

Sphere in Hand: Exploring Tangible Interaction with Immersive Spherical Visualizations

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ABSTRACT

The emerging possibilities of data analysis and exploration in virtual reality raise the question of how users can be best supported during such interactions. Spherical visualizations allow for convenient exploration of certain types of data. Our tangible sphere, exactly aligned with the sphere visualizations shown in VR, implements a very natural way of interaction and utilizes senses and skills trained in the real world. This work is motivated by the prospect to create in VR a low-cost, tangible, robust, handheld spherical display that would be difficult or impossible to implement as a physical display. Our concept enables it to gain insights about the impact of a fully tangible embodiment of a virtual object on task performance, comprehension of patterns, and user behavior. After a description of the implementation we discuss the advantages and disadvantages of our approach, taking into account different handheld spherical displays utilizing outside and inside projection.

Index Terms: Human-centered computing—Interaction paradigms—Virtual reality;

1 INTRODUCTION

Developments in the commercialization of virtual reality open up many opportunities for enhancing human interaction with three-dimensional objects and visualizations. While common drawbacks of VR regarding visual display issues, such as field of view, resolution, and latency are constantly improved, the concepts for tangible feedback are less straightforward. As Anthes et al. [1] state, a considerable variety of controllers exist, covering approaches for gestural input and methods for passive and active haptic feedback. However, it is still unclear which concept is best suited for which kind of application. A spherical display accommodates numerous visualizations and provides a unified surface that can be represented by a (simple and cheap) tracked object. This opens the opportunity to investigate the role of accurate topological feedback on an established visualization paradigm and its use cases, as well as the possibility to prototype interaction with novel display technologies. Besides the simple and self-explanatory character of the shape and its natural affordance for rotation and focus, a spherical visualization provides multiple advantages that may even be amplified by tangible interaction such as placing an inverse element at the back side of the sphere indicating an opposing relationship. We demonstrate the practicability of tracked spherical proxy objects that allow tangible interaction for spherical visualizations. Our implementation relies on common off-the-shelf VR hardware and is therefore easily reproducible.

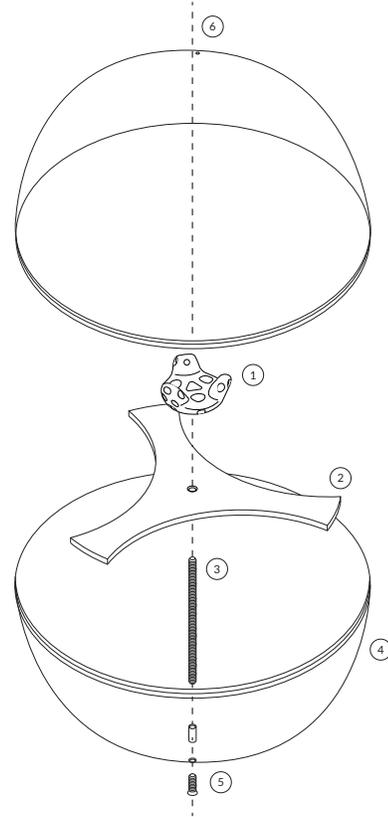


Figure 1: A Vive Tracker (1) is fitted to the center of an acrylic sphere (4) by a thread rod (3) together with a stabilization piece (2). The assembly is held by a countersunk screw (5) from the outside. A tiny hole at the top is used for switching on the device (6).

2 RELATED WORK

Recent advances have been made in the field of Handheld Perspective-Coupled Displays (HPCDs) [3–5]. This method tracks the user’s position and the location of a spherical prop to project a perspective-correct image of an object from the outside onto its surface, which also makes it possible to display 3D objects that appear to be inside the sphere. Louis and Berard [7] compared an HPCD to an opaque Head-Mounted Display (HMD) on a docking task performed with a tangible sphere. They found that the HPCD approach was superior in terms of efficiency, user proprioception and the quality of visual feedback but acknowledged that the system had a number of drawbacks compared to the HMD—most prominently a limited and partially obstructed view of the sphere’s projected content. Another interesting example is the work of Belloc et al. [2]. By positioning multiple calibrated high-performance laser pico-projectors inside the socket of a translucent sphere, they realized a handheld spherical display with support for multi-user in-

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teraction and stereoscopic 3D rendering. Both of the above examples demonstrate that the technology does not only require considerable effort in terms of costly or custom-built hardware, but yet cannot overcome a number of significant disadvantages.

3 A HANDHELD SPHERE AS AN INTERACTION OBJECT

The spherical props for our prototype had to be robust, simple in construction, low cost, and provide a largely unobstructed and complete spherical surface. Another main goal of the construction and the hardware concept was to enable an effortless reproduction. Thus, we present an alternative to specialized and expensive hardware previously used in this field. The disadvantage of user instrumentation can obviously not be eliminated but the concept does not suffer from crucial drawbacks such as a limited view, a severely restricted operation area, obstruction of the visualization (e.g., shadowing by the users' hands or masking by tracking markers) or an incomplete spherical shape.

4 CONSTRUCTION & HARDWARE

We chose the HTC Vive lighthouse tracking system because it provides a low-latency, room-scale tracking with sufficient accuracy [8] at a refresh rate of 90 Hz. For tracking the spherical object, the commercially available Vive Tracker¹ is used. We found that the operation of the infrared-based tracking system was not restricted in any noticeable way when the tracker is placed behind transparent material. Consequently, we ordered two acrylic glass spheres (diameter: 25cm, 40cm) from a decoration equipment manufacturer. As seen in Figure 1, the spheres can be split into two halves and had to be fitted with a mount for the tracker. This was done by attaching a 1/4 inch threaded rod to one of the "poles" of the sphere with a countersunk screw from the outside. To achieve an optimal mapping to the virtual object and an unobstructed line of sight for the tracking system, we put the tracker in the center of the sphere. To center the rod and to avoid its vibration (and in turn the tracker's) we inserted a stabilization piece made of acrylic glass. Such a piece can be created with a laser cutter, 3D printer or simply with a jigsaw. When assembled completely, the smaller sphere has a total weight of 970g while the larger one weighs 2390g. For multi-touch input on the spheres' surfaces, we use the Noitom Hi5 VR Glove², which is designed for the integration with a Vive setup.

5 DISCUSSION & LIMITATIONS

Our prototype shows that current VR technology can provide credible and fast visual feedback even though the tracking device is placed behind transparent material. Some current limitations are rooted in HMD technology. In addition to a high level of user instrumentation, users still remain quite isolated from their surroundings, multi-user collaboration is not possible without effort and the display resolution is not yet high enough to show elaborate detail. Since these limitations are of technical nature and likely to improve, we see great potential in the proposed method especially because it is not suffering from the various drawbacks that outside and inside projected handheld spherical displays have to deal with.

One major advantage of placing the tracker inside the tracked object is the result of a completely unobstructed surface and visualization—a condition the HPCD approach as well as the inside projection method cannot maintain. The former is dependent on visible tracking markers on the surface and additional obstruction can occur when the user's body or hands get in the way of the projectors, while the latter needs a socket to which the sphere is mounted, strongly distorting its topology. Additionally, the level of obstruction by the user's hands can be adjusted freely with our approach by either changing the opacity of the tracked 3D hand model or

by completely disregarding hand tracking. Moreover, the visualization can be examined unrestricted from any viewpoint without any limitation. This is also not possible for HPCDs since the image is commonly projected from above the sphere and therefore only can cover the upper part. Improving HMD technology increasingly offers possibilities of blending between real and virtual world, mainly by the use of stereoscopic cameras alleviating the isolation problem of VR environments. Therefore VR setups are likely to catch up on advantages of AR as they were investigated by Krichenbauer et al. [6]. We recognize that the weights of our prototype are yet not low enough to encourage long term usage. This is mainly due to the fact that we focused on a stable fixation of the tracker, but are confident that the mounting method can be improved, reducing the overall weight of the spheres.

6 CONCLUSION & OUTLOOK

Three-dimensional spherical visualizations in VR cannot only cover a wide field of applications but may also provide a convenient medium for data analysis, especially when fully embodied by a physical sphere. Due to its simplicity in hardware and construction, and presented manifold positive characteristics our approach is widely applicable for larger audiences. The natural way of interaction may also indicate beneficial future applications in education or for public VR technology demonstrations with first-time users.

A logical step for follow-up research we plan to design and evaluate more complex UI elements, along with a further exploration of the importance of tangible feedback. Another intriguing future direction is presented by the ability to go beyond the capabilities of actual spherical physical displays while retaining tangible feedback, for example by showing simulated holographic content emanating from the sphere into the space around it.

The natural versatility of VR and AR technology combined with the simplicity of the tangible sphere interaction approach supports spherical visualization and data analysis in VR. Holding a tracked sphere can provide an interesting and beneficial alternative to established interaction techniques, addresses the haptic sense in a very realistic way, and may help in further bridging the gap between the physical and the virtual world.

REFERENCES

- [1] C. Anthes, R. J. García-Hernández, M. Wiedemann, and D. Kranzlmüller. State of the art of virtual reality technology. In *Aerospace Conference, 2016 IEEE*, pp. 1–19. Ieee, 2016.
- [2] O. Belloc, M. Nagamura, D. Fonseca, A. Rodrigues, D. Souza, C. S. Kurashima, M. Almeida, E. Z. Borba, R. Lopes, and M. K. Zuffo. Orbevr: a handheld convex spherical virtual reality display. In *ACM SIGGRAPH 2017 Emerging Technologies*, p. 19. ACM, 2017.
- [3] F. Berard and T. Louis. The object inside: Assessing 3d examination with a spherical handheld perspective-corrected display. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 4396–4404. ACM, 2017.
- [4] F. Berard and T. Louis. A low-latency, high-precision handheld perspective corrected display. In *Adjunct Proceedings of the IEEE International Symposium for Mixed and Augmented Reality 2018 (To appear)*, 2018.
- [5] F. Ferreira, M. Cabral, O. Belloc, G. Miller, C. Kurashima, R. de Deus Lopes, I. Stavness, J. Anacleto, M. Zuffo, and S. Fels. Spheree: a 3d perspective-corrected interactive spherical scalable display. In *ACM SIGGRAPH 2014 Posters*, p. 86. ACM, 2014.
- [6] M. Krichenbauer, G. Yamamoto, T. Taketomi, C. Sandor, and H. Kato. Augmented reality vs virtual reality for 3d object manipulation. *IEEE Transactions on Visualization and Computer Graphics PP*, 99:1–1, 2017.
- [7] T. Louis and F. Berard. Superiority of a handheld perspective-coupled display in isomorphic docking performances. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces*, pp. 72–81. ACM, 2017.
- [8] D. C. Niehorster, L. Li, and M. Lappe. The accuracy and precision of position and orientation tracking in the htc vive virtual reality system for scientific research. *i-Perception*, 8(3):2041669517708205, 2017.

¹Vive Tracker: <https://www.vive.com/de/vive-tracker/>

²Noitom Hi5 VR Glove: <https://hi5vrlove.com/>