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Developing virtual museums towards the smart museum: a theoretical study

Research – English Summary

Marwa Mohamed Abd Elmagied
Director of Electronic Publishing, Technological Media and Digital Transformation, Ministry of Culture, Egypt
marwadesign25@gmail.com

Abstract
The study focuses on the latest advancements in virtual applications and virtual reality devices for displaying museum information. It reviews successive technological developments that have impacted virtual museums, culminating in the smart museum. This includes advancements in communication, artificial intelligence, metaverse, internet of nothings, and integration of virtual technologies. Emphasis is placed on showcasing libraries that have shown interest in virtual museums, highlighting the importance of museum information through virtual museum content in libraries, among other examples, to underscore its significance.

Keywords
Virtual Museum, Virtual Reality Technology, Artificial Intelligence, Metaverse

Study Problem

The study arises from the scarcity of research on hybrid museums and the future of smart museums, particularly in relation to the integration of virtual technologies. This evolution will inevitably be influenced by advancements in next-generation communication technologies (6G) and the concept of the Internet of Nothing.

Study Importance

This study explores the transformation of hybrid museums and the evolution of virtual museums into smart museums. It examines the role of the Internet of No Things, its connection to advanced communication technologies (6G) in the post-smartphone era, and the integration of virtual technologies. Additionally, it highlights the key devices used in advanced virtual museum applications.

Study Objectives

- Analyze the development of virtual museums leading to the emergence of smart museums.
- Examine the technologies and devices used in advanced virtual museum applications.

Study Questions

- How have virtual museums evolved into smart museums?
- What technologies and devices are utilized in advanced virtual museum applications?

Study Methodology and Tools

This study employs a descriptive research approach, reviewing relevant literature to establish a comprehensive theoretical framework.

Literature review

This section reviews the most significant Arab and international studies related to the research topic, arranged chronologically from the oldest to the most recent:

- Zakaria (2015) examined museums as information institutions that share the role of libraries and archives in preserving human heritage. The study focused on the application of information technology in Arab virtual

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museums, their role in providing museum-related information, and the importance of the internet in enhancing heritage preservation and accessibility. Using a field study approach on a sample of 39 museum websites, the study found that all sampled museums (100%) included artifact images, locations, and descriptive texts. Additionally, 56.4% utilized multimedia technologies, 35.9% provided virtual access to collections, and 76.9% included physical descriptions of artifacts. However, interactive information display was the least utilized feature (33.3%).

- Donia (2021) explored the use of augmented reality (AR) in museums to enhance visitor experiences. The study employed a case study approach, applying AR technology to a selection of educational museum collections at the Faculty of Arts, Tanta University, using the Zapper AR application. The findings highlighted that integrating AR into museum services significantly enhances educational, historical, cognitive, cultural, social, and economic value while improving visitor satisfaction. The study also noted that smartphones are the preferred platform for AR applications in museums due to their ease of implementation, low cost, reliability, and ability to support efficient AR applications.
- Al-Rayani (2021) investigated the foundations of museum display, particularly the application of virtual reality (VR) in presenting submerged artifacts from the Port of Alexandria. The study employed a descriptive-analytical and historical approach to design an internet-based virtual museum model and used questionnaires to gather data. The results emphasized the need for museum administrators to prioritize the development of virtual museum displays for underwater cultural heritage, ensuring broader accessibility beyond specialized researchers.
- Passebois & Euzéby (2021) examined hybrid museums within the context of museum marketing, focusing on France's approach to cultural heritage, historical events, and museum ecosystems. The study adopted a qualitative case study methodology, analyzing two French museums: *Cité du Vin* (Wine Museum in Bordeaux) and *Cité de l'Océan* (Museum in Biarritz). Findings were assessed from both an administrative perspective and the visitor experience perspective. The study concluded that hybrid museums play a crucial role in offering both educational and entertainment value. It also emphasized the need for further research in hybrid museum marketing strategies.

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- Al-Sharif (2022) emphasized the significance of virtual reality (VR) technology in preserving internal architectural heritage and ensuring its sustainability in the event of damage or destruction. Using a descriptive and analytical approach, the study focused on the archaeological interior architecture of the Great Pyramid, which is challenging to access in reality. The research problem highlights the need for modern display techniques to showcase archaeological interior architecture, thereby enhancing cultural heritage and enabling it to compete globally in the era of technological advancement. The study ultimately aimed to improve tourism and intellectual exchange between cultures through advanced visualization methods.

- Similarly, the study by Arayaphan, Sirasakmol, Nadee, and Puritat (2022) explored the impact of virtual reality on digital content preservation in museums. It particularly examined the effectiveness of VR in enhancing learning and motivation among university students unfamiliar with digital preservation in museums. The research employed a case study approach, applying VR technology to display ancient fabric at the Wing Yong Museum, alongside a quasi-experimental methodology. The findings highlighted VR's role as a valuable tool for learning and future career development, demonstrating its ability to boost student engagement in classrooms. The study underscored the necessity of integrating VR courses into library and information science curricula, particularly in the context of museums.

- Bao and Zhang (2022) conducted an analytical study that underscored the importance of artificial intelligence (AI) integration and VR environment design for digital museums. The study proposed a system structure for digital museum design, including software and hardware development for image processing, the selection and installation of appropriate lighting, and defining system requirements for VR-based modeling. The research concluded that AI-driven algorithms play a crucial role in generating dynamic and immersive visual effects, enhancing the realism of virtual environments for users.

- Sargsyan (2022) further reinforced the significance of combining augmented reality (AR) and VR technologies. While VR allows users to fully immerse themselves in virtual environments, AR blends digital and real-world elements through visual overlays. The study focused on the application of these technologies in museums, emphasizing their potential to enhance visitor engagement and ensure museum sustainability. Using the Mondville Archaeological Park as a case study, the research analyzed

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the impact of AR and VR on visitors' educational, aesthetic, and recreational experiences. Notably, the study demonstrated the feasibility of using standard cameras and headsets with AR technology as cost-effective alternatives to expensive eye-tracking systems for analyzing visitor interactions.

- Van Nguyen et al. (2022) explored the growing role of VR and AR in digital heritage, tourism, and museum applications. The study employed a case study approach to evaluate an application that integrates VR and AR for visualizing a virtual museum. A key outcome of the research was a new method for reconstructing 3D representations of tangible cultural heritage objects using a combination of engineering modeling, computer graphics, VR, and AR technologies. The study confirmed that this approach could also be applied in other fields, such as 3D gaming and digital tourism.

- Al-Hamrawi (2023) highlighted the future potential of virtual digital transformation in education. The study examined the effectiveness of a virtual museum with an integrated library in enhancing kindergarten teachers' knowledge of digital skills and their attitudes toward digital learning, aligning with Egypt's 2030 strategic vision for education. Using an experimental approach, the study involved a sample of 40 kindergarten teachers from the Bandar Damanhour Education Administration in Beheira Governorate. Research tools included a learning assessment test and a questionnaire. The findings revealed significant cognitive and performance improvements after implementing the virtual museum, leading to recommendations for workshops and training programs to enhance teachers' digital skills and promote VR-based learning in kindergartens.

- Study by Anastasovitis and Roumeliotis (2023) assessed the usability and user satisfaction of virtual applications featuring 3D artifacts in museums. The research involved a project that converted 2D-scanned images into high-resolution 3D digital reconstructions. Using a case study approach, the study conducted a quantitative evaluation involving 62 volunteers in a laboratory setting. The results confirmed high levels of user satisfaction and usability due to the accuracy and clarity of the 3D-rendered artifacts in the virtual museum application.

- The case study by Banfi et al. (2023) highlighted the significance of digitizing the Nazionale Museum in Rome through virtual reality (VR) and augmented reality (AR). These technologies have facilitated the digital preservation of artifacts and enabled the development of innovative virtual

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museum applications, including mobile platforms for museums and archaeological sites housing historical collections. The study underscored the value of virtual applications in delivering content in an engaging and interactive manner. It particularly focused on establishing a foundation for the development of virtual museum mobile platforms and proposed a web-based platform for one of ancient Rome's most historically significant sites.

A review of previous Arab and international studies reveals a consensus on the importance of hybrid museums, virtual technologies, and the digitization of museum information. However, prior research has not thoroughly explored the role of libraries in supporting virtual museums or the evolution of virtual museums toward the concept of a "smart museum." Furthermore, existing studies have yet to examine the integration of virtual museums with emerging technologies such as the Internet of No Things (IoNT) and next-generation communication systems (6G), marking a transition beyond the smartphone era.

Results

The study successfully verified its objectives and addressed the related research questions. The findings are as follows:

First Objective: The Evolution of Virtual Museums Towards Smart Museums

The study examined the development of virtual museums and their transition into smart museums. In response to the first research question:

What developments have virtual museums undergone to evolve into smart museums?

The findings highlight the relationship between virtual museums and advancements in web technologies, as well as their integration with virtual reality (VR) applications through wearable devices. These technologies enhance user immersion, allowing visitors to interact with collections in novel ways.

Key developments include:

- The integration of emerging technologies such as augmented reality (AR), extended reality (XR), and holograms to enhance visitor experiences.

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- The shift toward hybrid museums, combining virtual and physical elements to attract a broader audience.
- The potential impact of 6G technology, which will usher in the "Internet of No Things" era, closely linked to AI, the Metaverse, and immersive digital environments.
- The transformation of museums and libraries, especially virtual museums, through Metaverse technology, allowing for deeper and more interactive virtual experiences.
- The integration of blockchain, smart mobile robots, and AI-driven virtual assistants, which will play a pivotal role in shaping the next generation of smart museums.
- The transition beyond smartphones, leveraging 6G connectivity to enhance real-time, multi-sensory interactions in virtual and smart museum environments.

Second Objective: Devices Used in Advanced Virtual Museum Applications

The second research question addressed:

What devices are used in advanced virtual museum applications?

Technological advancements in virtual applications and communication systems have driven the development of cutting-edge display devices for virtual and smart museums. Several major technology companies, including Google, Facebook (Meta), and Microsoft, have invested in head-mounted and hand-worn devices, such as:

- Meta 2, designed for immersive virtual museum experiences.
- Oculus Rift and HTC Vive, which provide high-fidelity virtual environments.
- Wireless VR headsets, offering standalone, smartphone-independent virtual museum interactions.

These innovations enable more immersive and interactive museum experiences, enhancing engagement with historical and cultural content.

Recommendations

- Encourage further research into modern virtual technologies and their role in enhancing museum experiences.

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- Explore the potential of AI, blockchain, and 6G networks in shaping the future of smart museums.
- Invest in the development of interactive, hybrid, and fully virtual museum environments to attract and engage diverse audiences.

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