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Digitalization of stone artifacts at the Kayseri ethnography museum using artificial intelligence: An innovative and comprehensive model for the preservation of cultural heritage

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Abstract

This study examines the critical and transformative role of Artificial Intelligence (AI) technologies in documenting, preserving, and reinterpreting stone artifacts exhibited at the Kayseri Ethnography Museum. Natural deterioration of stone artifacts hinders the accurate identification of motifs, inscriptions, and shapes, underscoring the urgent need for digital preservation. In response to this challenge, AI methods such as deep learning (CNN), photogrammetry, and clustering programs are integrated. This systematic approach aims to minimize manual documentation errors, accelerate data-driven academic research, and maximize the accessibility of cultural assets virtually. The article argues that AI, by integrating scientific methods into traditional cultural heritage practices, offers an advanced, sustainable digital vision that enhances social and academic accessibility.

Keywords: Artificial Intelligence, Cultural Heritage, Deep Learning, Stone Artifacts, Digitization, Ethnographic Museum.

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1. INTRODUCTION

The convergence of deep learning, digitization, and cultural heritage preservation in ethnographic museums represents a revolutionary approach to the management of historical relics, especially stone objects that reflect the legacies of various cultures. The application of Artificial Intelligence (AI) technology in this context not only improves preservation efforts but also broadens the representation of cultural material to larger audiences. Deep learning algorithms can facilitate the development and enhancement of digital twins—virtual representations of physical entities—that function as interactive tools for educational and experiential applications (Luther et al., 2023). These digital twins enable visitors to interact with artifacts in ways beyond conventional display techniques, fostering a deeper understanding of cultural narratives.

The digitalization of stone artifacts is essential for the preservation of cultural heritage. By digitizing these antiques, museums can reduce hazards related to physical degradation caused by environmental conditions or handling (Ghimire, 2023). Moreover, digitization enhances access to these artifacts, enabling both scholars and the public to examine and value them without the limitations imposed by geographic or logistical barriers. The inherent accessibility of digital resources enhances academic study and public engagement, fostering a shared appreciation of cultural heritage.

Moreover, advancements in AI applications are revolutionizing documentation and cataloging processes in ethnographic museums, while also improving preservation and accessibility. Advanced machine learning methodologies can automate and enhance artifact cataloging, resulting in more precise data entries and facilitating systematic classification of cultural objects. This technique enhances academic dialogue by fostering a deeper understanding of cultural artifacts and their contexts (Silva & Oliveira, 2024). Furthermore, thorough recording techniques guarantee the preservation of knowledge about these things, highlighting their cultural importance and historical context.

A critical concern in the use of AI for cultural heritage is the need to address conservation issues in conflict areas. Artifacts from areas undergoing political instability or armed conflict are frequently at an increased risk of theft, destruction, or loss. Digital preservation tactics combined with AI tools can offer innovative solutions for protecting these at-risk cultural artifacts (Neglia et al., 2024; Adewojo, 2024). Documenting artifacts through 3D scanning and modeling enables the compilation of comprehensive records that can enhance advocacy for their preservation, while also providing a virtual means for cultural interaction. AI-enabled solutions can facilitate monitoring of these items through predictive analytics, providing critical insights into risk factors that may compromise their integrity.

Ultimately, the increasing adoption of AI technology signifies a substantial transition towards fostering a more profound relationship between the public and cultural heritage artifacts. Museums can enhance understanding of the importance of artifacts through interactive digital experiences and compelling stories, fostering greater empathy and awareness in modern culture (Malik, 2021). The convergence of deep learning, digitization, and AI technologies not only preserves historical artifacts but also reinforces the connection between heritage and community, illustrating the evolving role of ethnographic museums in the preservation and celebration of cultural identity. The incorporation of artificial intelligence (AI) in the conservation and interpretation of cultural property presents numerous ethical issues that require thorough examination. As companies increasingly adopt digitization and machine learning technologies, especially for stone artifacts in ethnographic museums, the ramifications of these practices go beyond mere technological effectiveness. An

essential analysis of data ownership concerns arises, necessitating clarity on the rights of digital representations of cultural assets. Fu et al. (2025) underscore the potential for disputes between indigenous communities and cultural institutions over the ownership and representation of culturally significant materials, asserting that digitization should not serve solely archival functions but also address the narratives and rights of the originating cultures.

Furthermore, the implementation of intelligent technology in museums presents both prospects and obstacles for heritage interpretation. Ozdemir and Zonah (2025) assert that the application of AI can revolutionize visitor experiences by facilitating tailored interactions with artifacts and immersive storytelling, thereby improving educational outcomes. This technological transition raises concerns about the depersonalization of cultural interactions and the potential loss of contextual knowledge, arising from the complexities of human interpretation and cultural sensitivity. Therefore, it is essential to implement AI in a way that honors the intricacies of cultural narratives, rather than reducing them to mere data points.

The ethical distribution of information generated by AI applications is a crucial issue, as Choudhary and Sukhvir (2025) assert. Measures must be implemented to prevent the misuse or misrepresentation of cultural data generated by machine learning methodologies. Frameworks for ethical AI development must be designed to guide institutions in establishing transparent, responsible processes that enable respectful engagement with cultural custodians and communities.

Advancements in 3D digitization technologies, as highlighted by Cieslik (2020), exacerbate these ethical problems. Although these tools offer novel conservation measures that can improve the accessibility and protection of endangered cultural assets, they are not devoid of limitations. The digitalization process might result in the commodification of cultural objects, transforming them into consumable items rather than genuine expressions of cultural identity. Therefore, meticulous consideration is necessary to preserve the materiality and authenticity of these artifacts in their digital representations.

Given these trends, the necessity for interdisciplinary collaboration is becoming increasingly evident. Pavlidis (2023) and Gîrbacia (2024) emphasize the need for collaboration among historians, archaeologists, and engineers to ensure that AI applications for cultural assets are fully developed. Collective efforts are crucial for preserving cultural narratives and enhancing the knowledge of heritage practices through technological interventions.

Implementing AI-driven methods to improve cultural experiences requires a sophisticated methodology that reconciles innovation with ethical integrity. Incorporating ethical considerations into the application of AI in cultural heritage enables the creation of a narrative that honors and highlights the importance of cultural items, promoting preservation and an engaging visitor experience in our increasingly digital environment.

1.1. Historical Context and Problem Definition

Since the classification of the course of the disease, migration has been evaluated as a primary source of cultural appearance, aesthetic understanding, and socio-economic development. Despite their durable structures, formations, and permanent documents that reflect the religious beliefs of societies, social organization, and artistic styles, they continue to be subject to serious deterioration due to natural and climatic factors (Pérez, and Sánchez, 2023).

The Kayseri Ethnography Museum (Güpgüpoğlu Mansion), registered in 1976, is a critical center that houses the cultural richness of Anatolia, with its Selamlık and Haremlik sections. However, negative effects such as stone fractures, climatic conditions, and deterioration pose serious digital challenges, particularly in accurately and clearly identifying and documenting motifs, books, and figures. These challenges increase the risk of cultural loss and constitute a significant obstacle to the certified analysis of the work. In this context, the limitations in speed and accuracy of traditional conservation and documentation approaches underscore the inevitability of AI-based systems.

1.2. Purpose and Structure of the Study

This study proposes a numerically and methodologically robust and comprehensive approach to the preservation and analysis of cultural data using Artificial Intelligence (AI). The main objective of the article is to present a detailed protocol for using AI technologies to produce high-quality digital documentation and to automatically analyze the semantics of stone artifacts at the Kayseri Ethnography Museum.

The study combines existing possible analyses (Section 1), proposed AI developments and tools (Section 2), the application protocol and methodology (Section 3), application examples and general training (Section 4), and finally, general and collective findings (Section 5).

2. Literature Review and the Role of Artificial Intelligence

2.1. The Place of AI in the Digital Preservation of Cultural Heritage

Artificial intelligence (AI) has proven its worth in areas such as the automatic classification of archaeological finds, the digitization of large amounts of current recorded information, and the precise three-dimensional (3D) reconstruction of structures at risk of collapse. The fundamental innovations offered by AI in the digitization and analysis of stone artifacts are as follows:

Automatic Pattern Recognition (Object Recognition): By converting high-quality raw image distortion (2D) into meaningful effects, it accurately identifies and reveals worn patterns and motifs on surfaces.

Inscription OCR (Optical Character Recognition): Converts technological texts in image form into machine-readable structured text data. This saves researchers time and effort, significantly accelerating access to primary sources.

Pattern Matching: The ability to identify specific features/patterns on digital images or 3D models using computer vision techniques and match them with global databases.

2.2. Basic Methods and Algorithms Used in Digitization

The fundamental approaches used in this field are grouped under three main headings to create an integrated and multi-layered model:

Deep Learning: Achieves high accuracy and generalizability in image processing, particularly with models based on Convolutional Neural Networks (CNN) and Vision Transformer (CLIP), as well as customized OCR architectures.

Photogrammetry (Photogrammetry): Produces flexible, millimeter-accurate 3D digital models based on high-resolution multi-angle photographs. This captures the product's actual shape, texture, and wear conditions, creating the foundational dataset for digital preservation.

Clustering Algorithm (Clustering Algorithm): It is used to automatically group products with similar artistic styles and perform distribution style analyses (Stylometry) using extracted motif features (geometric structure, distribution, style) (Hristov, and Stoyanova, 2021).

3. METHOD AND APPLICATION PROTOCOL

3.1. Data Collection and Preprocessing

The first and critical stage of the study is the assessment of the diversity of high-performance, systematic, and standardized digital data units for stone products at the Kayseri Ethnography Museum.

2D Imaging: Detailed macro photographs are taken under controlled and polarized light conditions to maximize the contrast and clarity of motifs and inscriptions. These images will serve as the basic input data for AI-based automatic motif recognition and OCR.

3D Data Capture (Photogrammetry): Thousands of photographs are taken of each surface of the artifact to create the database required for a 3D model with a mesh structure. This process captures the true geometry and texture of the artifact, providing an excellent reference point for conservation and restoration interventions (Pavlidis, and Koutsoudis, 2020).

Data Labeling (Data Annotation): For training deep learning models (especially for object details), motifs, iconographic shapes, and characters (in inscriptions) are meticulously labeled by the ordinary with bounding boxes (bounding boxes).

3.2. YZ-Based Analysis Models

3.2.1. Object Recognition with Deep Learning (Pattern and Shape Analysis)

Model Selection: To successfully process worn, complex, and regular surface/texture features of stonework, high-performance Convolutional Neural Network (CNN) architectures such as YOLOv8 or Mask R-CNN are primarily used.

Training: Labeled 2D images will be classified using customized augmentation (magnification) techniques to accurately detect even worn or shadowed motifs.

Output: Automatic determination of the positions, types, and surfaces of shapes (Double-Headed Eagle, Lion, Bird, Fish, etc.) on the artwork with quantitative data.

3.2.2.3D Reconstruction and Damage Testing

3D Model Creation: Multi-angle photographs captured with photogrammetry are processed to produce highly detailed, geometrically accurate 3D digital models (Structure from Motion section). (Remondino, 2018).

Damage Tracking and Quantitative Analysis: These 3D models provide a reference point for visualizing and instantly detecting fractures (cracks, breaks, surface losses) that the artifact has been exposed to over time, with millimeter precision. This enables proactive and targeted planning for conservation interventions (López, and Lerma, 2022).

3.2.3. Clustering with Stylometry (Style Analysis)

Feature Extraction: AI automatically extracts topological and geometric features of motifs (line density, symmetries, and morphometry of the fonts used).

Clustering: Based on this extracted high-dimensional dataset, Clustering Algorithms (particularly noise-resistant DBSCAN or K-Means) are applied. This analysis enables grouping products with similar structures in the museum inventory (Hristov, and Stoyanova, 2021).

Scientific Purpose: This analysis is essential for recording chronological/cultural interactions, period-specific stylistic differences, and anonymous workshop/artisan traces.

4. Application Examples and Findings (Comprehensive Semantic Analysis)

The speed and accuracy provided by the AI-based automatic motif recognition system have revealed the iconographic and mythological richness of the figures in the museum more quickly, objectively, and comprehensively (Alican, Ö. 2017).

4.1. Iconographic and Semantic Analysis of Bird Figures

Symbolism: Bird figures are universally symbols of the immortality of the soul and freedom. In Turkish mythology, birds are considered cosmic messengers between heaven and earth and representatives of the immortality of the soul.

Special Motifs: The system has accurately identified the double-headed eagle motifs, which are critical in Seljuk period works. This motif symbolizes dual sovereignty (east and west), power, justice, and cosmic protection, and has become an emblem of the empire (Pektaş, 2019).

Figure 1-2:

Kayseri Ethnography Museum, Bird Illustrations (Uğurlu, 2025)

4.2. Lion Figures and Mythological Context

Power and Leadership: Lion figures symbolize power, leadership, courage, and nobility in Turkish and Islamic art. These depictions, whose origins date back to Göbekli Tepe, have persisted across Anatolian civilizations.

Guardian Spirits: The lion depictions in the Kayseri Ethnography Museum have been interpreted as guardian spirits (guides) in Shamanistic beliefs and powerful beings that assist in the journey to the other world.

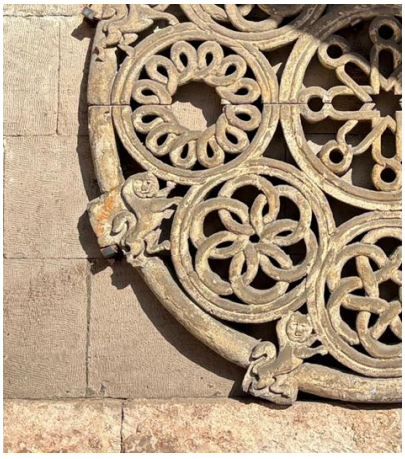
Eternal Life: Lions are depicted in important Seljuk works, such as the Kayseri Döner Kümbet, alongside motifs of the Tree of Life and the Sun, reinforcing their roles as guardians of eternal life and the gardens of paradise. YZ's motif-matching capability has enabled automatic linking and rapid contextual analysis of complex iconographic compositions.

Figure 3:

Kayseri Ethnography Museum, Stone Sculpture Depicting a Lion (Uğurlu, 2025).

Figure 4:

Kayseri Ethnography Museum, Stone Sculpture Depicting a Lion Detail(Uğurlu, 2025).



4.3. Fish Figures and Cultural Interactions

Abundance and Continuity: Fish figures symbolize abundance, prosperity, and continuous life, and are frequently used in Seljuk water architecture, fountains, and bathhouses.

Multi-Layered Meaning: AI-supported comparative analyses have shown that these shapes are not limited to local meanings, but also have a multi-layered meaning enriched by external influences such as Indian mythology and illuminated by the convergence of heavenly religions (Öztürk, 2020).

Figure 5:

Kayseri Ethnography Museum, Stone Sculpture Depicting Fish Detail (Uğurlu, 2025).

5. DISCUSSION

5.1. The Scientific and Social Impact of AI-Supported Digitalization

The intersection of Artificial Intelligence in the preservation and analysis of cultural heritage plays a role in global change in understanding the past. The fundamental scientific and social benefits of the AI-supported digitalization approach proposed in this study are:

Sustainable Preservation: High-quality and reliable digital archives are created, minimizing the physical deterioration of artifacts.

Academic Data Richness: Research is radically accelerated through automatic object and book recognition, learning, tagging, and the creation of large data sets.

Education and Global Access: Accessibility to cultural diversity is increased, independent of physical barriers, through virtual museum consolidation and digital archives.

Technological Contribution: Concrete contributions to technological developments are made by creating local/national artificial intelligence models and cultural data packages.

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6.CONCLUSIONS AND FUTURE RESEARCH

Documenting stone artifacts at the Kayseri Ethnography Museum using Artificial Intelligence, initiating and developing a sustainable approach from the perspectives of preserving cultural diversity, scientific analysis, and reinterpretation. This systematic approach allows products that expand the accessibility of cultural data through virtual museums and digital archives to be rediscovered by a wide audience.

Future work should focus on fully replicating different motif recognition and OCR models into real-time museum inventory management systems. Furthermore, testing the generalizability and execution of these models on art books from different geographical regions and cultural periods is planned. To fully leverage AI's potential for cultural heritage, interdisciplinary collaboration among art history, computer science, archaeology, and data science is vital.

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