Research on the Interactive Effects of Augmented Reality (AR) Technology: A Case Study in Science Museum Applications

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Abstract. With the swift progression of technology, Augmented Reality (AR) has progressively emerged as a pivotal innovation, transitioning from avant-garde research settings to mainstream applications, encompassing a myriad of industries. This article delves profoundly into the deployment of AR within science museums, a domain quintessential for the dissemination and popularization of scientific knowledge. Leveraging its unique capabilities, AR amalgamates virtual and real-time interactions, bestowing audiences with an enhanced immersive learning experience, radically transforming conventional museum exhibitions. While the potential of AR in enriching the content display of science museums and proffering immersive experiences is palpable, it also introduces challenges, especially in the realms of tracking precision and the intricacy of interaction design. This manuscript furnishes a comprehensive overview of AR's definition, its distinction from Virtual Reality (VR), its interactive advantages, and its tangible applications within science museums. The insights proffered aim to steer the future trajectory of science museums, underscoring the transformative potential of AR in public scientific education and outreach.

Keywords: AR; Science Museum; Technological Application; Interaction Design

1 Introduction

With the swift progression of modern technology, our ways of living and learning are undergoing unprecedented transformations. Among these, Augmented Reality (AR) technology, recognized as a cutting-edge comprehensive information technology in the 21st century, has garnered extensive attention and research. AR technology amalgamates a myriad of techniques such as digital image processing, sensing technology, 3D modeling, computer graphics, and multimedia technology, offering users an immersive experience of the real world. Compared to Virtual Reality (VR) technology, the hallmark of AR lies in its capability to integrate real-world information with a virtual environment, crafting a wholly immersive and interactive virtual experience for users. The advent of this technology not only furnishes us with sensory experiences that transcend reality but also equips us with novel perspectives and methodologies to explore the micro and macro realms and to study the evolution of entities.

Science museums, acting as disseminators and popularizers of scientific knowledge, play an indispensable role in science communication and education to public. With technological advancements and updated public demands, the conventional exhibition formats of science

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museums no longer satiate the contemporary audience's needs. Under the impetus of technology, the exhibition modalities and cultural resource development of science museums are at a pivotal juncture. AR technology proffers a novel exhibition and interaction modality to science museums, not only enriching the display content but also bestowing an immersive experience upon the audience, enabling them to grasp scientific principles and applications more directy and profoundly.

However, the application of AR technology in science museums still confronts challenges, such as the precision of tracking and registration technology and the intricacy of interaction design. These issues are expected to further research and refinement. Nonetheless, AR technology introduces immense opportunities for the development of science museums, presenting new possibilities for public science education and popularization[1].

This article endeavors to explore the concept of AR technology, its distinctions from VR technology, the interactive advantages and characteristics under the influence of AR, and the manifestation of AR technology applications in science museums. Through an in-depth analysis of AR technology's application in science museums, we aspire to provide valuable references and insights for the future development of science museums[2].

2 Analysis of the AR Technology Concept

2.1 Definition of AR Technology

By the end of the 20th century, a cutting-edge comprehensive information technology known as Augmented Reality (AR) emerged. It amalgamates various technologies such as digital image processing, sensing technology, 3D modeling, computer graphics, multimedia technology, real-time tracking and registration, intelligent interaction, artificial intelligence, scene fusion, and parallel processing. This technology integrates information from the real world with virtual content, overlaying them within the same space or frame. Through various output devices, it aims to provide users with an immersive real-world experience[3].

The characteristic of blending virtual and real-time interactions in AR technology allows some information, which is hard to access in the real world, to be digitally transformed and presented before us. This not only offers us a sensory experience beyond reality but also provides a novel perspective and method for exploring the micro and macro world and studying the evolution of things.

2.2 Differences Between AR and VR

Augmented Reality (AR) lies in its ability to integrate real-world information with a virtual environment, creating a completely immersive and interactive virtual experience, which is significantly distinguished from Virtual Reality (VR) systems. VR systems focus on creating a closed, immersive illusionary atmosphere, immersing users in a virtual environment without the perception of the real world. In contrast, AR requires comprehensive tracking and positioning of the real environment, embedding virtual elements in real-time, and rendering virtual objects to ensure a perfect fusion of virtual and real scenes. This creates a relatively real virtual environment, allowing users to experience a sense of reality within the virtual world. Both technologies have their own merits, but it's evident that AR technology demands higher accuracy in tracking and registration. Any errors in these processes can negatively impact the interaction between real and virtual elements, thereby affecting the user's visual perception.

2.3 Interaction Advantages and Features under AR Influence

Being different from the past single-output methods, AR technology emphasizes multi-level real-time spatial interaction. It requires interactivity between devices and between observed objects and humans. The former involves coordination between the display screen and the interaction processing system, and the tracker with the interaction processing system. The latter demands infrared trackers to calibrate the positional difference between virtual and real information[4][5].

2.3.1 Virtuality and Reality

AR technology strives to create a slightly real scene, immersing visitors within. It doesn't sever the connection between users and the real environment but overlays digital content onto the real scene using interactive feedback, multi-screen splicing, and changes in light and shadow within the space.After generating digital content, it overlays this content onto the real scene, preserving the natural environment while augmenting it with virtual elements. This provides participants with a sensation of moving within both the real and virtual dimensions, akin to cinematic montage techniques, exemplifying the intertwined nature of reality and virtuality within AR.

2.3.2 Temporality in AR

With technological advancements, the concept of temporality in aesthetic environments is becoming more prominent. How to use the temporal characteristics within a specific range to enhance experiences and explore senses is a significant trend in AR technology.

In essence, AR constructs a spatial medium for participants, one that encompasses not only bodily perceptions but also sensory and cognitive immersion. This space is relatively isolated to minimize external distractions, combining environmental and technical means, employing tools such as sound, imagery, and experimental apparatus that express the creator's intent. It elevates two-dimensional content to a four-dimensional art form, intending to stimulate participants' distinct understandings and insights into the "here and now."

2.3.3 Prospects of Interaction under AR Technology

The interactivity of AR subverts the sole dominance of creators. The audience is no longer passively observing but can interact with the work on a psychological level, achieving resonance. This open nature of new media art, with the continuous advancement of smart devices and network visual technology, has been widely applied in fields such as medicine, art, design, real estate, cultural tourism, teaching, and entertainment.

It disrupts the conventional unidirectional knowledge transmission model, enriches immersive experiences, and generates significant economic benefits for society.

3 Features of AR Technology

3.1 Types of Interaction

The interaction modes in the field of Augmented Reality (AR) exhibit a multilayered nature, primarily categorized into touch-based, spatial gesture-based, and device-dependent mechanisms. Touch-based interaction relies on touchscreen interfaces to control three-dimensional objects using two-dimensional data, but it is constrained by the range of hand movements and device interfaces, exhibiting significant limitations. Spatial gesture-based interaction involves capturing user gestures to control virtual objects, but this method may face challenges such as mutual gesture obstruction, leading to user fatigue during prolonged use. Device-dependent interaction utilizes tools like gyroscopes and cameras to track the relative position of three-dimensional objects, but it can result in a misalignment between virtual and real elements when users perform large-scale, frequent, or significant-angle rotations.

3.2 Tracking and Registration Technology

In augmented reality systems, tracking and registration technologies are crucial. Tracking primarily relies on capturing and analyzing real-time environmental information based on user activity, anchoring and following two-dimensional or three-dimensional content to determine the position and orientation of user devices. Registration ensures a continuous alignment between virtual content and the real environment, accurately placing virtual content within the actual scene. Currently, this technology is mainly divided into three categories: computer vision-based, hardware sensor-driven, and hybrid tracking. Computer vision technology captures real-world scene information through cameras, processes image data, and establishes spatial correspondences between the real scene and virtual content. This approach has relatively low device requirements and is the most widely used in AR technology. However, it has its drawbacks, such as susceptibility to recognition failure when markers are obstructed. Hardware sensor-driven technology employs magnetic, acoustic, optical, and inertial sensors, using algorithms for feature or edge detection, offering significant accuracy but potentially resulting in high system latency during prolonged use. Hybrid tracking combines the advantages of the previous two approaches, using hardware devices to track real-time information, followed by algorithm-based three-dimensional alignment, achieving high stability and precision.

4 Manifestation of AR Application Interaction in Science Museums

Science museums play a crucial role in the dissemination of scientific knowledge, serving as effective mediums for science communication and public education. The core value of science museums lies in facilitating communication between science and the public, igniting enthusiasm for innovation and exploration, enhancing public scientific literacy, and fostering community and cultural exchanges.

Currently, the development of cultural resources and exhibition formats in Chinese science museums is at a critical stage. Rapid technological advancements have led to increased visitor numbers in science museums, prompting a gradual evolution of exhibition formats. Simple combinations of technology and equipment in traditional science museums are no longer sufficient to meet the public's demands. Most traditional science museums' display forms are considered monotonous and lack creativity, failing to provide visitors with extensive information. As an emerging digital technology, AR effectively enhances the dissemination of cultural resources in science museums, reconstructs the format of technology-guided tours, and offers diverse ways to display exhibits. It not only addresses issues related to inadequate coverage and passive knowledge transmission but also delves deeper into the unique features of technology to meet the personalized demands of modern users.

4.1 Design of AR Application Interactive Content in Science Museums

Firstly, interactive icons are used for annotating real exhibits to reduce the time users spend searching for information. Secondly, dynamic information is added to static exhibits to help users quickly grasp dynamic content, emphasizing the significance of static exhibits. Thirdly, "scene recreation" is employed for scientific stories or experimental processes to effectively reduce the difficulty of user imagination. Fourthly, a navigation model is constructed to optimize users' touring routes. Lastly, serious games are introduced into the interactive mechanism, drawing inspiration from adventure, simulation, action, leisure, role-playing, and puzzle games to stimulate visitors' curiosity through immersive and inspirational gaming approaches[6][7].

4.2 Interactive Advantages of AR Technology Applications in Science Museums

The exhibits in science museums symbolize advanced scientific ideas and technologies. However, within the confines of science museum spaces, these abstract concepts can often lead visitors to merely skim the surface. AR technology, committed to transforming visitors from passive recipients into engaged, two-way interactive participants, effectively addresses this issue. The core function of AR technology is to overlay virtual information onto real exhibits in various multimedia forms, such as images, audio, video, animations, and 3D models[8].

5 Conclusion

Augmented reality technology has gradually become an indispensable technical means in the development and construction of science museums. Its unique blending of virtual and real-time interaction characteristics provides a new display and interaction method for science museums. Augmented reality technology not only enriches the display content of science museums but also provides visitors with an immersive experience, allowing them to understand scientific principles and applications more intuitively and deeply[9]. However, the application of augmented reality technology in science museums still faces some challenges, such as the accuracy of tracking and registration technology and the complexity of interaction design, which need further research and improvement. Augmented reality technology brings tremendous opportunities for the development of science museums and provides new possibilities for public science education and popularization.

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