarly shaped object opens interesting opportunities for future research.

Our current results show that tangible spherical objects have advantages in a number of use cases. However, the full potential of this method could lie within conjunction with more commonly used interaction techniques. For example, a sphere could play an important role in a toolkit of tangible objects in which it could take over the tasks of rotation and alignment while other shapes are more suited to other kinds of interaction. Apart from that, an application in research for gradually modulating various levels of real and simulated tangible feedback is interesting in its own right.

If we consider our environment to become more and more digitized in the future the attribution of virtual content to real-world objects is inescapable. Therefore, we see our research as a foundation that may expand to more complex shapes while building on the knowledge gained from basic objects just like a sphere.

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