DEVELOPMENT OF VIRTUAL TOUR SYSTEMS FOR BUKHARA'S HISTORICAL SITES (THE SEVEN PIR SHRINES) BASED ON THE INTEGRATION OF VIRTUAL REALITY AND ARTIFICIAL INTELLIGENCE

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Abstract

This article provides an in-depth analysis of the digitalization of the famous Seven Pir shrines, which constitute an essential part of the spiritual and historical heritage of the Bukhara region, through the integration of modern digital technologies, particularly Virtual Reality (VR) and Artificial Intelligence (AI). Special attention is given to the development of remote pilgrimage tourism and the implementation of these technologies in educational processes. Furthermore, the article explores methods for reconstructing the architectural and spiritual characteristics of these sacred sites in virtual environments using advanced three-dimensional scene reconstruction architectures, such as 3D Gaussian Splatting and Neural Radiance Fields (NeRF).

Keywords: Virtual Reality, Artificial Intelligence, pilgrimage tourism, 3D Gaussian Splatting, Neural Radiance Fields (NeRF), life-experience-based learning environment, cultural heritage.

Introduction

The rapid development of the digital economy and information technologies worldwide has significantly influenced tourism, cultural heritage preservation, and education. The ancient city of Bukhara and its surrounding districts, recognized as one of Uzbekistan's historical treasures and a major center of Islamic civilization, continue to attract tourists from around the world with their centuries-old architectural monuments and sacred pilgrimage sites. In particular, the Seven Pir shrines, associated with prominent representatives of the Sufi tradition, are regarded as important sacred destinations not only in Uzbekistan but also throughout the Muslim world.

However, geographical distance, physical travel restrictions, climatic conditions, and the natural deterioration of historical monuments create certain challenges in making these sites accessible to a wider audience. Therefore, preserving these monuments for future generations and creating opportunities for their remote exploration have become essential requirements of the modern era.

The integration of Virtual Reality and Artificial Intelligence technologies provides a foundation for developing immersive environments that allow users not only to observe historical and spiritual sites through digital screens but also to virtually enter these environments and experience their historical atmosphere.

Theoretical Foundations and Architecture of VR and AI Technologies

Virtual Reality enables users to become fully immersed in a three-dimensional (3D) digital environment, while Artificial Intelligence systems make this environment interactive, dynamic, and adaptable to individual visitors. In particular, recently developed automated 3D scene reconstruction architectures, including 3D Gaussian Splatting and Neural Radiance Fields (NeRF), have significantly transformed the quality of virtual pilgrimage experiences.

Traditional 3D modeling requires considerable time and computational resources. In contrast, NeRF and Gaussian Splatting technologies enable the reconstruction of architectural details of the Seven

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Pir shrines, located across areas extending from Gijduvan to the Bukhara district, including the complexes associated with Khoja Abdulkhaliq Gijduvani, Khoja Bahauddin Naqshband, and other prominent spiritual figures.

These technologies offer the potential to reproduce individual brick patterns, tile colors, and architectural elements with a high degree of visual accuracy based on photogrammetric data. Under suitable acquisition and calibration conditions, they can support highly detailed spatial reconstruction, although millimeter-level geometric accuracy requires separate validation.

Furthermore, AI-based modules can contribute to optimizing rendering processes in VR headsets, reducing rendering latency, and ensuring rapid system responses to users' head movements. Such technological improvements are essential for creating realistic, comfortable, and immersive virtual environments.

Stages of Creating Virtual Environments for Bukhara's Seven Pir Shrines

The digitalization of the sacred Seven Pir shrines in the Bukhara region and the development of a VR/AI-based virtual tour system involve several consecutive stages.

Data Collection and Scanning

The initial stage involves collecting high-resolution drone imagery and 360-degree panoramic photographs around each of the Seven Pir pilgrimage sites, including historical complexes located in the Gijduvan, Romitan, Vobkent, and Kogon districts.

These visual datasets provide the foundation for reconstructing the spatial characteristics, architectural structures, and surrounding environments of the sacred monuments.

AI-Based Data Processing

At this stage, neural network algorithms are applied to remove image noise, correct lighting imbalances, and improve the overall quality of the collected visual data.

Subsequently, the 3D Gaussian Splatting model is employed to generate photorealistic spatial scenes, allowing historical monuments to be represented in an immersive virtual environment.

Development of Interactive Scenarios

An AI-powered virtual guide is integrated into the system to provide visitors with interactive information about the Seven Pir shrines.

The virtual guide is designed to answer users' questions through voice or text communication in Uzbek, English, and other languages, offering detailed explanations of the historical background, philosophical principles, and spiritual traditions associated with the Seven Pir Sufi heritage.

This functionality enables visitors to explore the pilgrimage sites according to their individual interests and educational needs.

Immersive Testing and Evaluation

The developed virtual environment is tested using VR headsets, including Meta Quest, Apple Vision Pro, and other compatible devices.

The evaluation process focuses on users' freedom of movement, interaction capabilities, visual comfort, and the overall usability of the virtual pilgrimage system.

These tests are essential for identifying technical limitations and improving the quality of the immersive experience.

Practical Significance in Education and Tourism

The practical implementation of the proposed digital system is of fundamental importance not only for advancing Uzbekistan's pilgrimage tourism potential but also for improving the intellectual and methodological quality of educational processes.

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In the contemporary global educational environment, digital transformation and the introduction of immersive technologies are increasingly recognized as important factors contributing to the development of students' cognitive abilities.

The integration of this VR/AI system into the curricula of higher educational institutions, particularly in the fields of history, philosophy, architecture, digital technologies, and tourism, as well as general secondary schools, can facilitate the development of a life-experience-based learning environment.

Unlike traditional educational approaches, this methodology allows students not only to acquire theoretical and statistical information but also to directly observe and study the lives of Bukhara's great spiritual masters, including Khoja Abdulkhaliq Gijduvani, Khoja Bahauddin Naqshband, and other prominent figures.

Moreover, students can explore the philosophical foundations of Sufism and examine the structural and architectural characteristics of historical monuments dating from the ninth to the sixteenth centuries within a virtual environment.

Such immersive experiences provide opportunities to develop a deeper understanding of historical and spiritual heritage through interactive observation and experiential learning.

In addition, the implementation of these technologies in the pilgrimage tourism industry can significantly improve access to Bukhara's sacred sites for potential visitors who face physical travel limitations or live in geographically distant regions.

Consequently, the development of virtual pilgrimage tourism may contribute to the international promotion of Uzbekistan's cultural and spiritual heritage while potentially encouraging greater interest in physical visits to the country.

AI-powered virtual guides can automatically personalize excursion scenarios according to each visitor's interests, educational background, and spiritual needs.

This adaptive approach can enhance the effectiveness of educational activities, cultural communication, and the dissemination of historical knowledge.

Furthermore, the proposed system may serve as an innovative digital platform for promoting the Seven Pir heritage among international audiences, strengthening cultural exchange, and supporting sustainable tourism development.

Conclusion

In conclusion, the digitalization of Bukhara's sacred Seven Pir shrines through the integration of Virtual Reality and Artificial Intelligence technologies represents a promising strategic approach to preserving the rich spiritual and historical heritage of great scholars and spiritual masters, promoting this heritage internationally, and creating an advanced intellectual and interactive educational environment for future generations.

The proposed system not only expands the geographical accessibility of pilgrimage tourism but also plays an important role in educating younger generations in the spirit of national identity, cultural awareness, and respect for historical heritage.

The combination of immersive visualization, intelligent virtual guidance, and advanced 3D reconstruction technologies creates new opportunities for the preservation, interpretation, and dissemination of cultural heritage.

Future research should focus on further improving the proposed system and developing global multi-user virtual pilgrimage and distance-learning platforms operating in real time.

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The implementation of such platforms remains a relevant scientific and practical objective in the fields of digital heritage preservation, educational innovation, and intelligent tourism technologies.

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