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Research Article

A comparative analysis of augmented reality supported virtual guides in cultural heritage tourism[1]

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Abstract

This paper focuses on the growing importance of augmented reality technology, especially in the case of applications of virtual tours in relation to cultural heritage and tourism. Augmented reality superimposes digital information on the real world, enhancing users' experiences with interactive and educative ways of exploring cultural destinations. The paper discusses three different case studies: the Taiwan Lantern Festival, the Institute of Contemporary Art San Diego, and the Singapore Tourism Board. These cases demonstrate how augmented reality, often through the use of virtual mascots, can be integrated into various cultural and geographical contexts to achieve a variety of goals. This article provides an overview of the development of AR, its access through any common device, and its potential for disrupting cultural tourism. This study tries to analyze how AR-based virtual guide applications perform through case studies of these cases and categorizes various methods and tools used in applications.

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Introduction

Advancements in technology continue to create profound effects across all areas of life. New technologies are continuously researched and developed to enhance the quality of life, being integrated into daily routines in more functional and practical ways. This process not only involves improving existing technologies but also fosters the development of entirely new innovations.

Since the rapid evolution of computer technologies in the 1980s, accessing and processing information has become increasingly significant. In this context, augmented reality (AR) technology has emerged as a remarkable innovation. Augmented reality refers to technologies that integrate virtual components with physical elements in real-time applications (Cheng & Tsai, 2014). With the growing computational power of computers, the introduction of the internet, the proliferation of mobile devices, and the diversification of wearable technologies, AR has evolved in various dimensions over the years (Altınpulluk, 2015).

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AR integrates virtual objects into the real world, providing users with an experience where both virtual and real elements coexist. According to Berryman (2012), AR represents a new technological domain where digital environments and the real world converge. AR rapidly gains popularity as a technology that enriches user experiences by overlaying digital information onto the real world.

In recent years, AR technology has been effectively utilized in virtual tour applications, especially in the fields of cultural heritage preservation and tourism. This approach offers an innovative method for destination marketing and the promotion of cultural heritage, allowing visitors to interact with destinations in a more engaging and informative manner.

One of the key reasons for AR's widespread use is that it no longer requires expensive hardware such as head-mounted displays (HMDs) or complex equipment. Today, AR technology is accessible through computers or mobile devices, making its adoption significantly more convenient (Akçayır & Akçayır, 2017).

By enabling an innovative approach to promoting cultural heritage through virtual tour applications, AR allows destinations to provide visitors with interactive and educational experiences. This combination of virtual and real-world interactions enhances the potential of virtual tour applications and creates new opportunities in tourism and cultural heritage.

The rapid development and proliferation of AR technology have led to the emergence of innovative applications in the arts, extending the reach of technology to a broader audience (Willett et al., 2023). With AR applications integrated into ubiquitous devices like smartphones and tablets, this technology has become a part of everyday life, making it easier to share artistic content with wider audiences (Ferrão et al., 2023). For example, the Google Arts & Culture app allows users to virtually tour museums and galleries worldwide, exploring artworks through AR. These applications enable users to examine details of the works closely and gain insights about the artists.

This study examines examples of AR-supported virtual guide applications, focusing on projects such as the Taiwan Lantern Festival, the Institute of Contemporary Art San Diego, and the Singapore Tourism Board. These examples were chosen to reflect geographical, cultural, and technological diversity, with their common feature being the use of mascots as virtual guides. However, each project employs AR technology with distinct objectives and approaches.

The selected projects originate from different regions- Asia, Europe, and North America-allowing for an examination of how AR-guided applications are used in diverse cultural and geographical contexts. The study begins with a review of the definition and historical development of AR technology and evaluates the impacts of AR-supported virtual guide applications through an analysis of these three distinct cases. The technologies discussed here are categorized based on various techniques and tools employed in virtual tour applications.

Virtual Guide Applications

Virtual guide applications serve as an essential tool for enhancing the visitor experience in museums and cultural sites. These guides aim to attract, educate, entertain, and direct visitors by providing verbal or non-verbal instructions and information (Best, 2012). Virtual museum guides, in particular, hold significant potential to improve interaction and social communication among visitors (Kopp et al., 2005). By increasing engagement and interest, they can enrich the museum experience (Rzayev et al., 2019) and contribute to the economic importance of tourism, serving as a vital revenue source for museums (Rosentraub & Joo, 2009).

Traditional museums often use systems that include transmitters, receivers, and communication channels to deliver verbal and non-verbal information to visitors (Munodawafa, 2008). However, virtual museum guides, supported by advancements in science and technology, have created new opportunities for enhancing user experiences in museums and exhibition halls. These guides offer diverse and valuable services that support users throughout their visits. Visitors can receive personalized, adaptive content tailored to their needs and preferences, leading to a more effective and individualized experience (Ardissono et al., 2011).

In this context, mobile guides also play a significant role. According to Joel Lanir and colleagues (2013), mobile guides surpass traditional museum tools by offering personalized content delivery based on visitors' specific needs. These guides integrate multimedia elements such as images, videos, and audio commentaries to support diverse learning styles

and are accessible at any time, unlike human guides. Additionally, they cater to various populations, including those with disabilities, by providing content in multiple languages and accommodating different interaction preferences. Numerous studies have explored the role of virtual guides and how they can educate visitors (Best, 2012; 1999; Horn, 1980; Zhang & Chow, 2004). For example, Best (2012) highlighted the shift toward AR guides to enhance visitors' educational experiences in museums. AR interactions within a museum context strengthen the guidance functions, fostering more profound engagement between visitors and exhibits (Ng Giap Weng et al., 2011; Trunfio et al., 2020). Furthermore, the gamification of AR guidance systems in museums has been shown to increase visitor participation and promote active learning (Raptis et al., 2017).

Contemporary digital guides have evolved significantly from the simplistic "play, pause, play" audio guides of the past (Best, 2012). These systems now provide personalized content based on user preferences. Many modern audio and multimedia guides utilize location-aware technologies to deliver content tailored to visitors' positions within galleries (e.g., Tate Modern Multimedia Tour, London) or tourist areas (e.g., BT MySpace). Additionally, research has focused on robotic tour guides that respond to visitor feedback to adapt the tour dynamically (Bennewitz et al., 2005; Kuzuoka et al., 2008). These technological systems enable users to experience tailored tours based on their individual needs.
Bennewitz and colleagues (2005) developed a humanoid robot system designed for museum guidance. This system uses visual perception, sound localization, and speech recognition technologies to interact with multiple visitors simultaneously. The robot can shift its attention between individuals based on audio-visual input and uses gestures to draw visitors' attention to exhibits. Experiments demonstrated that the robot effectively interacted with multiple visitors, capturing their interest and facilitating engagement. This approach highlights the potential of virtual guides in offering personalized experiences tailored to users' interests and engagement levels.

Similarly, Chen et al. (2014) proposed an AR-based museum guidance system that provides intuitive, user-friendly interactions through computer vision techniques. The system allows users to interact with museum content by performing specific gestures, such as pointing to symbols on a brochure. It displays 3D models of museum artifacts and multimedia content in real-time without requiring additional hardware like keyboards or touchscreens. This approach reduces costs and minimizes the risk of contamination in public environments, making it an efficient solution for museum settings.

In another study, Damala et al. (2008) explored the impact of virtual guides on visitor behavior in museum environments. Their findings indicated that visitors using virtual guides spent more time in the museum and focused more on the exhibits. However, the study also revealed that such guides could decrease group interactions and increase physical distance among visitors.

Finally, Teixeira et al. (2021) examined the use of AR-based virtual guides at the Ecomuseu in Foz do Iguaçu. The prototype allowed visitors to interact with virtual AR elements positioned at various locations within the museum, enhancing their understanding and perception of the exhibits. The application was adapted for virtual use during the COVID-19 pandemic and received positive feedback from users.

Zikky et al., (2024) study developed an augmented reality (AR)-based tourism guidance application for heritage sites in Surabaya and examined how this application transformed the user experience. The study proposed a mobile application supported by GPS navigation and AR gamification features as a solution to the challenges brought by the COVID-19 pandemic to the tourism sector. The results showed that gamification and augmented reality elements increased users' interest and interaction with the app, and users were more motivated by gamified elements such as collecting virtual objects and completing tasks.

Overview of Virtual Guide Applications in the Cultural Field

Advances in science and technology have increased human-machine interaction in the service sector, leading to the adoption of robots and artificial intelligence applications. In this context, digital tourism applications have strengthened the human-machine relationship in museums and exhibition halls (Yıldız, 2019). Virtual guide applications have increased human-machine interaction in the service sector with developments in science and technology, and offered new experience opportunities, especially in museums and exhibition halls. Augmented reality (AR) and virtual reality

(VR) technologies provide visitors with advantages such as visualization, navigation and interactive experience. Mobile applications and AI-assisted guidance have strengthened the human-machine relationship by offering personalized experiences to users (Benyon, et al. 2013).

The digitalization process of museums started with the digitization of written sources, followed by the creation of museum websites and online archives. Technologies such as digital projection and audio guides provided visitors with more interactive experiences (Güzel, 2024). Later, the concept of virtual museums emerged. Virtual museums are designed as "Meta-Museums" or "web-based museum networks" as digital copies of physical museums. By integrating traditional and digital museums into this framework, physical and temporal barriers between the museum and the visitor were removed and interactive and functional experiences were offered online (Vargün, 2024). Virtual museums, which were initially perceived as web pages opened by museums, have been narrowed down over time as the name given to three-dimensional virtual spaces where visitors can visit the museum interior and artifacts 360 degrees interactively (Vargün, 2024).

While in the past, visitors used to learn about artworks in museums by using audio guides with headphones, today this technology has evolved into comprehensive multimedia systems. The rapid development of digital technologies in the 2000s has contributed to the expansion of museums' digital assets by providing more interactive, gamified experiences for museum visitors, through tools such as virtual tours and digital games. Mobile devices increase the flexibility and accessibility of museum visits by providing virtual tours and guidance services that users can access from anywhere. In this way, museum tours have become an interactive and dynamic experience that is shaped according to the needs of users rather than just providing information (Batuhan, 2024).

Today, virtual tour applications are frequently seen in the world (Bağçı & İçöz, 2019). The use of virtual tours, especially in destination and museum visits, is becoming more and more common. For example, the British Museum in London and the Metropolitan Museum in New York have succeeded in bringing their cultural heritage to a global audience thanks to the virtual tours they offer in digital environments and have attracted great international attention (Durmaz et al., 2018). These tours offer visitors the opportunity to explore cultural and artistic collections without being physically present in the museum, thus increasing accessibility and strengthening the global appeal of museums.

Augmented Reality Technologies

Augmented reality is a new branch of technology that combines the digital environment with the real world (Berryman, 2012). In other words, augmented reality is a joint representation of the real world and the computer-generated environment (Walsh, 2011). The foundations of augmented reality technology date back to the 1950s and the device called "Sensorama" developed at that time is the first example of this technology (H. Altınpulluk & M. Kesim, 2015). Then, Ivan Sutherland invented the head-mounted display in 1966. In 1968, Sutherland was the first person to create an augmented reality system using an optically transparent head-mounted display (Figure 2). With all these developments, the term augmented reality was first used by Ronald Azuma and entered the world literature (Eroğlu, 2018).

Figure 1. The Sensorama machine

Azuma defined augmented reality technology as the reproduction and enhancement of the natural environment with hard-to-perceive information (Azuma, 1997). The efficient and practical use of this technology requires the simultaneous presence of a mobile device, camera and triggering visual (Çankaya, 2019).

Augmented reality refers to the technology that projects digital materials onto real objects. This definition can be summarized as defining a wide range of technologies from completely virtual environments to real environments (Milgram & Kiyono, 1994).

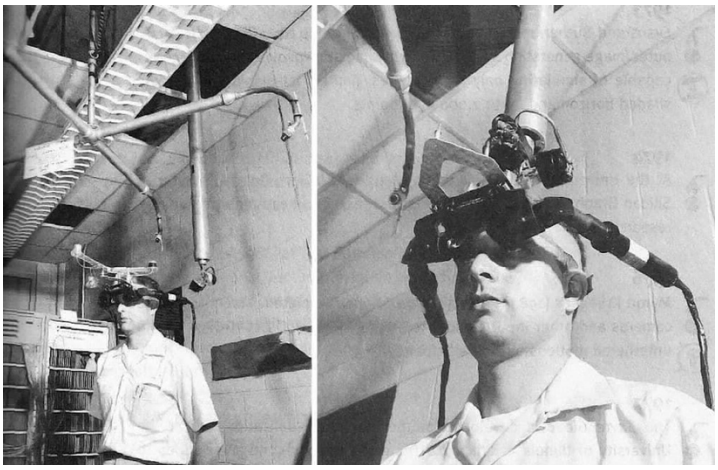

Figure 2. Ivan Sutherland's HMD

Höllerer and Feiner (2004) define augmented reality as a system that combines real and computer-generated information interactively and in real time in a real environment, reconciling virtual and physical objects. Ludwig and Reimann (2005) conceptualize augmented reality as a human-computer interaction that adds virtual objects to the sense of reality provided by a video camera in real time.

Augmented reality technology provides intuitive information for a better perception of the real world. This technology makes it possible to improve the user's perception by embedding virtual objects or information cues into the real world (Behringer, 2001). Augmented reality involves the enhancement and support of reality by providing information that is not normally detectable by human senses and cognitive processes (Azuma, 1999).

Augmented reality technology was initially applied in defense industry, industry and medicine (Caudell, & Mizell, 1992 and Cover, et al., 1993). The usefulness and effectiveness of the applications in these fields and the widespread use of various devices such as mobile phones/tablets with the cheapening of technology have led to the use of augmented reality technology in different fields. Today, the extraordinary speed of technological developments has increased the

accessibility of augmented reality technologies and enabled its use in many fields (Morales, Arenas, Delgado, & Huamani, 2022).

In recent years, many curators and artists have applied new technologies to various events, tourist attractions, museums and exhibitions with the rapid development of technology, especially with the use of augmented reality technologies (Moorhouse, Dieck, & Jung, 2019).

Especially in education and cultural heritage conservation, the experiential learning opportunities offered by AR are remarkable (Damala et al., 2008 and Klopfer & Squire, 2008) and researchers have emphasized that AR adds an innovative dimension to teaching environments. In addition, in the fields of entertainment, art, marketing and advertising, AR allows users to have interactive and immersive experiences (Moltenbrey, 2011).

Types of Augmented Reality by Use Technologies

Throughout the development of augmented reality (AR) technology, various classifications have been made. One of these classifications is based on the devices that provide the AR experience. AR can be realized with wearable and non-wearable devices. Wearable devices include headsets and helmets, while non-wearable devices include mobile devices (smartphones, tablets), fixed devices (televisions, computers). Another classification is based on how the AR experience is triggered. AR systems can be marker-based or markerless.

Marker-based AR is triggered by visual markers such as QR codes, printed images or real-world objects. Marker-based AR is also called image recognition because it requires a special visual object and a camera to scan it. This can be anything from a printed QR code to special markers (Estrada et al., 2022). In some cases, the AR device also calculates the position and orientation of a marker to position the content. Thus, a marker initiates digital animations for users to view and the images can be transformed into 3D models. Marker-based AR may require downloading an application specific to the device being used.

Image tracking is one of the prominent technologies in marker-based AR. In this method, virtual content is overlaid on an image or photo identified by the camera. When the image target is detected, the system recognizes this image and integrates virtual objects over it. Image tracking is an augmented reality (AR) technology that provides applications with the ability to recognize 2D images and overlay digital content over them. This triggers the display of a variety of digital content such as videos, slideshows, 360° panoramas, audio, text and 3D animations (Gaikwad, 2020).

Figure 3. Image tracking

Markerless AR detects the user's environment through mobile device cameras and sensors without the need for physical markers. Common types of markerless AR include location-based systems and surface tracking. These types can be further diversified; projection-based, overlay-based and outline-based systems are examples of markerless AR systems. Various classifications of augmented reality are based on the input/output systems and technology types used (Kuhail et al., 2022). Table 1 presents examples of different AR systems included in existing classifications.

Table 1. Augmented Reality Classifications

Type	Technology
Marked-based	Image Tracking
Markerless	Location-based Surface Tracking

Location-based augmented reality (AR) works by using sensors such as GPS, compass, gyroscope and accelerometer that provide data based on the user's location (El Filali and Krit, 2018). This data determines how AR content is

presented in a given region. Mobile devices and AR applications powered by these sensors typically offer maps, business information, directions and interactive content. Google Maps uses location-based AR systems to provide users with directions and information about points of interest (Kuhail et al., 2022). The user can access this content by scanning physical surfaces with their mobile device. For example, the world-famous AR-based game application "Pokemon Go" enables interactive experiences based on geolocation and places AR objects in the physical world using SLAM (Simultaneous Localization and Mapping) technology (Ketchell et al., 2019). Simultaneous Localization and Mapping (SLAM) is a technology that detects and maps the features of the environment and tracks the location of users. SLAM, which has become widespread with smartphones in recent years, improves object tracking in augmented reality (AR) applications and more accurately places virtual objects in the real world (Chi, 2020).

Figure 4. Google Maps app

Figure 5. Pokemon Go

Surface tracking technology is used to obtain measurements of real-world deformable systems. Tracking object surfaces is used continuously in the fashion and film industries for CGI and special effects (Bradley et al. 2008). This type of AR detects real-world surfaces and places virtual objects on them. Surface tracking recognizes horizontal and vertical surfaces and uses them to overlay virtual content (Saez Martinez, 2019).

Figure 6. IKEA Catalog application

For example, applications that scan a floor and place a virtual piece of furniture on it are of this type. The IKEA Catalog application, which allows users to place virtual items from furniture catalogs in their rooms, is an example of surface tracking.

Aim/problem of the Study

The aim of the research is to discuss the role of Augmented Reality (AR)-supported virtual tour applications in the tourism industry, particularly in enhancing user experience, visitor engagement, and destination marketing. AR technologies are increasingly being integrated into museums, historical sites, and city tours, yet there remains a lack of comprehensive understanding regarding their effectiveness, usability, and impact on tourism experiences.

This study seeks to address the following research questions:

- How do AR-supported virtual tour applications influence user experience in the tourism industry?
- What technologies are utilized in AR-based virtual guide applications, and how is their effectiveness evaluated?
- What role does AR play in the marketing and visitor engagement strategies of tourism destinations?

Method

This research evaluates the effects of augmented reality technology in educational and cultural promotion areas by comparing the variety of content offered by virtual guide applications and the use of interactive elements. The use and effects of augmented reality supported virtual guide applications are examined using qualitative research methodology. In the first phase of the research, a comprehensive literature review was conducted to understand the applications of AR technology in the fields of virtual guidance and cultural heritage. After reviewing current research and applications, basic concepts were identified. The differences and similarities between the Taiwan Lantern Festival, Institute Of Contemporary Art San Diego and Singapore Tourism Board projects were evaluated.

These three projects offer a broad perspective in terms of geographical, cultural and technological diversity. Taiwan Lantern Festival is an example from Asia, showing how traditional folklore and storytelling are enriched by AR technology. ICA San Diego demonstrates how AR is used for spatial navigation and artistic guidance in the context of a North American art gallery, while the Singapore Tourism Board demonstrates the potential of AR for promoting cultural and historical fabric in the context of modern city guidance.

These projects also demonstrate different technological approaches. The Taiwan Lantern Festival used location-based services (LBS) and SLAM technologies, while ICA San Diego emphasized static image recognition and animation. The Singapore Tourism Board used innovative tools such as Google ARCore and Geospatial Creator to digitally map the city and provide AR guidance systems. Each project enriches the user experience in different dimensions such as gamification, educational content delivery and spatial guidance, demonstrating the impact of AR technology in these areas.

The research aims to understand the contribution of the technological components used in these projects to the user experience and to evaluate the potential of AR to enhance spatial awareness, support the learning experience and strengthen the cultural context. The examples examined provide a comprehensive framework of how AR can be applied in different contexts and illustrate the opportunities and challenges that this technology offers.

Procedure

The study was conducted through the following steps:

- Literature Review – Analyzing existing academic research on AR in tourism.
- Project Selection – Identifying three AR-supported virtual tourism applications for case study analysis.
- Data Collection – Gathering information from literature, technical reports, and user feedback.
- Content Analysis – Examining the selected projects based on predefined research categories.
- Interpretation of Findings – Evaluating the results in relation to the research questions.

Results

Using Augmented Reality in Virtual Guide Applications

Virtual guide applications supported by augmented reality offer users richer and more interactive experiences by adding digital content to the physical environment. Especially in museums and tourism, AR provides visitors with real-time information about artifacts or places.

Augmented reality technology provides a more enriching experience by allowing visitors to interact with museum artifacts. Visitors can access detailed information about the objects on display, watch related animations or participate in gamified activities offered within the museum (Akkuş and Akkuş 2018).

Taiwan Lantern Festival 2020

The Taiwan Lantern Festival is Taiwan's globally recognized and important lantern day event. The Lantern Festival is the first full moon sighting after the Spring Festival. Taiwan has organized lantern exhibitions at the Lantern Festival every year since 1990 (Taiwan Tourism Bureau, 2021). The festival reflects the cultural identity of the cities where it is held, stimulates tourism, and promotes Taiwan's traditional lantern culture around the world. Held in 2020, the festival included a lantern display as well as light performances, cultural parades, and various interactive elements (Taiwan Tourism Bureau, 2021).

These elements include immersive projections and virtual reality experiences that allow visitors to participate. These experiential activities incorporate gaming elements and mechanics in a non-gaming context. As 2020 is the year of the mouse according to the Chinese calendar, visitors attending the festival were offered a DIY kit to make a mouse lantern. The festival was held in Taichung from February 8 to 23, 2020, attracting a total of 11.82 million visitors (Taiwan Tourism Bureau, 2021).

The Lantern Festival was a tourism festival related to a series of events that took place during the same time period. Each festival represents a collective event of religion, culture and entertainment. This cultural preservation has created important measures for intangible traditions (Shih and Chen, 2022).

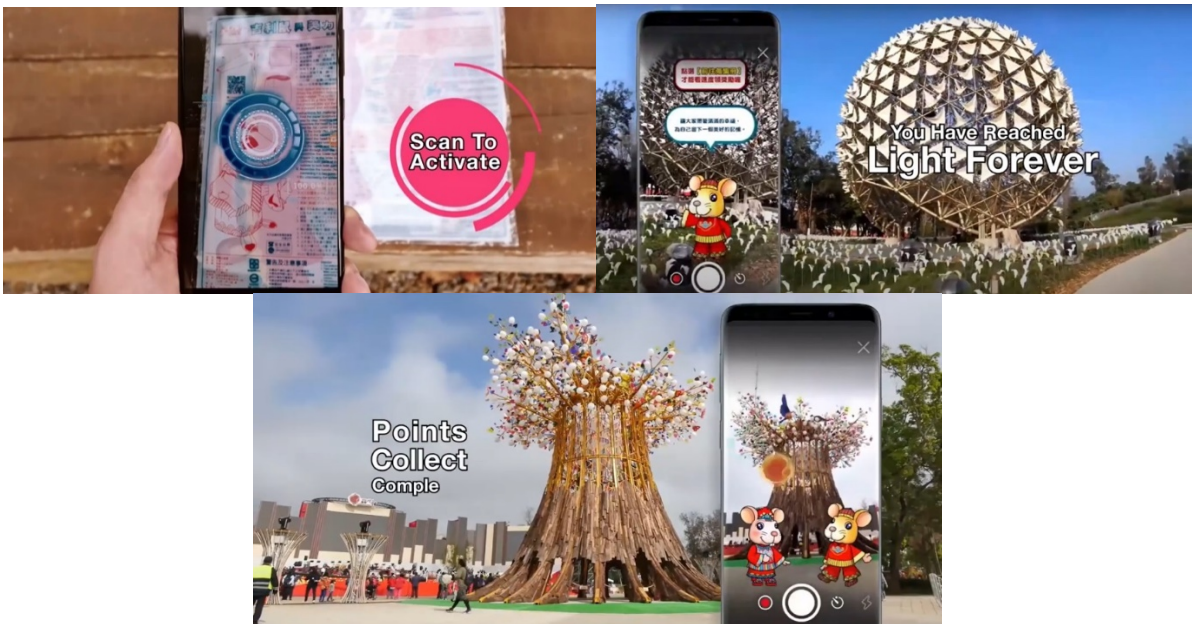

Figure 7. Screenshots from the Marq+ Application

Technological Infrastructure and AR Usage

Taiwan Lantern Festival 2020 combines augmented reality (AR) and real-time location-based service (LBS) to create a unique blend of technological innovation and traditional folklore through the classic folktale "Mouse Gets Married". In this interactive experience, the mouse groom guides visitors through the festival grounds, helps them find the mouse bride, and finally lets them watch the AR fireworks display. Participants also immortalize their memories with a Taiwan Lantern Festival themed AR photo frame.

Visitors to the festival site use AR navigation to find the coordinates of the 10 most beautiful scenic spots. At the same time, they log in to the system using their mobile devices to complete the treasure hunt task and get a chance to participate in the gift raffle.

An application called marq+ is used for the AR system used in the festival. The marq+ application, which supports the AR system in the festival area, not only guides visitors between certain points, but also provides information about the festival with a gamified mobile guide system. Using real-time location data, the app optimized visitors' routes and enabled them to have a more meaningful experience during the festival. The mission design in the puzzle game is based on a traditional story, placing storyboards at vantage points to enhance understanding of historical information. Storytelling is often adopted in AR applications. People can mentally process and organize information more efficiently when it is communicated through a story (Evagelou, Athanasios, Alexandros Kleftodimos, and Georgios Lappas. 2024). The LBS (Location Based Service) system increased the visitors' awareness of the space and enabled a deeper exploration of the festival site through interactive tasks.

This experience enriched the participants' experience by combining the educational and playful aspects of AR, while at the same time enabling visitors to become active participants, not just spectators.

Institute of Contemporary Art San Diego

Another Reality Studio developed an augmented reality (AR) based virtual tour guide for the exhibition Gabriel Rico: Unity in Variety exhibition at the Institute of Contemporary Art San Diego. Running from September 24, 2021 to January 23, 2022, the exhibition features striking works that question the pandemic and the human relationship with nature. The various materials used by the artist reflect the balance created by the combination of nature and human beings through a visual language (Institute of Contemporary Art San Diego, 2021).

The artist is known for his sculptures, installations and poetic assemblages inspired by contemporary culture, nature, science, physics, philosophy and history. Using a variety of materials such as neos, branches, rocks, porcelain flowers, old cell phones and CDs, she creates socially conscious works that question the relationship between man and nature (Institute of Contemporary Art San Diego, 2021).

Figure 8. A frame from the Unity in Variety exhibition

Another Reality Studio developed an Augmented Reality (AR) guided tour for this art gallery exhibition. The downloadable mobile application, ICA San Diego, includes a digital mascot that guides customers through an art exhibition.

Technological Infrastructure and Use of AR

For the AR interaction in the art gallery it is necessary to use the ICA San Diego app. The app first recognizes a physical image on the gallery floor to calibrate the scene and give a fixed path for the coyote to start. Once recognized, the coyote mascot appears and moves in a fixed path while integrating animations.

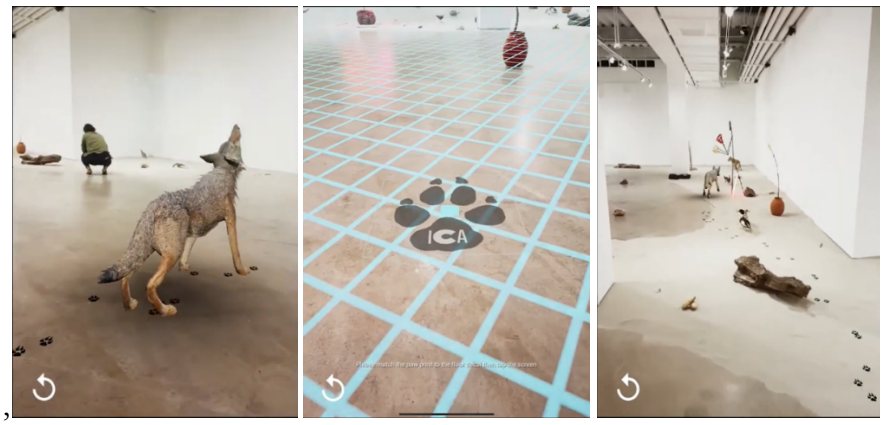

Figure 9. Screenshots from the ICA San Diego application

Instead of allowing visitors to interact with the exhibition, this AR guide aims to help them navigate the exhibition space more effectively. The technology provides visitors with a wayfinding facility, allowing them to use the physical space more efficiently. Controlling the visitors' process of exploring the exhibition is the main function of this AR guide. Although it does not provide direct information about the artworks, this orientation in the exhibition space helps visitors to follow a specific route without getting lost in the space.

The fact that there is no direct interaction with the artworks or additional information about them suggests that the AR guide keeps the experience more at the level of spatial guidance. Therefore, it can be argued that AR technology functions here as a visual guide for visitors rather than deepening the art experience.

Singapore Tourism Board

The Singapore Tourism Board has created an innovative project that aims to transform the tourist experience in the city using augmented reality (AR) technology. Using Google ARCore and Unity platforms, this project offers visitors the opportunity to explore Singapore's major tourist attractions and hidden gems with a virtual guide. Users can download the VisitSingapore Travel Guide application to their phones and experience Singapore through a virtual guide (Google AR & VR, 2023).

With this project, users can gain both cultural and historical information, while also interactively experiencing touristic elements such as local cuisine. During the guided tour, Merli, Singapore's official tourism mascot, guides the user by introducing visitors to the city's iconic buildings (Silva, 2023).

Merli, Singapore's mascot, guides visitors as a virtual guide in this project. Starting from the iconic Merlion Park, Merli introduces visitors to important buildings such as the Victoria Theater and Concert Hall (Silva, 2023). In this route, Merli not only shows visitors around the sites, but also provides them with cultural and historical information supported by AR technology.

Figure 10. Screenshots from Visit Singapore Travel Guide app

Technological Infrastructure and AR Usage

The technologies underpinning the project are Google ARCore and Unity's Geospatial Creator tool. These tools enable the digital mapping of key tourist attractions in the city and their presentation to visitors through augmented reality. The ARCore platform integrates real-world and digital content, allowing the virtual guide Merli to accompany the user on specific routes, depending on the location of the visitor. This digital guidance helps to present the historical and cultural values of the city in a more interactive and instructive way during the physical tour (Silva, 2023).

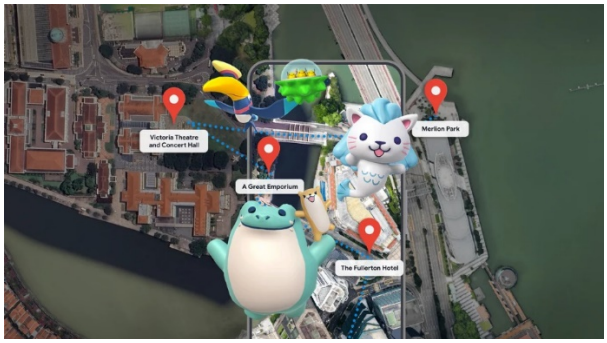

Figure 11. Visit Singapore Travel Guide app

Discussion

This study analyzes the use of augmented reality (AR) technology in virtual guide applications through the Taiwan Lantern Festival, Institute Of Contemporary Art San Diego and Singapore Tourism Board projects. Each project offers interactive experiences to its users by integrating AR technology with different purposes and methods. This study examines the projects in four main categories: gamification and interactivity, technologies used, interface design and visual use. The findings related to these categories are summarized as follows:

Gamification and Interactivity

Taiwan Lantern Festival: Gamification elements like tasks, rewards, and interactive stories significantly increased user engagement.

Institute of Contemporary Art San Diego: No gamification elements were included, but spatial guidance enhanced visitors' navigation through the exhibit.

Singapore Tourism Board: Delivered gamified and interactive guidance using the Merli mascot, which drew tourists' attention.

Technologies Used

Taiwan Lantern Festival used location-based services (LBS) and SLAM technology.

ICA San Diego provided AR guidance with static image recognition and animation features.

Singapore Tourism Board integrated Google ARCore and Geospatial Creator platforms.

Interface Design

The Taiwan Lantern Festival and Singapore Tourism Board apps provided easy navigation and information with user-friendly interfaces.

ICA San Diego's mobile application adopted a design to guide users only spatially.

Visual Use

Taiwan Lantern Festival emphasized visuals with AR fireworks and interactive visuals.

ICA San Diego adopted a more minimalist visual approach and focused on navigation.

Singapore Tourism Board enriched the visual narrative with the Merli mascot.

Table 2. Comparative Analysis of Augmented Reality Supported Virtual Tour Applications

Criteria	Taiwan Lantern Festival	Institute of Contemporary Art San Diego	Singapore Tourism Board
Technologies Used	AR, LBS, SLAM	AR, Surface Tracking	AR, LBS,SLAM
Gamification	Yes. Engagement is increased with tasks and rewards; the user completes interactive tasks.	No. It does not include gamification elements; only guidance is provided.	Yes. It provides a gamified experience in the city with interactive quests and exploration.
Interactivity	Users interact with the virtual guide, providing a dynamic experience filled with wayfinding and virtual elements.	Provides access to artistic information with AR guide; interactive elements are limited.	AR guidance where users can interact with location-based content.
Interface Design and Visual Use	A design that draws the user in with lighting, projection and colorful 3D content.	The AR guide focuses on artworks with a simple interface; minimal animation.	User-friendly interface, visual focus with landmarks and local information for city guidance.

Taiwan Lantern Festival, Institute of Contemporary Art San Diego, and Singapore Tourism Board projects have enriched virtual guidance experiences by using augmented reality (AR) technology in different ways. The projects analyzed in this study demonstrate different applications of augmented reality technologies. The technologies used in these projects include innovative solutions such as location-based services (LBS), SLAM and ARCore. However, the scope of augmented reality technologies is not limited to this study. There are examples in the literature where AR is used in a wider range of applications such as face recognition, augmented audio, holographic projection, etc. The study

focuses on technologies appropriate to the context of the projects analyzed, and other applications are excluded from the study.

At the Taiwan Lantern Festival, location-based services (LBS) and SLAM (Simultaneous Localization and Mapping) technology were used to locate users in the festival area. This provided real-time guidance and allowed users to be guided around the festival site. Interactivity was enhanced through gamification elements (e.g. quests and rewards). By completing tasks, visitors both interacted with the cultural heritage and explored the festival site. This shows that AR makes users' experiences more engaging through gamification. Natalia Teixeira et al. (2021) examined how augmented reality (AR) technology can be gamified with interactive elements and its effects in increasing user engagement. They find that gamification elements such as tasks and rewards increase user engagement. The case of the Taiwan Lantern Festival demonstrates the potential of AR technology in gamification and interactivity. The location-based services and interactive tasks used at the festival enabled visitors to connect with cultural heritage and increased participants' interest in gamified experiences. This application is in line with the theoretical themes outlined in previous studies and provides an example that reinforces the impact of AR in enriching the user experience. A simple and intuitive navigation interface was provided for users to explore the festival site. The AR map serves as a guide for completing tasks and winning prizes. The visuals are designed to visually entice users, in line with the theme of the festival. AR elements are visually enriched by integration with the physical space.

In the Institute of Contemporary Art San Diego project, a guided tour application was created using AR technology in the context of an art gallery. There are no gamification elements in this project. AR was used to guide visitors through the exhibition space and provide information about the artworks. Interactivity was limited. A simpler implementation was used for AR. The guide is focused on guiding users through the physical exhibition space. The technology used here is a visual tool to guide the visitor experience, but less focused on interactivity and information presentation. AR guidance was used to optimize the orientation in the exhibition space. Here the interface is more minimal and focused on providing spatial guidance rather than information about the artworks.

The Singapore Tourism Board used AR technology to allow exploration of the city's key cultural and historical landmarks. Gamification elements and interactive guidance allowed tourists to learn about landmarks in the city, while providing an interactive learning experience about local culture and history. The AR is enriched with interactive tasks and tourist items while exploring the city's highlights. The Merli mascot provides the historical and cultural context of the city while guiding users. This allows users to actively participate. Using Google ARCore and Unity platforms, key areas of the city were digitally mapped and an AR experience was provided. This provided a multi-layered AR experience for the discovery of tourist spots and allowed users to explore the city in a more interactive way. The AR navigation and interactive tour is integrated with an interface that provides information on the city's key landmarks. The Merli mascot effectively presents information for each point while guiding users. AR visuals are designed to make the city more attractive and are combined with landmarks. While the Merli mascot conveys historical information to visitors through AR, the visual elements make the city vibrant and attractive.

Zikky et al. (2024) found that the combination of technologies such as AR and GPS navigation enhances the user experience and strengthens the orientation function in heritage sites. This combination of technologies offers an effective solution that combines physical space exploration with a digital experience, similar to the Singapore Tourism Board's location-based AR guidance application.

Visual elements in AR projects act as a bridge connecting the digital and physical worlds. Azuma et al. (2001) emphasized the importance of ensuring visual consistency in AR when adding digital content to the real world. The Singapore Tourism Board's visualization of local culture using the Merli mascot is an example of this principle. The AR fireworks display and visual effects in the story “Mouse Gets Married” at the Taiwan Lantern Festival succeeded in capturing the attention of visitors and presenting a visual story.

Conclusion

This paper analyzes three case studies of the use of augmented reality (AR) technology in virtual directory applications. The projects analyzed how AR was integrated, the purposes for which it was applied, and the interactive experiences it offered to users. The study reveals how the Singapore Tourism Board, the Institute of Contemporary Art San Diego and the Taiwan Lantern Festival all utilize AR in different ways, such as deepening user experiences, increasing spatial awareness and digitally presenting cultural stories.

The immersive experiences offered by AR take users beyond physical spaces and offer a new way of exploration through interactive guidance. In this sense, the use of AR adds a new dimension to traditional guidance approaches. AR enables users not only to passively consume information, but also to make the experience more meaningful through active participation. Digital guiding with AR technology not only provides visitors with information, but also makes cultural heritage more accessible and interactive. However, in addition to the advantages offered by this technology, user feedback and technical improvements should also be considered.

Gamification and interactivity have emerged as a powerful way to increase user engagement, particularly in the Taiwan Lantern Festival and Singapore Tourism Board projects. Task-based gamification elements enabled users to have fun and interact with cultural heritage at the same time. Technological infrastructure played a critical role in the success of the projects, with the effective integration of technologies such as LBS, SLAM and ARCore enhancing the user experience. Interface design focused on providing a user-friendly experience in each project, providing practical solutions for navigation and information presentation. The use of visuals emphasized the educational and artistic potential of AR by presenting cultural and historical content in both aesthetic and informative ways.

Looking at the intensity and prevalence of digitalization today, it is estimated that the use of "artificial intelligence, augmented reality, personalized services and robots" will increase in tourism businesses and activities in the future (Bağcı & İçöz, 2019). In the future, various improvements can be made to ensure that augmented reality (AR)-based guidance systems become more accessible and widespread. Integrating artificial intelligence (AI) technology into these applications can facilitate a more personalized and dynamic guidance experience. AI-powered systems have the potential to increase user satisfaction by providing content recommendations tailored to visitors' interests. Furthermore, the combination of AR and AI can analyze visitor behavior to create a more interactive and efficient experience. To expand the reach of this technology, it is crucial to develop cost-effective and user-friendly AR systems for smaller museums and tourist destinations.

AR technology remains an important tool for redefining the user experience and strengthening cultural context. However, the integration of this technology with other advanced technologies such as AI, big data analytics and MR offers the opportunity to develop more personalized, effective and sustainable applications. Future work should consider in more detail how such integrations can be applied in societal and cultural contexts.

In the future, AR technology is expected to offer more advanced, personalized and contextual guidance through its integration with artificial intelligence (AI). By analyzing users' interests, learning habits and individual needs, AI-powered AR systems can deliver content tailored to each user. For example: Speech recognition and natural language processing technologies allow users to interact with the guide by voice, ask real-time questions and receive instant information. In addition, recommendation systems allow visitors to be directed to exhibits or areas of interest based on previous interactions. Visual recognition and advanced AR technologies enable users to recognize an artifact in real time and learn about its historical, cultural or artistic context. These integrations strengthen both the educational and entertainment aspects of AR, enabling users to make a more meaningful connection between the physical and digital worlds. Integrating such technologies can further deepen both educational and entertainment-oriented experiences, especially in museums and tourism spaces. AI-enhanced AR can provide a more interactive and natural user experience, enhancing visitors' spatial perception and contextual understanding.

Recommendations

Both researchers and practitioners should focus on enhancing the effectiveness and accessibility of AR in tourism. Researchers should conduct user-centered studies to assess AR's long-term impact on engagement and satisfaction, while

also comparing it with other immersive technologies like VR and MR. Practitioners, including tourism organizations and cultural institutions, should prioritize intuitive design, interactivity, and seamless integration to maximize AR's potential. Collaboration between academia and industry can drive cost-effective, scalable, and engaging AR solutions, ultimately improving tourist experiences.

Limitations of Study

This study has several limitations. First, the research primarily relies on case study analysis, which provides an in-depth examination of selected AR-based tourism projects but may not be generalizable to all tourism applications. Future studies could employ quantitative methodologies, such as surveys or experimental designs, to collect user feedback and performance metrics on a larger scale.

Second, the study focuses on three specific AR projects (Taiwan Lantern Festival, ICA San Diego AR Guided Tour, and Singapore Tourism Board AR Application), which may limit the scope of findings. A broader dataset, including a more diverse range of AR applications across different cultural and geographical contexts, would offer a more comprehensive understanding of AR's role in tourism.

Lastly, technological advancements and evolving user expectations could impact the relevance of current findings. As AR technology continues to develop, future research should address new hardware capabilities, artificial intelligence integration, and evolving user behaviors to ensure continued relevance in the tourism sector.

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