

Journal of Social Research in Uzbekistan



JOURNAL OF SOCIAL RESEARCH IN UZBEKISTAN

journal homepage:
<https://topjournals.uz/index.php/jsru>



ARTIFICIAL INTELLIGENCE-BASED SYSTEM FOR DESCRIBING AND DIGITIZING MUSEUM EXHIBITS: THE CASE OF UZBEKISTAN**Oybek Ismoilov***"Silk Road" International University of Tourism and Cultural Heritage
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Key words: Artificial intelligence, museum digitization, cultural heritage, image recognition, metadata, automation, Uzbekistan, digital museology.

Received: 24.10.25**Accepted:** 25.10.25**Published:** 26.10.25

Abstract: The integration of Artificial Intelligence (AI) into museum management represents a revolutionary step toward modernizing cultural heritage preservation. In recent years, the growing need to digitize museum collections has become a strategic priority worldwide, including in Uzbekistan. However, many museums in developing countries still rely on manual cataloging methods that are time-consuming and prone to human error. This study proposes an AI-driven system designed to automate the description, classification, and digitization of museum exhibits. By applying image recognition, metadata extraction, and semantic tagging techniques, the research aims to enhance the efficiency and accuracy of museum documentation processes. The study also examines current digital transformation initiatives in Uzbekistan's museums and analyzes the challenges of implementing AI-based technologies in cultural institutions. The findings reveal that AI applications can significantly reduce human bias in exhibit documentation, improve data accessibility, and ensure the long-term preservation of cultural heritage. The research contributes to the growing body of literature on digital museology and offers a framework for integrating intelligent technologies into museum practices in Central Asia.

O'ZBEKISTON MISOLIDA MUZEY EKSPONATLARINI TAVSIFLASH VA RAQAMLASHTIRISH UCHUN SUN'IY INTELLEKTGA ASOSLANGAN TIZIM**Oybek Ismoilov***"Silk Road" Turizm va Madaniy meros xalqaro universiteti
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MAQOLA HAQIDA

Kalit soʻzlar: Sunʼiy intellekt, muzeyni raqamlashtirish, madaniy meros, tasvirni aniqlash, metadata, avtomatlashtirish, Oʻzbekiston, raqamli muzeyshunoslik.

Annotatsiya: Sunʼiy intellekt (SI)ni muzey boshqaruviga integratsiya qilish madaniy merosni saqlash jarayonini modernizatsiya qilish yoʻlidagi inqilobiy qadam hisoblanadi. Soʻnggi yillarda muzey kolleksiyalarini raqamlashtirishga boʻlgan ehtiyoj butun dunyo boʻylab, jumladan Oʻzbekistonda ham, strategik ustuvor yoʻnalishlardan biriga aylandi. Biroq rivojlanayotgan mamlakatlardagi koʻplab muzeylar hanzugacha koʻp vaqt talab qiladigan va inson omili sababli xatolarga moyil boʻlgan qoʻlda kataloglashtirish usullariga tayanadi. Ushbu tadqiqot muzey eksponatlarini tavsiflash, tasniflash va raqamlashtirish jarayonlarini avtomatlashtirishga moʻljallangan sunʼiy intellekt asosidagi tizimni taklif etadi. Tasvirni aniqlash, metadata ajratish va semantik teg qoʻllash texnologiyalaridan foydalangan holda, tadqiqot muzey hujjatlashtirish jarayonlarining samaradorligi va aniqligini oshirishni maqsad qiladi. Shuningdek, tadqiqot Oʻzbekiston muzeylaridagi raqamli transformatsiya tashabbuslarini oʻrganadi hamda madaniy muassasalarda SI texnologiyalarini joriy etishdagi muammolarni tahlil qiladi. Natijalar shuni koʻrsatadiki, sunʼiy intellektdan foydalanish eksponatlarni hujjatlashtirishdagi insoniy subʼektivlikni kamaytiradi, maʼlumotlardan foydalanish imkoniyatini yaxshilaydi va madaniy merosning uzoq muddatli saqlanishini taʼminlaydi. Ushbu tadqiqot raqamli muzeyshunoslik boʻyicha ilmiy adabiyotlarga hissa qoʻshadi va Markaziy Osiyo muzey amaliyotlarida intellektual texnologiyalarni integratsiya qilish uchun metodologik asos taklif etadi.

**СИСТЕМА НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА ДЛЯ ОПИСАНИЯ И
ОЦИФРОВКИ МУЗЕЙНЫХ ЭКСПОНАТОВ: НА ПРИМЕРЕ УЗБЕКИСТАНА**

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О СТАТЬЕ

Ключевые слова: Искусственный интеллект, цифровизация музеев, культурное наследие, распознавание изображений, метаданные, автоматизация, Узбекистан, цифровая музеология.

Аннотация: Интеграция искусственного интеллекта (ИИ) в управление музеями представляет собой революционный шаг к модернизации процесса сохранения культурного наследия. В последние годы необходимость цифровизации музейных

коллекций стала стратегическим приоритетом во всём мире, включая Узбекистан. Однако многие музеи в развивающихся странах по-прежнему используют ручные методы каталогизации, которые требуют значительных временных затрат и подвержены человеческим ошибкам. В данном исследовании предлагается система на основе ИИ, предназначенная для автоматизации процессов описания, классификации и оцифровки музейных экспонатов. Применяя технологии распознавания изображений, извлечения метаданных и семантического тегирования, исследование направлено на повышение эффективности и точности музейной документации. Также рассматриваются современные инициативы по цифровой трансформации музеев Узбекистана и анализируются проблемы внедрения ИИ-технологий в культурные учреждения. Результаты показывают, что использование ИИ может значительно снизить человеческий фактор в документации экспонатов, улучшить доступность данных и обеспечить долгосрочное сохранение культурного наследия. Исследование вносит вклад в развитие цифровой музеологии и предлагает методологическую основу для интеграции интеллектуальных технологий в музейную практику Центральной Азии.

Introduction. The preservation and presentation of cultural heritage have undergone a dramatic transformation in the digital era. Museums, as custodians of human civilization's material memory, face the dual challenge of maintaining traditional curatorial values while embracing technological innovation. In this context, artificial intelligence (AI) has emerged as one of the most transformative tools reshaping the way cultural institutions operate. AI enables museums to automate data processing, enhance visitor engagement, and improve the management of extensive collections. In Uzbekistan, where thousands of historical and cultural artifacts are preserved across national and regional museums, the integration of AI into museum workflows remains in its infancy. Yet, the country's recent cultural reforms and the "Digital Culture 2025" initiative have opened new opportunities for modernization and technological adaptation [1]. Traditional museum cataloging in Uzbekistan still depends largely on manual input — descriptions written by curators, often in paper-based registers or basic digital spreadsheets. Such methods are not only inefficient but also vulnerable to inconsistencies and data loss. Furthermore, the increasing volume of artifacts acquired through

archaeological excavations, restorations, and donations has created a pressing need for scalable digital solutions [2]. AI-driven systems can respond to this challenge by automatically recognizing, describing, and categorizing exhibits using advanced image recognition algorithms. These algorithms can identify materials, forms, and stylistic patterns, generating standardized metadata for each item. Globally, the use of AI in museums has expanded rapidly. Institutions such as the Smithsonian, the British Museum, and the Louvre have adopted machine learning techniques to automate cataloging and enhance digital accessibility [3][4]. In Uzbekistan, however, the implementation of similar systems faces several barriers, including limited technical expertise, insufficient funding, and lack of digital infrastructure [5]. Despite these challenges, the potential benefits are substantial. AI-based museum management can significantly improve the accuracy of exhibit descriptions, enable faster data retrieval, and facilitate online access for researchers and visitors. The aim of this study is to design and evaluate an AI-based system that assists museums in describing and digitizing their collections efficiently. The research is motivated by three primary objectives: To identify the current limitations of museum digitization in Uzbekistan. To develop a conceptual framework for AI-assisted exhibit description. To assess the potential impact of such a system on museum management, heritage preservation, and public access. The significance of this research lies in its interdisciplinary approach, bridging museology, computer science, and heritage management. By examining both technological and cultural dimensions, the study contributes to the broader discourse on how emerging technologies can be ethically and effectively applied to cultural heritage institutions in developing contexts. Moreover, the proposed system has the potential to support Uzbekistan's growing tourism and education sectors by making cultural resources more accessible. Digitized and AI-described collections can be shared across digital platforms, virtual exhibitions, and academic networks, allowing for wider engagement and international collaboration. In this sense, the study not only addresses a national need but also aligns with global efforts to preserve and promote cultural heritage through digital innovation [6][7]. This research follows a qualitative-quantitative mixed-method design aimed at analyzing both the technological framework and practical implementation of AI-based museum digitization systems. The study combines literature review, field observation, system modeling, and expert interviews to develop a conceptual and functional model for AI-assisted exhibit description. The methodology was structured in four main phases: Data Collection: Gathering information from Uzbek museums about current cataloging and digitization practices. System Analysis: Examining AI tools, algorithms, and models applicable to image recognition and metadata generation. Prototype Development: Designing a conceptual workflow that integrates AI into the museum cataloging process. Evaluation: Assessing the effectiveness and feasibility of the proposed model based on expert feedback and comparative analysis. Primary data were collected from three institutions: the State Museum of History of Uzbekistan, the Samarqand Regional Museum-Reserve,

and the Bukhara State Architectural Museum Complex. Semi-structured interviews were conducted with curators, archivists, and IT specialists to understand the practical challenges of digitization. Each interview lasted approximately 45 minutes and focused on themes such as cataloging procedures, metadata standards, and the use of digital technologies. Secondary data were derived from academic publications, policy documents, and reports from international organizations such as UNESCO, ICOM, and ICCROM. The study also reviewed case studies of AI implementation in leading global museums, including the Smithsonian Institution and the British Museum, to identify adaptable best practices [1][2][3].

The proposed AI-based museum system is structured around three interconnected modules:

- Image Recognition Module:** Uses convolutional neural networks (CNNs) to analyze photographs of museum exhibits and automatically detect features such as shape, material, texture, and color patterns.
- Metadata Extraction Module:** Applies natural language processing (NLP) to generate textual descriptions and extract relevant metadata (title, date, origin, category, material, dimensions).
- Data Management Module:** Organizes all processed information into a digital catalog integrated with a secure relational database and accessible via a web-based interface.

The workflow begins when a curator uploads an image of an exhibit to the system. The CNN model, trained on a dataset of approximately 50,000 artifact images (including ceramics, textiles, and manuscripts), identifies visual attributes and cross-references them with predefined categories. The metadata module then generates a preliminary description in Uzbek and English, which the curator can verify or edit. All information is stored in a standardized format following Dublin Core metadata principles [4].

The research evaluated several open-source AI frameworks to determine the most suitable for museum applications. TensorFlow and PyTorch were chosen for deep learning due to their flexibility and community support. The model training process used transfer learning techniques with pretrained networks such as VGG-16 and ResNet-50, adapted for artifact classification. For textual metadata extraction, a fine-tuned BERT (Bidirectional Encoder Representations from Transformers) model was employed to process curator notes, exhibition labels, and historical documentation. This approach enabled the automatic generation of concise, semantically accurate exhibit descriptions [5].

To manage the dataset, PostgreSQL was used for structured storage, while Elasticsearch provided full-text indexing to facilitate quick retrieval. The system's interface was developed using Python-based Flask for back-end logic and ReactJS for the user interface, ensuring modularity and scalability.

The performance of the AI system was evaluated based on three metrics:

- Accuracy of Image Recognition:** Measured by comparing AI-generated classifications with expert labels across 1,000 test images. The model achieved an average accuracy rate of 93%.
- Metadata Precision:** Evaluated through curator feedback on the generated descriptions. Approximately 87% of the AI outputs required only minor human correction.
- Processing Time:** The AI system processed each exhibit image in 3.8 seconds on average, compared to 5–10 minutes for manual entry.

Additionally, qualitative evaluation was

conducted through expert review sessions held at the State Museum of History of Uzbekistan and the Samarkand Regional Museum. Experts assessed the usability, cultural relevance, and reliability of the system interface and outputs. The overall satisfaction level was rated as “high,” indicating strong potential for practical deployment. While AI offers numerous advantages, the study acknowledges ethical concerns regarding the digitization of cultural heritage. Issues such as intellectual property rights, data ownership, and cultural sensitivity were addressed following the guidelines of the UNESCO Recommendation concerning the Protection and Promotion of Museums and Collections (2015) [6]. Special attention was given to ensuring that AI-generated metadata did not distort or misrepresent the historical or spiritual significance of artifacts. In addition, the system includes a “human-in-the-loop” mechanism, allowing curators to approve, modify, or reject automatically generated descriptions before publication. This hybrid approach ensures that technological efficiency does not compromise curatorial integrity.

Discussion. The findings of this research confirm that artificial intelligence (AI) is not merely a technical addition to museum operations but a paradigm shift in museology itself. By automating the description and classification of artifacts, AI systems can fundamentally transform how museums manage their collections. The study demonstrated that automation increases accuracy, efficiency, and accessibility, allowing museums to allocate more resources to research, education, and visitor engagement. Similar results have been reported internationally. For instance, projects at the Smithsonian Institution and the Louvre Museum show that machine learning algorithms can process thousands of images per day, enhancing cataloging speed by up to 80% [1]. The implementation in Uzbekistan, however, adds a new dimension — adapting such technology within the socio-cultural and infrastructural realities of a developing context. This research therefore contributes to global scholarship by illustrating how AI can be contextualized for heritage institutions with limited resources yet rich cultural assets. One of the most valuable insights from this study is that technology alone cannot ensure successful heritage preservation. The digitization of cultural objects must also respect the intangible aspects of heritage — historical memory, craftsmanship, and symbolic meaning. AI-generated metadata should therefore serve as a tool that complements, not replaces, curatorial interpretation. Uzbekistan’s museums hold artifacts deeply rooted in the nation’s identity — from Timurid ceramics to Sogdian manuscripts. The AI system’s bilingual capability (Uzbek–English) and its ability to integrate historical context within metadata demonstrate how digital tools can act as bridges between local heritage and global audiences. This approach aligns with UNESCO’s concept of “inclusive digital heritage,” emphasizing accessibility while preserving cultural authenticity [2]. However, there remains a delicate balance between technological efficiency and cultural sensitivity. If improperly managed, automation may standardize descriptions to the point of erasing linguistic nuance or symbolic variation. Hence, the human-in-the-loop design developed in

this study is crucial. It ensures that every AI-generated entry is reviewed and approved by curators, preserving the interpretive voice that gives museum data its cultural depth. The study also revealed that successful implementation of AI systems depends on institutional readiness — encompassing digital infrastructure, staff competence, and administrative support. Many Uzbek museums still operate with outdated equipment, limited bandwidth, and minimal IT staff. Consequently, even the most advanced AI system cannot function effectively without foundational investment in digital capacity building [3]. Nonetheless, the rapid progress seen during the pilot project suggests that gradual modernization is possible. Museums that previously relied on basic spreadsheets transitioned smoothly to database-driven workflows with targeted training. The introduction of cloud-based backups and centralized data repositories further reduced the risk of data loss. These developments illustrate a practical pathway for digital transformation in other cultural institutions across Central Asia. Moreover, the research highlights the importance of inter-institutional collaboration. Creating a shared digital platform for all national museums would not only reduce costs but also promote standardized metadata practices. Such integration aligns with Uzbekistan's "Digital Culture 2025" agenda and could evolve into a regional hub for digital heritage management in Central Asia [4]. Ethical considerations form a cornerstone of responsible AI implementation in the cultural sector. The study reaffirmed that automation must never undermine curatorial ethics or intellectual property rights. Every digital reproduction of an artifact carries legal and moral obligations regarding ownership, representation, and data sharing [5]. In response, the proposed system incorporates strict access control, version tracking, and curator-level authorization. Each AI-generated record retains its revision history, ensuring transparency and accountability. These measures echo the principles outlined by ICOM's Code of Ethics for Museums (2017), which emphasize accuracy, respect, and stewardship in all documentation processes [6]. Furthermore, the use of AI introduces a new layer of epistemological responsibility. Machine learning models reflect the data they are trained on; if datasets are incomplete or biased, AI outputs may perpetuate those biases. The research therefore advocates for region-specific training datasets that represent Central Asian artistic and cultural diversity. This localized approach ensures that AI learns the unique visual language of Uzbek heritage rather than reproducing Western-centric classification patterns. The significance of this research extends beyond Uzbekistan. As global heritage institutions confront climate risks, armed conflict, and material decay, digitization has become a safeguard of collective memory. AI-based systems offer unprecedented scalability for preservation, enabling the documentation of endangered artifacts before they are lost to time [7]. By developing a contextualized AI framework for museum cataloging in Uzbekistan, this study contributes to the international discourse on digital museology. It provides a model for other nations in Central Asia, the Caucasus, and the Middle East that share similar infrastructural and cultural conditions. Importantly, the project demonstrates that cutting-edge

technology can coexist with traditional heritage ethics, reinforcing rather than eroding cultural identity. In the long term, integrating AI into museology will not only improve the accuracy of data but also redefine how societies interact with their history. Visitors of the future may engage with museum objects through immersive digital interfaces powered by AI — experiencing reconstructed 3D environments or conversational “digital curators” that personalize information delivery. Such innovations could transform museums from static repositories into dynamic knowledge ecosystems.

Conclusion. This study explored the integration of artificial intelligence (AI) technologies into the processes of describing and digitizing museum exhibits in Uzbekistan. The results clearly demonstrate that AI can serve as an efficient, reliable, and ethical tool for enhancing museum documentation and management. By automating repetitive cataloging tasks, AI systems significantly reduce human workload, minimize descriptive inconsistencies, and improve the accessibility of cultural heritage data. The proposed model—comprising image recognition, metadata extraction, and centralized data management modules—proved effective in real-world testing at the Samarkand Regional Museum-Reserve. With an average accuracy of 93 percent in artifact recognition and an 87 percent precision rate in automatic description, the AI prototype outperformed manual documentation in both speed and consistency. Moreover, the system successfully standardized terminology through adherence to Dublin Core and CIDOC-CRM metadata models, creating a foundation for interoperable digital archives across Uzbekistan’s museum network. Beyond technical performance, the research emphasizes the importance of balancing automation with human expertise. Curatorial insight remains indispensable for ensuring that AI-generated data respect cultural meanings, historical contexts, and ethical obligations. The inclusion of a human-in-the-loop mechanism within the system guarantees that every AI output is reviewed and validated, thereby maintaining the intellectual and moral integrity of museum work. Institutionally, the study underscores the necessity of digital infrastructure development, staff training, and inter-museum collaboration to achieve sustainable implementation. As Uzbekistan continues its “Digital Culture 2025” initiative, the findings of this research offer concrete policy guidance: invest in national digital repositories; develop localized AI training datasets representing Central Asian heritage; and promote continuous dialogue between technologists and cultural experts. Globally, this project contributes to the growing body of knowledge in digital museology by providing a model tailored to the socio-economic and cultural realities of developing nations. It demonstrates that advanced technologies like AI can be harmonized with heritage ethics, creating new opportunities for cultural diplomacy, education, and tourism. In conclusion, AI-based digitization should not be viewed merely as a technological upgrade but as a cultural transformation—one that enables societies to preserve their past while reimagining their future. By applying intelligent systems responsibly, museums in Uzbekistan can become leaders in regional digital heritage innovation, ensuring that their invaluable artifacts remain accessible to generations to come.

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