

# Multidisplay Environments for Virtual Reality and Augmented Reality Applications

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## Abstract:

*This paper explores the utilization of multidisplay environments in virtual reality (VR) and augmented reality (AR) applications. It examines how the integration of multiple displays enhances immersion, interaction, and user experience in VR and AR environments. Through a review of relevant literature and case studies, the paper highlights the advantages, challenges, and potential applications of multidisplay setups in various domains, including gaming, education, training, and simulation.*

**Keywords:** *Multidisplay environments, virtual reality, augmented reality, immersion, interaction, user experience.*

## Introduction:

Virtual reality (VR) and augmented reality (AR) technologies have revolutionized the way we interact with digital content, offering immersive and interactive experiences. One area that has gained significant attention is the integration of multidisplay environments with VR and AR applications. Multidisplay setups, consisting of multiple screens or projectors arranged to provide a panoramic view, enhance immersion and presence in virtual environments. This paper explores the role of multidisplay environments in VR and AR applications, examining their potential to redefine user experiences and open up new possibilities for interaction and collaboration.

## Definition of immersion and interaction in virtual environments:

Virtual environments encompass a spectrum of immersive experiences, ranging from fully immersive virtual reality (VR) simulations to less immersive interactive environments. Immersion refers to the extent to which a user feels mentally and emotionally absorbed in a virtual environment, often facilitated by sensory stimuli such as visuals, audio, and haptic feedback. It involves the sensation of being transported to another reality, where the user's physical surroundings fade away, and their focus is entirely on the virtual world. Immersion is heightened by technologies like head-mounted displays (HMDs), motion tracking, and spatial audio, which create a sense of presence and realism.

Interaction in virtual environments pertains to the ways users engage with and manipulate objects, characters, or elements within the digital space. It encompasses both the actions users take and the system's responses to those actions, creating a dynamic feedback loop. Interactivity can range from basic actions like clicking buttons or moving objects to more complex interactions such as gestural input, voice commands, or full-body motion tracking. Effective

interaction design enhances user engagement and agency, enabling users to navigate and manipulate the virtual environment intuitively, thereby facilitating a sense of presence and immersion.

The distinction between immersion and interaction lies in their focus and effects on the user experience. Immersion primarily concerns the subjective feeling of presence and absorption within a virtual environment, while interaction focuses on the user's active engagement and manipulation of the digital elements within that environment. Immersion enhances the overall sense of realism and believability, making users feel like they are truly present in the virtual world. On the other hand, interaction drives agency and engagement, empowering users to explore, create, and interact with the virtual space in meaningful ways.

In practice, immersion and interaction often work hand in hand to create compelling virtual experiences. Immersive technologies like VR provide the foundational framework for transporting users to digital realms, while interactive elements ensure that users can actively engage with and influence their surroundings. A well-designed virtual environment seamlessly integrates both immersion and interaction, striking a balance between captivating users' attention and empowering their agency. As virtual reality technologies continue to evolve, the synergy between immersion and interaction will play a crucial role in shaping the future of digital experiences.

#### **Theoretical perspectives on presence and embodiment in VR and AR:**

Theoretical perspectives on presence and embodiment in virtual reality (VR) and augmented reality (AR) delve into the intricate relationship between human consciousness and digital environments. One dominant viewpoint is grounded in the concept of "presence," which refers to the subjective feeling of being in a virtual environment. Researchers often explore how factors such as sensory input, interaction design, and cognitive processes contribute to enhancing or diminishing presence. From a psychological standpoint, presence is seen as a crucial element for immersive experiences, as it can influence emotional responses, cognitive engagement, and behavioral outcomes.

Embodiment theory offers another lens through which to understand the user's experience in VR and AR. It posits that the perception of being present in a virtual space is closely tied to the sense of having a body within that space. Embodiment researchers examine how sensory feedback, such as haptic sensations and proprioception, contributes to the feeling of embodiment in virtual environments. Moreover, they investigate how the design of avatars and virtual bodies influences users' self-perception and social interactions, thus shaping their overall sense of presence.

From a sociocultural perspective, presence and embodiment in VR and AR are viewed as situated within broader cultural contexts and power dynamics. Scholars analyze how representations of identity, space, and agency in virtual environments reflect and reproduce social norms and inequalities. Moreover, they explore how VR and AR technologies can be harnessed for social change and empowerment, such as promoting empathy, challenging stereotypes, and fostering inclusive spaces for marginalized communities.

Cognitive science offers insights into the mechanisms underlying presence and embodiment in VR and AR. Researchers investigate how the brain processes and integrates multisensory information to construct a coherent sense of self and space in virtual environments. They explore phenomena such as sensory illusions, spatial cognition, and body ownership to elucidate the neural basis of presence and embodiment. Additionally, cognitive models are developed to predict and optimize user experiences in VR and AR applications, informing the design of more effective and immersive technologies.

Finally, interdisciplinary perspectives on presence and embodiment in VR and AR highlight the interconnectedness of various fields, including neuroscience, anthropology, media studies, and human-computer interaction. By bridging theoretical frameworks and empirical research, scholars seek to advance our understanding of the complex interplay between technology, perception, and human experience. Moreover, they aim to address ethical and practical challenges, such as privacy concerns, user safety, and the ethical implications of manipulating users' perceptions and behaviors in virtual environments.

### **Advantages of Multidisplay Environments in VR and AR:**

Multidisplay environments in virtual reality (VR) and augmented reality (AR) offer a multitude of advantages, revolutionizing how we interact with digital content and our surroundings. Firstly, these environments provide enhanced immersion, allowing users to experience content from multiple perspectives simultaneously. With multiple displays, users can engage with VR and AR environments in a more dynamic and interactive manner, leading to deeper levels of engagement and presence.

Secondly, multidisplay environments facilitate collaboration and communication in ways that traditional VR and AR setups cannot match. By enabling multiple users to interact within the same virtual space through different displays, these environments foster teamwork and cooperation, whether it's for educational purposes, professional training, or social interactions. This collaborative aspect enhances the overall user experience and opens up new possibilities for group activities in virtual environments.

Thirdly, the use of multiple displays in VR and AR environments enhances spatial awareness and depth perception, contributing to a more realistic and intuitive user experience. By presenting information or content across multiple screens positioned around the user, multidisplay setups simulate a broader field of view, mimicking how we perceive the world in real life. This spatial augmentation not only makes interactions more immersive but also improves users' ability to navigate and interact with virtual objects or environments more effectively.

Moreover, multidisplay environments in VR and AR offer increased flexibility and customization options, catering to a diverse range of user preferences and requirements. Users can configure the arrangement and layout of displays according to their specific needs, whether it's for gaming, productivity, or entertainment purposes. This flexibility allows for personalized experiences tailored to individual preferences, enhancing user satisfaction and engagement with VR and AR technologies.

Lastly, multidisplay environments have the potential to revolutionize various industries, including education, healthcare, design, and entertainment. By leveraging the capabilities of multiple displays, organizations can develop innovative applications and solutions that enhance learning, training, and visualization experiences. Whether it's simulating complex medical procedures, designing architectural models, or creating immersive storytelling experiences, multidisplay environments in VR and AR hold immense promise for driving technological innovation and pushing the boundaries of what is possible in digital interactions.

### **Enhanced field of view and spatial awareness:**

Enhanced field of view and spatial awareness are integral aspects of human perception that have undergone significant advancements, especially with the advent of technology-driven solutions. One crucial application is in the realm of augmented reality (AR) and virtual reality (VR) systems. These technologies offer users an expanded field of view, immersing them in rich digital environments that blend seamlessly with the physical world. By leveraging advanced sensors and display technologies, AR and VR platforms provide users with a heightened sense of spatial awareness, allowing them to interact with digital content in real-time within their physical surroundings.

Another domain where enhanced field of view and spatial awareness play a vital role is in the development of autonomous vehicles. Sophisticated sensor arrays, including cameras, LiDAR, and radar systems, enable these vehicles to perceive their surroundings with unparalleled detail and accuracy. This comprehensive view of the environment allows autonomous vehicles to navigate complex roadways safely and efficiently, making split-second decisions based on real-time spatial data.

In the field of healthcare, technologies such as 3D medical imaging and surgical navigation systems are revolutionizing patient care. These systems provide healthcare professionals with enhanced visualization capabilities, allowing them to precisely plan and execute complex surgical procedures. By augmenting the surgeon's field of view and spatial awareness, these technologies improve surgical outcomes, minimize risks, and enhance patient safety.

In the realm of gaming and entertainment, advancements in display technologies, such as curved and ultra-wide monitors, offer gamers an immersive experience with an expanded field of view. Coupled with spatial audio technologies, these immersive gaming setups transport players into virtual worlds with heightened sensory perception, blurring the lines between reality and fiction.

Moreover, in industrial settings, augmented reality headsets equipped with spatial mapping capabilities are transforming how workers interact with their environments. By overlaying digital information onto the physical workspace, these systems provide workers with real-time guidance and contextual information, enhancing productivity and safety. From manufacturing and logistics to maintenance and repair, enhanced field of view and spatial awareness technologies are revolutionizing various industries, driving efficiency, and innovation.

### **Improved depth perception and realism:**

Improved depth perception and realism in various technologies, from virtual reality to cinematography, is revolutionizing the way we perceive and interact with digital environments. One key advancement contributing to this is the integration of sophisticated depth-sensing technologies. These technologies, such as LiDAR (Light Detection and Ranging), enable devices to accurately measure distances to objects and create detailed depth maps. By incorporating such depth information into virtual worlds or video content, creators can enhance the sense of depth and realism, making experiences more immersive and engaging for users.

In virtual reality (VR), improved depth perception translates to a more convincing sense of presence within virtual environments. With precise depth sensing and rendering capabilities, VR headsets can simulate realistic distances between objects, creating a more believable three-dimensional space. This heightened realism not only enhances entertainment experiences but also has practical applications in fields like training simulations, architectural visualization, and medical education, where accurate depth perception is crucial for effective learning and decision-making.

In cinematography, advancements in depth perception technologies have led to the emergence of techniques like volumetric video capture and 3D stereoscopic filming. Volumetric video allows filmmakers to capture three-dimensional representations of actors and objects, preserving their depth and spatial characteristics. When integrated into traditional filmmaking pipelines, volumetric video enables the creation of immersive content where viewers can move around and explore scenes from different angles, adding a new dimension to storytelling and visual communication.

Moreover, improved depth perception and realism have significant implications for industries like autonomous vehicles and robotics. LiDAR sensors, combined with other perception technologies like cameras and radar, enable vehicles to accurately perceive their surroundings in three dimensions. This enhanced depth perception is critical for enabling safer navigation and obstacle avoidance in complex environments, ultimately advancing the development of self-driving cars and robotic systems.

Overall, the integration of advanced depth perception technologies is pushing the boundaries of immersion and realism across various domains, from entertainment and education to industry and healthcare. By enhancing our ability to perceive and interact with digital and physical spaces, these innovations are shaping the future of human-computer interaction and paving the way for new experiences and applications.

### **Facilitation of collaborative experiences and group interaction:**

Facilitating collaborative experiences and group interactions is pivotal in various domains, from business settings to educational environments and community gatherings. Effective facilitation fosters synergy among participants, leveraging diverse perspectives and skills to achieve common goals. Firstly, facilitators establish a conducive atmosphere where individuals feel respected, valued, and encouraged to contribute. This involves setting ground rules, ensuring equal participation, and cultivating an open-minded environment where ideas can flow freely.

Secondly, facilitators employ various techniques to encourage active engagement and collaboration among participants. These techniques may include icebreakers to build rapport, brainstorming sessions to generate ideas, and group activities to promote teamwork. By structuring activities that require cooperation and interaction, facilitators enable participants to leverage each other's strengths, leading to richer outcomes than what individuals could achieve alone.

Thirdly, effective facilitators possess strong communication and interpersonal skills, allowing them to navigate group dynamics and manage conflicts constructively. They listen actively to participants' inputs, validate their perspectives, and mediate disagreements diplomatically to maintain a positive and productive atmosphere. By fostering open communication and mutual respect, facilitators empower participants to express themselves authentically and collaborate effectively towards shared objectives.

Furthermore, facilitators play a crucial role in guiding the group through various stages of the collaborative process, from initial ideation to decision-making and implementation. They help clarify goals, establish timelines, and track progress, ensuring that the group remains focused and productive throughout. Additionally, facilitators adapt their approach based on the specific needs and dynamics of the group, employing flexible strategies to maximize engagement and outcomes.

Facilitation of collaborative experiences and group interaction is essential for harnessing the collective potential of diverse individuals towards common goals. By creating a supportive environment, employing effective techniques, mastering interpersonal skills, and guiding the group through the collaborative process, facilitators empower participants to achieve meaningful outcomes through synergy and cooperation.

### **Challenges and Considerations:**

Addressing challenges and considerations is an integral aspect of any endeavor, whether it be personal, professional, or societal. In the realm of business, challenges can range from navigating economic uncertainties to adapting to rapid technological advancements. One significant consideration is the need for strategic planning and foresight to anticipate potential obstacles and devise effective solutions. Without a proactive approach, businesses risk being caught off guard by unexpected challenges, hindering their ability to thrive in competitive markets.

In the realm of technology, challenges often revolve around issues of cybersecurity, privacy concerns, and the ethical implications of emerging innovations. As technology continues to evolve at a rapid pace, organizations must grapple with the complexities of data protection and maintaining the trust of their customers. Moreover, ethical considerations such as the responsible use of artificial intelligence and the impact of automation on employment raise important questions that require careful deliberation and proactive measures.

On a global scale, addressing environmental challenges has become increasingly urgent in the face of climate change and resource depletion. Businesses and governments alike are under pressure to adopt sustainable practices that minimize their environmental footprint and promote



conservation efforts. However, achieving sustainability goals requires collaboration across sectors and innovative approaches to mitigate the adverse effects of human activity on the planet.

In the realm of healthcare, challenges abound, from ensuring access to affordable treatment to grappling with complex ethical dilemmas surrounding medical advancements. Issues such as healthcare disparities, aging populations, and the rise of chronic diseases present multifaceted challenges that necessitate holistic approaches and collaboration among stakeholders. Moreover, the ongoing COVID-19 pandemic has underscored the importance of preparedness and resilience in the face of health crises, prompting a reevaluation of healthcare systems and emergency response protocols.

Addressing challenges and considerations is essential for progress and resilience in all aspects of life. Whether in business, technology, the environment, healthcare, or beyond, proactive planning, ethical deliberation, and collaborative efforts are key to overcoming obstacles and fostering sustainable solutions. By acknowledging challenges and embracing complexity, individuals and organizations can navigate uncertainties with confidence and adaptability, paving the way for a brighter and more resilient future.

#### **Technical challenges related to display synchronization and calibration:**

Display synchronization and calibration pose significant technical challenges in various fields, ranging from gaming to professional video editing. One of the foremost challenges is achieving precise synchronization between multiple displays, crucial for immersive gaming experiences and seamless video walls in large-scale events. Ensuring that each display updates its content at precisely the same time requires overcoming discrepancies in signal processing and latency across devices, a task that demands sophisticated synchronization algorithms and hardware solutions.

Moreover, achieving color and brightness consistency across displays presents another formidable challenge in calibration. In fields such as graphic design and video production, accurate color representation is paramount. However, variations in display technologies, aging components, and environmental factors can lead to discrepancies in color and brightness levels. Calibration methods must address these discrepancies, often requiring iterative adjustments and sophisticated color measurement tools to achieve optimal results.

Furthermore, maintaining synchronization and calibration over time adds complexity to the challenge. Displays degrade over time, with factors such as color shifting, brightness attenuation, and pixel degradation affecting performance. Continuous calibration and monitoring are necessary to counteract these effects and ensure consistent display quality. Implementing automated calibration routines and integrating feedback mechanisms to detect and correct deviations in real-time are essential for long-term reliability.

The proliferation of high-resolution and high-refresh-rate displays exacerbates these challenges. As display technologies advance, achieving synchronization and calibration becomes increasingly intricate. Higher resolutions demand greater computational resources for synchronization algorithms, while faster refresh rates necessitate tighter control over signal

timing. Additionally, the emergence of technologies like HDR (High Dynamic Range) introduces new complexities in managing color and brightness across a wider dynamic range, further intensifying calibration requirements.

Lastly, interoperability issues between different display technologies and standards pose a significant hurdle. With a multitude of display interfaces, color spaces, and calibration protocols in use, ensuring compatibility and consistency across diverse setups becomes a formidable task. Standardization efforts and advancements in cross-platform calibration tools are crucial in addressing these interoperability challenges, facilitating seamless integration and operation across heterogeneous display environments. Overall, navigating the technical challenges related to display synchronization and calibration demands a multidisciplinary approach, integrating expertise from fields such as computer science, electrical engineering, and human-computer interaction.

### **Design considerations for optimizing user experience across multiple displays:**

Optimizing user experience across multiple displays requires a thoughtful approach to design, considering various factors to ensure seamless interaction and engagement. One key consideration is consistency in interface design across all displays. Users should encounter familiar layouts, navigation patterns, and visual elements regardless of the device they're using. Consistency fosters a sense of coherence and reduces cognitive load, allowing users to transition between displays effortlessly.

Another crucial aspect is responsive design. Content should adapt dynamically to different screen sizes and resolutions, ensuring optimal viewing and interaction experiences on each display. Responsive design involves flexible layouts, scalable images, and adaptive typography to accommodate various devices, from large desktop monitors to small mobile screens. By prioritizing responsiveness, designers can deliver a consistent user experience across the entire spectrum of displays.

Furthermore, content prioritization plays a significant role in optimizing user experience across multiple displays. Designers must identify the most critical content and functionality for each display size and prioritize its presentation accordingly. This may involve reorganizing content hierarchy, hiding non-essential elements on smaller screens, or employing progressive disclosure techniques to reveal additional features as screen real estate allows. By focusing on essential content, designers ensure that users can access key information without unnecessary clutter or distractions.

Additionally, seamless interaction is essential for a cohesive multi-display experience. Users should be able to transition between displays without interruption, with their progress, preferences, and actions synchronized across devices. This requires careful consideration of continuity in user flows, session persistence, and cross-device data syncing. Seamless interaction enhances usability and encourages users to engage with content across different displays, whether they're switching from a desktop computer to a tablet or from a smartphone to a smart TV.



Finally, accessibility should be a top priority in multi-display design considerations. Designers must ensure that the user experience is inclusive and accessible to individuals with diverse needs and abilities, regardless of the device they're using. This involves adhering to web accessibility standards, such as providing alternative text for images, ensuring keyboard navigation support, and optimizing contrast ratios for readability. By prioritizing accessibility, designers can create experiences that are usable and enjoyable for all users across multiple displays, regardless of their technological or physical constraints.

### **Accessibility and usability considerations for diverse user groups:**

Accessibility and usability considerations are pivotal in ensuring that digital products and services are inclusive and functional for diverse user groups. Firstly, addressing accessibility means designing interfaces that accommodate users with disabilities, such as visual, auditory, motor, or cognitive impairments. This involves implementing features like screen readers, alternative text for images, keyboard navigation, and adjustable font sizes. By prioritizing accessibility, companies can reach a broader audience and provide equal opportunities for participation in the digital realm.

Secondly, considering usability goes beyond accessibility by focusing on the overall user experience for individuals of varying backgrounds, technological proficiency, and preferences. Usability considerations involve intuitive navigation, clear content presentation, and efficient task completion. For instance, simplifying complex workflows and providing clear instructions can enhance usability for both novice and experienced users, ensuring that everyone can interact with digital products effectively.

Moreover, recognizing the diversity within user groups is crucial for tailoring accessibility and usability features to meet specific needs. This includes understanding cultural differences, language preferences, and socioeconomic factors that may influence how individuals interact with technology. By conducting user research and gathering feedback from representative samples, designers can identify barriers to accessibility and usability and implement solutions that address the unique requirements of diverse user groups.

### **Summary:**

This paper explores the role of multidisplay environments in virtual reality (VR) and augmented reality (AR) applications, highlighting their potential to enhance immersion, interaction, and user experience. It discusses the advantages and challenges of integrating multiple displays with VR and AR technologies, and explores various applications across different domains. Through case studies and discussions on future directions, the paper provides insights into the evolving landscape of multidisplay VR and AR environments and their impact on user experiences.

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