Designing a Comparative Study to Evaluate VR Body-Mounted Menu Layouts: Challenges and Methodology

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Abstract

The increase of Virtual Reality and Augmented Reality technologies has prompted the development of user interfaces that are both efficient and intuitive to navigate. This study proposes a comprehensive comparative analysis of various VR menu layouts, with the aim of identifying the most effective design that balances efficiency, ease of use, and user satisfaction. Building upon foundational work on 3D menu taxonomy and ergonomic considerations, this research aims to evaluate conventional and innovative menu layouts through user performance metrics and cognitive load assessments. The anticipated outcome is a set of design recommendations for VR UI menus that enhance the user interface design landscape in immersive environments.

Keywords

Virtual Reality, Extended Reality, Body Mounted UI, MR Body Mounted Menus

1. Introduction

The arrival of Virtual Reality (VR) and Augmented Reality (AR), collectively referred to as Extended Reality (XR) [1], represents a strong shift in the way we interact with digital content. These immersive technologies have not only transformed entertainment but have also begun to reshape various industries by offering novel ways to visualize data, train personnel, and facilitate remote collaboration. As VR and AR become more widespread, designing user interfaces that are both efficient and intuitive to interact with is critical. These interfaces are the tools in which users interact with the virtual and augmented spaces, and their design can greatly influence the overall user experience.

While VR and AR technologies continue to expand and integrate into various sectors, there is still a gap in the analysis of user interface menu structures within these environments. Existing research focuses on individual aspects of UI design and doesn't consider all menu structures in VR and AR environments. For example, Bowman and Wingrave [2] discuss the importance of evaluating 3D menu systems within VR for usability and suggest that the field lacks a comprehensive understanding of how different UI types affect user interaction.

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These studies have shown that while users may prefer certain interaction mechanisms, such as gaze-based controls, these can introduce errors and demand additional investigation to refine their usability. The design of body mounted UIs in VR need be validated through user evaluations and are crucial in VR where traditional input devices are not visible to the user. The goal of this comparative study proposal on body mounted UIs is to determine which configurations offer the best functionality, user comfort, and satisfaction. This extends the scope of prior research by comparing traditional systems against a spectrum of new and existing body-mounted menu designs.

2. Background and Related Work

(a) Baseline Oculus Layout[3] (b) Radial Menu[4] (c) Hierarchical Drop-down[4]

Figure 1: Common Body-mounted UI Menus from Existing Studies[3, 4]

From the standard controller-based navigation seen in platforms like Oculus (Figure 1a) to innovative approaches like the rotating 3D hand menu, the evolution of menu interfaces in VR/AR is looking to maximize the spatial capabilities of these environments. Radial menus (Figure 1b) arrange options in a circular format for efficiency, while floating menus aim to reduce cognitive strain by leveraging users' natural spatial awareness. Hierarchical drop-down menus (Figure 1c) provide a familiar structure adapted for VR. Each of these interfaces, as discussed in studies by researchers [5, 4, 3, 6, 7] introduce distinct interaction schemes with their own pros and cons.

The challenge in VR body mounted UI development is finding a balance of user-centric design and functionality. Developing these intuitive and efficient body mounted UIs is difficult especially when considering diverse user preferences and capabilities. Innovations like the toolkit for automatically generating VR hierarchy tile menus [3] outline progress in this direction but adaptable authoring tools and empirical validation of UI effectiveness is still ongoing. This research focuses on the serious applications of VR such as immersive training and simulation, architecture, and urban planning. Using VR in these fields requires interfaces that prioritize efficiency, enabling users to access or navigate their desired functions without unnecessary distractions. This is particularly important in professional settings where the precision and speed of interaction can significantly impact the outcome.

Reviewing existing studies [8] on VR's impact on architectural design review meetings highlights the impact of VR in serious applications. Liu et al.'s findings show VR's potential not just for enhancing the design review process but also for developing a deeper understanding of architectural projects before construction. This showcases VR in professional fields, where immersive experiences can lead to better-informed decisions and collaborative outcomes. This comparative research study proposal specifically targets body-mounted UIs within VR environments, exploring their application in serious environments. By examining various UI layouts and their suitability for tasks in training, planning, and design, we hope to identify design principles that ensure these interfaces are both intuitive and effective. The goal is to contribute to the development of VR applications that are not only advanced but also practically useful, enhancing efficiency and user experience in professional and serious environments.

Additional related work on body-referenced graphical menus in VR environments [9] compares menu placements (spatial, arm, hand, waist), shapes (linear, radial), and selection techniques (ray-casting, head, eye gaze). The study found spatial, hand, and waist menus were significantly faster than arm menus, and eye gaze was more error-prone with higher target re-entries compared to other selection techniques. A toolkit for automatically generating and modifying VR menus, VRMenuDesigner [10], organizes menus and functions with object-oriented thinking to make the system understandable and extensible. It includes tools for quickly generating and modifying elements and several built-in menus. Depth-based 3D gesture multi-level radial menus [11] have also been explored for virtual object manipulation, using X, Y translations of the finger with boundary crossing for navigation between menus. An evaluation of pie menus for system control in VR [12] compared four implementations: Pick-Ray and Pick-Hand with 6-DoF selection, and Hand-Rotation and Stick-Rotation with 1-DoF. The study proposed examining their influence on selection time, error rate, user experience, usability and presence. LaViola et al.'s book "3D User Interfaces: Theory and Practice" [13] provides an in-depth view of 3D UIs, serving as a reference for both researchers and practitioners. It covers input/output devices, interaction techniques, UI design, and future directions like augmented reality.

3. Challenges

The research by Bao et al. primarily focused on hierarchical tile menus [3]. It did not explore the adaptability of these menus to various user preferences or how different body-mounted designs could enhance accessibility for users. Wang, Hu, and Chen compared fixed and handheld menus in VR environments, providing critical insights into performance and user preferences [14]. However, it limits its focus to these two types of menu interfaces without examining a broader spectrum of body-mounted UIs. Azai et al. explored an innovative approach to menu interactions using natural hand gestures but the study [7] does not actively compare all other menu types to determine its design and functionality to other published designs.

While these studies share insight into different body mounted UIs, there is a need for comprehensive research that compares the effectiveness and user satisfaction across a wider range of body-mounted UI designs. The complex input methods (controllers, gesture, and voice recognition), along with the various menu options that need to be developed to complete this comparative study creates several technical challenges. Since the research approach aims to deliver a seamless and intuitive user experience to users testing the various body mounted UIs, achieving accurate and consistent gesture recognition is very important and discrepancies in gesture recognition can weaken the user experience, leading to frustration and disengagement.

- **Limited Scope of Previous Studies**: Existing research [3, 7, 4, 5] concentrate on specific menu design aspects without covering the full spectrum of body-mounted UI possibilities, highlighting a gap in understanding and the need for broader explorations.
- **Accessibility Challenges of Body-Mounted UI Designs**: The exploration of body-mounted UIs as a means to improve accessibility remains limited. Designing intuitive, universally accessible interfaces requires innovative thinking and attention to diverse user needs.
- **Increasing Complexity of Multi-Modal Input Integration**: The integration of various input methods into VR menus introduces complexity in design and requires testing to ensure seamless operation across different interaction styles.
- **Problem of Achieving Accurate and Consistent Gesture Recognition**: Consistently interpreting user gestures correctly is vital for a positive VR experience. Technical challenges arise in ensuring reliable gesture recognition across various hardware and software configurations.
- **The Challenge of Creating a Seamless User Experience**: Crafting a VR interface that offers a seamless and intuitive interaction requires overcoming challenges related to system design, responsiveness, and user engagement, requiring the need for user-centric development strategies.

4. Methodology

For this study, we plan to use the MRTK3 library in Unity for the development of VR menus such as the Rotating 3D Hand Menu and the Tulip Menu, each presenting challenges as they are not readily available within the toolkit. While MRTK3 provides a solid foundation for developing immersive experiences, extending its functionalities to accommodate additional menu layouts requires an in-depth understanding of its architecture and the customization of its components. This includes the development of new input modules tailored for advanced gesture and voice recognition techniques, which are required for this study.

- **Implementing a Wide Array of Menu Layouts:** To improve on the existing research [7, 3, 4, 8, 15], our study will assess a variety of menu layouts including baseline, rotating 3D hand, radial, floating, tool rack, and tulip menus to ensure a comprehensive evaluation of their effectiveness, efficiency, and user satisfaction in VR settings.
- **Investigating impact of different input modalities:** The study will utilize multiple input modalities that are adapted on commercially available VR HMDs, such as controllers, hand tracking, and voice commands. We will investigate the usability of these input modalities when users interact with different body-mounted UIs and look into the potential impact brought by the integration of multiple input modalities.
- **Ergonomic Design Considerations:** To enhance accessibility with body-mounted designs, our study prioritizes the development of ergonomic menu designs to mitigate issues like the 'Gorilla arm' syndrome [4, 15], reducing physical strain and enhancing interaction comfort.
- **User-Centric Evaluation Framework:** We will employ a user-centric evaluation framework that includes metrics such as task completion time, error rates, ease of navigation,

and cognitive load, measured using the NASA Task Load Index. Additionally, user experience will be assessed through questionnaires and interviews to gather qualitative feedback.

5. Conclusion

This paper proposes a comparative study to address the critical gap in empirical research concerning the evaluation of various VR body-mounted menu layouts. By conducting the comparative analysis, our study sets out to identify the most effective design that focuses on efficiency, ease of use, and user satisfaction. Drawing upon foundational research on 3D menu taxonomy and ergonomic considerations [5, 4], we aim to evaluate a spectrum of conventional and innovative menu layouts, assessed through metrics such as task completion time, error rate, cognitive load, and user experience.

Our study will leverage the Mixed Reality Toolkit 3 for the development and testing of these menu layouts, applying a standardized labeling system to ensure consistent interaction focus. The intention behind this study is not just to improve the design landscape of VR interfaces but to do so in a manner informed by a deep understanding of user preferences and the cognitive demands involved. As we proceed with the detailed development and user testing phases, our goal is to derive actionable design recommendations that enhance the user interface design in VR environments. We believe that the outcomes of this study will contribute meaningful advancements to the field, promoting interfaces that are not only technologically advanced but also focused on the needs and preferences of users across diverse VR applications.

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