

Augmented Reality for Cultural Heritage: Bridging History and Technology in Museums*

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Abstract

This article examines the use of augmented reality (AR) technologies for the preservation and popularization of cultural heritage in museums. Augmented reality opens up new opportunities for combining history and modern technology, creating interactive and engaging ways for visitors to interact with cultural artifacts. By superimposing digital content on physical objects, AR allows for the provision of additional information, reconstruction of lost elements, and revival of historical events through visual and sound effects. The study covers the technical aspects of implementing AR in museums, including object recognition, creation of 3D models, and spatial positioning technologies. Particular attention is paid to the challenges associated with ensuring accessibility, authenticity of content, and its perception by different categories of users. It also provides examples of the successful use of AR in museums, demonstrating the impact of the technology on visitor engagement and their educational experience. An example of our own development of a mobile application for recognizing museum exhibits in the Republic of Kazakhstan using augmented reality technology is given. The authors present preliminary results of recognizing exhibits of a partner museum, describe the methodology used, and analyze the effectiveness of the proposed approaches. The results of testing a mobile application with recognition function in real museum conditions are also presented. It is shown that AR contributes to the preservation and popularization of cultural heritage, making it accessible to a wide audience. Recommendations are given for the effective implementation of AR in museum practice, emphasizing its potential for transforming approaches to the presentation of history in the digital age.

Keywords

cultural heritage, augmented reality, mobile application, object recognition, visualization

1. Introduction

In the era of digital transformation, technology has a significant impact on the preservation and promotion of cultural heritage. One of the most promising innovations that can combine historical heritage and modern technologies is augmented reality (AR). This technology allows you to superimpose digital information on real objects, creating interactive and exciting ways to perceive cultural artifacts. Museums, as custodians of cultural heritage, face a number of challenges, such as limited access to fragile or lost artifacts, the need to attract a young audience, and the creation of inclusive conditions for all visitors. In these circumstances, AR technologies are becoming a powerful tool that can not only solve these problems, but also offer new forms of interaction with the historical context.

AR technologies allow museums to expand the boundaries of physical space, offering visitors unique opportunities to explore history. With the help of augmented reality, it is possible to reconstruct lost architectural elements, revive historical events, visualize the processes of artifact creation, and provide additional layers of information that are not available in traditional exhibitions. The purpose of this article is to study the potential of using AR for the preservation and popularization of cultural heritage, as well as to identify key aspects of introducing the technology into museum practice. The paper considers technical approaches to the implementation

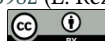
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of AR in museums, analyzes successful cases, and discusses the prospects for using the technology to increase engagement and educational value of the museum experience. The implementation of a proprietary mobile application using AR for the Abylkhan Kasteyev State Museum of Arts of the Republic of Kazakhstan is presented. To recognize exhibits in real time, the device's camera is used, which displays their 3D models and contextual information in augmented reality. The authors present preliminary results of recognizing exhibits of a partner museum, describe the methodology used, and analyze the effectiveness of the proposed approaches. The results of testing a mobile application with a recognition function in real museum conditions are also provided.

2. Related Works

Augmented reality (AR) has recently become a sought-after technology in the field of cultural heritage, providing innovative ways to interact with historical artifacts, objects and interpret them. This literature review provides recent studies in the field of cultural heritage conservation, their advantages and disadvantages.

One of the main benefits of augmented reality is its ability to enhance visitor engagement at cultural heritage sites. [1] proposed a framework that integrates AR, virtual reality (VR), and 3D printing to enrich visitor interaction and engagement with cultural heritage. A similar study was conducted in [2], which showed that augmented reality can enhance enjoyment and promote understanding of cultural heritage, thereby enhancing informal learning experiences. [3] proved that augmented reality applications can provide dynamic and interactive content, going beyond traditional text and audio guides, thus creating immersive experiences that resonate with visitors.

The evolution of AR from traditional 2D interfaces to immersive 3D environments has played a significant role in enhancing the experience of museum exhibits. It has been shown that AR can anchor digital content in the physical world, allowing users to interact with heritage objects in innovative ways [3]. The use of immersive technologies not only enriches the visitor experience, but also opens up new opportunities for educational initiatives. The authors in [4] provide developers and content creators with recommendations for implementing effective educational processes. This framework highlights the potential of AR to transform educational practices in cultural heritage contexts.

Sustainability is another important aspect of the application of AR in cultural heritage [5]. The use of AR in museums can contribute to sustainable practices by enhancing visitor experiences and ensuring the preservation of cultural artefacts [6]. Immersive technologies offer unique and immersive experiences by blending real-world elements with digital content [7]. This contributes to a deeper understanding of the vital role of VR in enhancing visitor experiences in museum settings. It also opens the way for further exploration and innovation in the field of immersive technologies.

The role of AR in the coverage of historical heritage is particularly evident in some studies. Thus, in [8] it is shown how AR can provide interactive information about historical sites, thereby improving the tourism sector. Their findings show that AR not only serves as an informative tool but also contributes to the overall development of cultural tourism. Similarly, a systematic literature review in [9] on the usability of AR mobile applications for cultural heritage reveals a growing body of research aimed at improving the user experience in this area. The condition of usability is crucial for the successful implementation of AR technologies in the field of cultural heritage.

The use of AR technologies is not limited to museums and tourist attractions; it also extends to educational contexts. [10] explores the use of Kinect technology in cultural heritage applications, demonstrating how AR can support interactive learning. This is supported by [11], which provides a comprehensive overview of AR applications in cultural heritage, highlighting the potential of the technology to transform visitor experiences. Their overview highlights the variety of methodologies and techniques used in AR applications, demonstrating the versatility of the technology in enhancing engagement with cultural heritage.

In addition to enhancing the visitor experience, AR can also play a significant role in the preservation of cultural heritage. [12] discusses the importance of modern technologies, including augmented reality, in the preservation and study of cultural heritage. They argue that AR can improve the user experience by providing contextual information about cultural artifacts, thereby facilitating a deeper understanding of heritage. This view is further supported in [13], which shows that an AR application developed to enhance the exploration of monuments, promoting engagement and preserving cultural heritage.

The integration of markerless AR systems has also been studied in the context of cultural heritage. [14] provides an overview of markerless AR applications, highlighting their importance in enhancing user interactions with cultural heritage sites. This approach allows for a more seamless integration of digital content with the physical environment, thereby enriching the visitor experience. [15] further explored cross-cultural differences in the adoption of mobile AR at cultural heritage sites, highlighting the need to consider cultural contexts when developing and implementing AR applications.

The application of augmented reality technologies in the context of cultural heritage depends on various factors. In [16], the key drivers of the use of augmented reality and virtual reality in cultural heritage sites were investigated, highlighting the importance of understanding user perceptions. It was shown that technological tools can significantly improve the core user experience in cultural heritage exhibits. This is also supported in [17], which compares virtual and mobile location-based augmented reality learning, revealing the emotional and educational outcomes associated with augmented reality applications.

The literature also addresses the challenges and opportunities that AR presents in cultural heritage. [18] conducted a bibliometric study that identified the proportion of AR research in specific regions, indicating the need for more research on AR applications in different cultural contexts. This highlights the potential of AR to bridge gaps in cultural heritage engagement, particularly in underrepresented regions.

Thus, the integration of AR into cultural heritage offers a wealth of opportunities to enhance visitor experiences, promote education, and ensure the sustainable conservation of historic sites. The literature shows growing recognition of the potential of AR to transform people's interactions with cultural heritage, facilitating deeper connections and understanding. As technology continues to evolve, further research will be important to explore the full impact of AR on cultural heritage and develop innovative applications that resonate with diverse audiences.

3. Development Methodology

Selection of technologies

The following key technologies were used to implement the project:

- Augmented reality (AR) – implemented using ARCore (for Android devices) and ARKit (for iOS), which ensures stable tracking of objects in space.
- Machine learning (ML) for exhibit recognition – deep learning models trained on the basis of convolutional neural networks (CNN) were used, which allows classifying museum objects by images.
- Unity 3D – selected as the main platform for developing the application, providing cross-platform support and integration with the AR SDK.
- Cloud database – Firebase was used to store data on exhibits, which allows for quick updating of information without the need to update the entire application.

Data collection and preparation

In collaboration with the Abylkhan Kasteyev State Museum of Arts of the Republic of Kazakhstan, exhibits were photographed from different angles to form a training dataset. The total number of images in the dataset was 10,000+ shots, including various lighting conditions and backgrounds.

The data was pre-processed. Low-quality images and those with strong shadows were removed, augmentation (contrast change, rotation, scaling) was performed to increase the model's robustness to real conditions, and key features of the exhibits were noted for their subsequent identification.

Recognition Algorithm

The processed data was used to train a machine learning model, which was YOLOv8 (You Only Look Once, version 8). This algorithm provides high accuracy and efficiency in detecting and classifying objects in images and videos. The YOLOv8n (nano) and YOLOv8s (small) models were used for training, which is due to the high ratio of the object size to the frame (more than 70%) and the accuracy of identification (more than 90%). Fast and accurate recognition is achieved by repeatedly passing the model through the entire dataset (training epochs).

Testing of the mobile application

The developed mobile application was tested in real museum conditions (Figure 1):

- During testing, the application was used to scan exhibits.
- The time for processing and displaying information was less than 2 seconds.
- Users noted the ease of navigation and the ability to obtain multimedia materials about each exhibit.

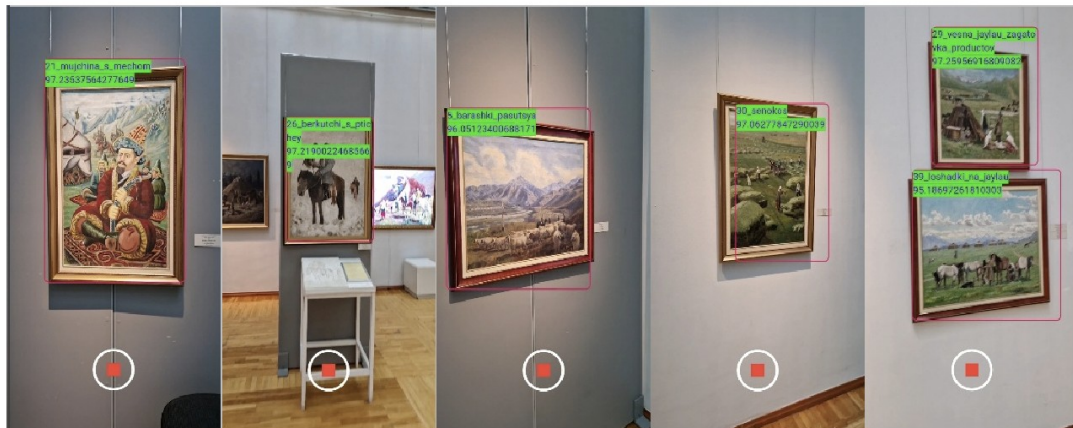


Figure 1: Mobile application testing

Some shortcomings requiring improvement were also identified:

- Problems with recognizing exhibits in difficult lighting conditions.
- Delays in loading 3D models with low internet connection speed.
- Limited set of exhibits in the database at the current stage of development.

Environmental factors such as lighting variability and optical interference significantly affect recognition accuracy. A recent study by Beknazarova and Kozhamzharova (2024) analyzes the degree of influence of natural phenomena on visualization systems, providing insights that may help in optimizing AR performance under real-world conditions [19].

4. Conclusion and development prospects

The presented mobile application project demonstrates high efficiency of museum exhibit recognition in real time using augmented reality technology. The developed methodology based on machine learning and AR technologies allows to significantly improve the interaction of visitors with museum objects.

To further improve the system, it is planned to:

- Expand the database and train the model on a wider range of images.
- Optimize image processing algorithms for operation in difficult lighting conditions.
- Add multimedia content, including audio guides and interactive excursions.

The results of the study confirm the prospects of introducing such technologies into the museum sphere, which contributes to the digitalization of cultural heritage and increased interest in history and art among a wide audience.

The presented research aligns with broader initiatives at IITU aimed at advancing immersive interaction technologies. In particular, our team recently published a related study on real-time hand and object recognition for virtual interaction [20] in PeerJ Computer Science. This research lays a methodological and technical foundation for applying gesture and object recognition in AR-based educational and cultural environments, such as the museum application discussed in this paper.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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