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REVIEW

Applications of augmented reality in museums, impact on cultural heritage

Aplicaciones de la realidad aumentada en los museos, impacto en el patrimonio cultural

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ABSTRACT

Introduction: the museum is a site that collects, exhibits, researches and classifies material objects that represent nature and human cultural heritage. They are one of the sources of knowledge about history and culture. To face the current digital revolution they have used technologies such as augmented reality. The objective was to characterize the application of augmented reality (AR) technology in museums.
Methods: a total of 20 articles in Spanish and English were reviewed, from Science, Scielo and Dialnet; using as keywords: augmented reality, museum, museum exhibits, interactive exhibits, immersive technologies, being more than 50 % of the last five years.
Results: the vast majority of museums as institutions try to find various methods to excite and involve their audiences. The technology behind AR improves visitor perception, as historical and cultural relics can be displayed through augmented reality and virtual compositions. The AR also ensures accessories and applications to improve the experience at the center, resulting in greater educational, historical and social impact.
Conclusions: augmented reality technology in museums makes it possible to captivate diverse audiences, adapt to the personal interests of the visitor, remodel the design of exhibitions, the combination of art and technology, improve understanding and ensure positivity of the museum experience. This is guaranteed through mobile applications, accessories and websites.

Keywords: Augmented Reality; Museum; Museum Exhibits; Interactive Exhibits; Immersive Technologies.

RESUMEN

Introducción: el museo es un sitio que recolecta, exhibe, investiga y clasifica los objetos materiales que representan la naturaleza y el patrimonio cultural humano. Son una de las fuentes de conocimiento sobre la historia y la cultura. Para hacer frente a la actual revolución digital han empleado tecnologías como la realidad aumentada. El objetivo fue caracterizar la aplicación de la tecnología realidad aumentada (RA) en los museos.
Métodos: se revisaron un total de 20 artículos en español e inglés, provenientes de Science, Scielo y Dialnet; utilizando como palabras clave: realidad aumentada, museo, exhibiciones en museo, exhibiciones interactivas, tecnologías inmersivas, siendo más del 50 % de los últimos cinco años.
Resultados: la gran mayoría de los museos como institución intentan encontrar diversos métodos para entusiasmar e involucrar a su público. La tecnología detrás de la RA mejora la percepción del visitante, as reliquias históricas y culturales se pueden mostrar mediante realidad aumentada y composiciones virtuales. La RA asegura además accesorios y aplicaciones para mejorar la experiencia en el centro, resultando en mayor impacto educativo, histórico y social.
Conclusiones: la tecnología de realidad aumentada en los museos posibilita cautivar a audiencias diversas, adaptarse a los intereses personales del visitante, remodelar el diseño de las exhibiciones, la combinación de arte y tecnología, mejora el entendimiento y asegura positividad de la experiencia museística. Ello lo garantiza a través de aplicaciones móviles, accesorios y sitios web.

Palabras clave: Realidad Aumentada; Museo; Exhibiciones en Museo; Exhibiciones Interactivas; Tecnologías Inmersivas.

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INTRODUCTION

The museum is a place that collects, exhibits, researches, and classifies material objects representing nature and human cultural heritage. It also provides a place for visitors to study, research, and be entertained. Providing high-quality information services is the core value of museums.[1]

Cultural heritage refers to the generational transmission of customs, practices, places, objects, artistic expressions and unique and irreplaceable values that form the identity of a community to keep alive the traditions of the past for the benefit of future generations.[2]

It is estimated that about 47 % of travel is motivated, directly or indirectly, by culture and, therefore, cultural heritage can be used for tourism purposes as a strategy to preserve the past, transmit traditions to future generations and raise awareness of the importance of heritage.[2]

Museums are one of the sources of knowledge about history and culture. To increase these cultural institutions' competitiveness, especially to attract the younger generation, it is necessary to use new communication platforms with a modern audience.[3] These institutions face the danger of culture and art being weakened or even absorbed. So, it is urgent to inject new content into development.[4]

To cope with the pace of the current industrial revolution, museums are well aware of the importance of digitization and machine learning-based approaches to enhance the visitor experience.[5] New technologies are enabling a radical change in the approach to transferring knowledge about culture and history, just as they are changing how people interact.[3]

Due to the trend to use technologies such as augmented reality (AR) in digitizing cultural heritage and the interesting visualization, interactivity, and gameplay of applications based on them, they have acquired great significance in this medium.[3]

AR consists of the superimposition of layers with information of different types, such as video and two-dimensional (2D), three-dimensional (3D) graphics, and audio, to the real environment. [6] It induces a dynamic landscape where multi-perspectivism is encouraged through immersive simulations, exhibits and games.[7]

The application of AR is widespread in various fields: marketing, retail, events, education, culture, culture, tourism, architecture, design, medicine and automation.[6] It can be used effectively in the context of a museum exhibition to support both storytelling and interaction.[8,9,10] The limitations of physical museum visits have highlighted the importance of alternative means of engagement, and immersive technologies have emerged as promising solutions.[11] AR can become a key player in the invaluable preservation of cultural heritage.[12]

Given the above, the present work was conducted to characterize AR technology's application in museums.

METHOD

Bibliographic research of original articles and reviews was carried out, considering studies in Spanish and English related to the use of AR in museums, using as keywords: augmented reality, museum, museum exhibits, interactive exhibits, and immersive technologies from databases such as Science, Springer, and Dialnet.

Twenty articles were selected, of which more than 50 % are from the last five years. The information of interest was extracted, and its analysis and arrangement contributed to the correct development of this research.

DEVELOPMENT

In places rich in history, such as museums, the visitor's main objective is rather to immerse himself in the environment and try to live a personalized experience that allows him to feel part of the place visited.[13] The key factor on which the social work of museums depends is the acceptance of the visitor.[14] Alma Leopardi[15] believes museums should focus on visitors and the visitor experience rather than the collection and marketing. Enjoyment results from participation in immersive, absorbing activities or processes that offer a sense of escape from the monotony of everyday life.[16]

On the current state of museums

Museums are responsible for disseminating knowledge to the public and should take full advantage of the outreach function of popular science education. It requires a simple list of exhibits and a beautiful and efficient organization of these.[4] The museum is an open space for the preservation of knowledge and culture. Despite being recognized as an imprescriptible learning site, it still contributes to popularising knowledge.[14] Museums constitute a preserved source of cultural traditions and idiosyncrasies; their educational and perpetuating role ensures historical memory.

Traditional museums are the cultural custodians, the source of information, and the avenue of research that educates and entertains visitors. Under specific curatorship, the museum is a picturesque tourist and imprescriptible learning centre.[14] Museums are seen as informal learning environments where the functions of collection, research and exhibition, education and recreation are fulfilled.[12]

The traditional image of the museum is mainly based on the display of objects, images and words, focusing on the beauty and interest of the exhibition creation. Users can only passively receive and confirm information; most information is obtained from large text display tables. The museum has many expensive artefacts, but users need help to get close. People can only observe from a distance and leave a general impression in their minds. This display mode cannot satisfy the public's desire to know and participate in the experience.[4]

Traditional methods ensure that visitors acquire a minimal view depending on the museum's purpose. The evolution of information technologies means that the public is often unsatisfied or uncomfortable when these experiences are limited to dialogue and personal interpretation. It is valid to clarify that, in general, visits to museums depend, in addition to the knowledge provided by

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the guide and the institution's accessories, on the visitor's ability to interpret and understand what is shown there.

Museums often provide text-based introductions to support visitors' learning purposes.[12] The main purpose of their use is to make the museum visit much more engaging, immersive and suitable for different types of visitors;[8] However, this learning process involves time and the ability to analyze and understand images, and some visitors are unwilling to spend time reading text.[12] Often, due to lack of funds, talent, expertise and other problems, museums have yet to achieve continuous development or gradual growth.[4] Although not properly addressed in this paper, the author is aware that cultural heritage institutions are often subject to economic problems, perhaps because they are seen as sites that do not evolve along with the rest of science because of their historical and conservative nature. This means that occasionally, these limitations impede the evolution of museums.

Created as "chambers of wonders", over the years, science and technology museums have revised their objectives and innovated their contents according to new modes of communication. The challenge is to engage visitors in complex cultural experiences, stimulating them emotionally and cognitively. Therefore, these museums are becoming public spaces that include scientists, non-scientists, the elderly, and the young.[8] Another peculiar fact is that the characteristics of the tours inside the museums, either by the time allotted or by the amount of content included in a specific branch, affect the experience negatively because sometimes, topics such as astrology, physics, archaeology are difficult to understand and demand a differentiated treatment that the traditional dialogue-text exchange cannot provide.

Art museums are at the forefront of staging experiences in today's experiential economy. As museums face serious financial challenges, they focus on improving the visitor experience to increase admission rates.[16] Wenru Zhao,[4] argues that modern museums must change how they exhibit to maintain public interest.

If museums mark and display artefacts according to traditional concepts, the goal of museum communication may be defeated.[4] However, museums may only have space for some exhibits. Another element to consider is that visitors like to interact with the exhibits.[12] Public acceptance is the key factor on which the success of such an environment depends; if the experience is considered enjoyable/beneficial, the mission of this institution will succeed.

Typically, museums are more crowded during the vacation season or school tourism studies. The number of visitors often makes them less likely to enjoy and learn about the museum's historical relics.[17] On the other hand, some museums are very crowded, which generates dissatisfaction among those interested because of the long lines to enter or the short duration of the experience; it is the duty of those in charge of these sites to find ways to alleviate the flow of visitors.

Leisure, learning, new experiences, and entertainment in an attractive and stimulating environment are motivating aspects that influence users' intentions to visit museums. Research suggests that the success or failure of a user's overall museum experience may be determined by perceived experiential value.[12]

With the development of information processing technology, the public's demand for information and experience is continuously increasing, which has become the inevitable development of museum management.[1]

With the advent of AR and other technologies

Most museums are trying to find various methods to excite and engage their audiences. Context-sensitive audio guides, AR and 3D modelling-based applications, as well as interactive digital storytelling, are the most commonly used tools to attract the user's attention.[13] The technology behind AR is constantly evolving and enhancing visitor perception, which maximizes the potential of AR in design and conceptualizes it as an integrated and holistic visitor learning experience.[17]

AR's role in supporting education, especially in history during the COVID-19 pandemic, was highly supportive. Through 3D assistance, audio, and highly interactive visual aspects, the learning and experience were optimized. With engaging algorithms and visualizations, the result is an increase in interest of up to 70 %.[17]

Many authors support that AR environments increase students' motivation and interest, which in turn can help develop their research skills and provide them with avenues to accumulate a better knowledge base on specific topics.[12]

Museum professionals, AR, and virtual and mixed AR developers should emphasize the educational and entertainment factors that help immerse visitors in the virtual environment for an enhanced experience. Three four aspects affect the experience in the AR world, especially in museums: object annotation, object visualization, guidance and data visualization;[17] these determine the quality of the experience and define the socio-cultural work of museums. By seamlessly merging digital elements with the real world, AR offers a unique way for visitors to explore historical sites.[2]

The actual value and degree of implementation of AR technology in the interest of preserving cultural heritage, mainly in museums, has yet to be discovered with certainty. The author believes that their current situation determines the real impact and the acceptance of AR in this area.

Immersive technology

Immersion can be defined as the degree to which a system can reproduce natural perception and action through multi-sensory display tracking.[15]

Immersive technologies create interactive, sensory-rich experiences that evoke a strong sense of presence, transport visitors to different times and places, and foster emotional connections to the content. The integration of immersive technology into museum exhibits has a profound impact on the user experience, offering visitors unique and engaging encounters with cultural artefacts and historical contexts.[11] Immersive technology emerges as a suitable solution to many of the dilemmas within the museum environment, its application advantages ensuring improvements for both the customer and the worker.

Studies have shown immersive experiences improve information retention, facilitate deeper understanding, and stimulate

critical thinking skills. By providing interactive, multimodal experiences, immersive technology supports various learning styles and encourages active learning.[11] Considering the museum as an indirect learning site and appreciating the positive impact of these technologies on the education sector, only better results should be expected from this merger.

Early applications of immersive technology in museums focused on novelty, offering stand-alone virtual reality experiences or integrating AR markers into exhibits. By leveraging digital interfaces, immersive technology has the potential to attract and engage a wider audience, including younger generations, thus fostering inclusivity and broadening the reach of cultural heritage institutions.[11] Accommodating the breadth of audiences is also a challenge for these institutions, especially when it comes to younger audiences, whose intellectual capacity and interests demand other types of approaches such as AR and even gamified environments.

Historical and cultural relics can be shown through AR and virtual compositions compared to viewing images of books in the real world, generating a real-scale visualization with the characteristic of not damaging tangible cultural relics.[14] Augmenting immersive scenes, such as a virtual historical, natural or cultural environment that reflects the contents of the exhibits, offers visitors a new level of virtual presence.[16] Virtual tours could be an effective solution for eventualities such as those mentioned above, especially since access can be from the comfort of the home.

Full immersion combined with adaptive user preferences requires the development of automated content personalization systems. These systems adapt dynamically to each user, taking into account their profile, interests and history.[13]

3D sound has been found to increase the sense of immersion, providing a more realistic virtual environment. When developing audio AR systems, interaction with and customization of the system are two essential components to focus on, as the main goal is to provide an entertaining, informative and user-friendly experience.[13]

The authors consider that the specific aspects in the improvement of the application of immersive techniques should be placed in second place and initially devote more attention to achieving success in the application of these techniques since the degree of acceptance in these institutions is unknown.

Impact of AR technology in the museum environment

AR is an emerging area that can provide museums or art galleries with numerous valuable and distinctive opportunities to increase access to their collections and enhance people's learning and enjoyment.[12] Dario Cianciarulo six reports in his paper on using AR at the Local Traditions museum in Viggiano, Sweden, to correct the idea that museums are collections of objects and tools.

AR's ability to incorporate interactive features into these real-world experiences distinguishes AR from conventional information and communication technologies. This integration has the potential to captivate diverse audiences, which can subsequently enrich the learning process by promoting a general engagement with the cultural heritage of the place.[2]

It has the potential to reshape the design of museum exhibits and environments and influence the allocation of users' attention; it can be used as an auxiliary tool in the management of museum experiences.[16] It combines content and display media, points of knowledge and forms of entertainment, art and technology, and interactive participation with experiential effects.[4]

One of the great premises of AR is its adaptive nature to the interests and needs of the user who uses it. When applied to museums, this would allow for the improvement of the experience integrally by emphasizing what captivates the visitor in an isolated way, guaranteeing a successful fulfilment of the cultural and social work of these spaces.

It acquires the capacity to bring visitors closer to the cultural space, promote the site's sustainability, and provide a good learning moment, providing visitors with an attractive overall experience.[2]

Museums could incorporate adaptive algorithms or artificial intelligence techniques for personalization, thus tailoring the visitor journey to individual preferences. These improvements could optimize visitor satisfaction and pave the way for future research on effective personalization of immersive technologies in museum contexts.[11]

Through real-time rendering, it is possible to argue archaeological features in a real-world setting, allowing the audience to get a much more realistic and richer museum experience.[1] Dynamic image visualization not only makes the display of various buildings or exhibition halls vivid but also improves the speed of people's understanding of buildings.[4]

Limits would be few when it comes to AR applied to these sites full of history, science and culture; the possibilities in terms of projections, adaptations and even education of staff involved in the cultural heritage environment would be almost limitless, only contained by the investment skills and possibilities of each institution.

By offering the unique ability to display computer-generated multimedia within the user's sphere of vision and merge with the world of nature, AR can be specified as a technique that augments realistic feedback to the operator with simulations and cues.[12] The possibility of feedback during a museum visit or tour, in the author's opinion, contributes greatly to the effectiveness of the experience and visitor compliance.

Soundscapes influence viewer engagement with virtual exhibits in museums. The literature suggests that virtual exhibits could better engage visitors by carefully designing soundscapes. This is supported by the fact that sound can modify an individual's affective state.[17]

Virtual museums can analyze the interest of exhibits for subsequent physical placement, thus shifting the position of less observed objects to more active locations.[3]

One of the topics where AR technology can be particularly effective is the communication of abstract concepts that are difficult for the human mind to imagine, such as those related to astronomy. Despite the cultural importance of historical, scientific instruments housed in museums in this branch of science, the current exhibition often needs to allow visitors to understand their meanings and uses autonomously.[8]

Applications

Immersive technology engages visitors through multisensory experiences. The Tate Sensorium project at Tate Britain incorporated sound, taste, touch and smell through virtual reality to create an immersive and memorable museum experience that engages all the senses.[11] It is widely known how somatosensory experiences contribute to the enjoyment of everyday activities and equipping museums with these tools could reverse the delicate situation many are currently experiencing.

AR technology offers a new realm of possibilities for content development in museum exhibits.[11] Dong Han,[1] through the research, analysis and design of Mawangdui Han's tomb, promotes and implements the application of AR technology in exhibitions, aiming to achieve seamless integration between a three-dimensional virtual scene and the real scene on the Android mobile device.

The "Exhibit" intelligent audio guide system, field-tested with the statue of a prominent politician in Heraklion, Greece, combines AR audio chatbot and artificial intelligence technologies to facilitate natural interactions between visitors and exhibits, creating an immersive learning experience.[11]

Many museums worldwide offer visitors devices that allow them to listen to audio content describing the artefacts on display. However, most require the visitor to manually select the artefact of interest to be sent the appropriate audio content through the audio guide. Recently, some research efforts have begun to experiment with automatically detecting the visitor's location within the museum building in order to deliver audio content to the visitor seamlessly.[13]

The use of digital devices constitutes one of the principles of the application of AR in any field; the possibilities vary from a head-mounted device to the cell phone itself. However, their use must be rational since each one acquires a maximum value depending on the application it is given.

Audio guides in AR addiction were found in the bibliography as one of the most frequent innovations in museums, guaranteeing a better quality experience for visitors and guides.

The ec(h)o project is designed as an interactive audio guide for the museum. The system captures the visitor's position throughout the museum using cameras. Therefore, audio content related to what the visitor is looking at is sent through the headphones. In addition to motion capture, the visitor interacts with the audio content by using a wooden cube asymmetrically to manipulate it during the visit.[13]

An excellent example can be seen in the British Museum's virtual reality Bronze Age exhibit, which used Samsung Gear AR headsets to give viewers an interactive 3D view of domestic life in Bronze Age Britain.[11]

Cristina Fenu,[18] describes the design and evaluation of an AR experience using storytelling techniques, targeting visitors to a literary museum; developed in order to increase the museum's space, accessibility to its collections, and enhance the visitor experience, its impact is seen primarily with older adults who are the site's core audience.

At the Musée des Arts et Métiers Museum, they present an audio AR system (SARIM) based on adaptive gestures, where content personalization is a key design for the interaction experience, developed to capture user interests better while providing the most immersive and adaptive experience possible when visiting a museum.

Elena Spadoni and collaborators eight present a research project, MARSS, in which AR technology is effectively used alongside others to enhance the user experience of the Museo Astronomico di Brera located in Milan in order to design and develop a new digital journey inside the museum to allow different categories of visitors to enjoy the exhibition engagingly and interactively.

Unchana Klentien,[17] developed a prototype virtual museum for young people and identified key elements to be considered for designing and developing virtual museums. It involved three steps: studying the demands and expectations of virtual museums through surveys and visits, developing a virtual museum prototype, and having experts evaluate the prototype format, media presentation, virtual tools, and evaluation of quality and efficiency using the item-objective congruence index. The prototype received high scores from experts, university students, and others who evaluated it as appropriate for all elements.

AR applications have gained popularity in recent years; in the specific case of museums, their use can generate better work-life by decreasing human attrition within the staff of these centres; they can appeal to younger generations, thus increasing the audience and even facilitating the creation of new experiences not conceived within traditional approaches.

Daniel Kevin Kurniawana,[17] in his study on AR of relics in the British Museum, developed an AR application with the aim of decreasing the density in the museum, helping people to recognize the importance of relics, paintings and sculptures, which was recognized as easy to use and understand, interactive and informative.

Ali Khan et al.[5] propose an AR-based smartphone application that recognizes artefacts through real-time deep learning and retrieves supporting multimedia information for visitors at the Taxila Museum in Pakistan. The results show the proposed method's superiority over traditional guidance in providing enhanced user experience and bridging the gap between museum artefacts and visitors.

Mauricio Hincapié,[19] assessed the impact of an application when used during the guided tour of the Cisneros Market Square using AR and GPS. The results report improvements in learning about cultural heritage.

Dmitrii Kaplunab et al.[3] designed an app to show an archaeological site in Delphi. It was developed for high school students and allows playful exploring of the area, depending on the geological position of the user. Students can learn about important monuments of sacred Delphi and its history through interaction with the app. It allows them to become familiar with the cultural heritage sites of Chania, Crete, Greece.

Romiza, in 2021,[17] showed results that the Museum visitors' way of seeing could be enriched through the ADDIE Model. This ARAR application runs and provides users with a good impression and experience.

Cieutat et al.[20] explored the relevance of a mobile AR Tour as a tool to assist museum visitors. It constitutes an interface that

allows the description of museum exhibits, reporting improvements in linking visitors with the descriptions and exhibits, favouring the learning experience.

Diego Hernández Guzmán,[7] proposes the fusion of AR technology and Makerspace Museums as a powerful means to catalyze multifaceted learning experiences. The diversity of AR-enhanced activities, ranging from interactive simulations to role-playing and virtual field trips, is instrumental in engaging users with diverse perspectives, fostering an enriched understanding of conflict and resolution strategies.

Disadvantages

Mass adoption of modern technology in museums is a concern due to competitive labour costs, affordable accessibility, and the expectation of AR in real-world settings.[14] The authors also consider it important to highlight the need for qualified personnel for its use. AR technology requires a great deal of digital support, and in many cases, this can be a constraint.

Researchers have expressed concern about simulator sickness that the accessories, including headache, disorientation, and nausea, can cause.[12] Properly using AR props should be a priority within the site where they are employed; their adverse effects should be assessed and closely monitored; the authorship found no reports of these consequences within museums specifically.

Zeya He,[16] in her study on the role of AR in enhancing experiences in these centres, indicates that although AR visual animation designs appear eye-catching in many cases, they do not necessarily result in a better visitor experience. Dynamic visual animation could impede visitors' mental images in the art appreciation experience. *Aesthetic appreciation* is a personal experience requiring individuals' understanding and mental imagination.

The quality and reliability of AR kits used in exhibitions also pose challenges, as accurate tracking technology is crucial to augment digital content accurately. Designing inclusive immersive experiences for visitors with disabilities is another challenge, requiring consideration of hearing and visual impairments, mobility limitations, and cognitive differences.[11]

Among the main limitations of this research are its bibliographic nature, the fact that only Spanish and English bibliography was used, and the updating criteria within the articles to be used.

CONCLUSIONS

AR technology in museums makes it possible to captivate diverse audiences, adapt to the visitor's interests, remodel the design of exhibits, combine art and technology, improve understanding and ensure the positivity of the museum experience. This is ensured through mobile applications, accessories and websites.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Aaron Samuel Bracho Mosquera.
Data curation: Aaron Samuel Bracho Mosquera.
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