

ARTIFICIAL INTELLIGENCE IN CULTURAL HERITAGE PRESERVATION: THEORETICAL FRAMEWORKS AND QUANTITATIVE ANALYSIS

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Abstract: *The paper offers a journey inside the use of AI for preservation of the cultural heritage. By harnessing advances in machine learning, computer vision, and a variety of AI approaches, the cultural heritage field changes in unprecedented ways when it comes to the documentation, restoration, predictive conservation, and classification of objects (both movable and immovable) and sites of historical and artistic interest. The conceptual model consists of four major areas: digital documentation and artifact digitization, restoration and reconstruction of disrupted elements, predictive conservation via environmental and material analysis, and the automatic categorization of cultural artifacts. AI is used for high-resolution scanning and 3D modeling of objects that are used for interactive digital archives focused on both academic research and public sharing. Methodologically, the study follows a quantitative method through the administration of a structured questionnaire of 10 questions multiple-choice for visitors of heritage sites. This measurement tool is focused on measuring the effect and adherence to AI-based preservation approaches.*

Keywords: Artificial Intelligence; cultural heritage; quantitative; analysis

INTRODUCTION

Cultural Heritage Preservation is one field which has been dependent for decades on traditional methodologies for documenting, conserving and interpreting art objects and historic sites. But artificial intelligence (AI) has ushered in new opportunities that are changing these practices in a very basic way. In this paper, we focus on two aspects. First, we examine theoretical frameworks as well as existing applications of AI in Cultural Heritage Preservation. Second, to evaluate the impact and effectiveness of AI systems in the context of preservation, this paper employs a quantitative research approach. We integrate these approaches, to offer a unified interpretation which, while theoretically sound, is empirically informed. Current research on AI in cultural heritage is relatively limited, focusing on specific technical applications without ethical, or experiential dimensions. Concerns about authenticity, cultural sensitivity, and potential algorithmic bias have been highlighted.

1. Digital Documentation and Artifact Digitization

Perhaps the most revolutionary applications of AI in cultural heritage is through digital records and digitization of artifacts. Tools such as laser scanning and computer vision have enabled the creation of high resolution 3D

models that encompass complex item details of cultural artifacts. An example would be the Digital Michelangelo Project, which utilized cutting edge laser scanning tools to produce high-precision digital copies of Michelangelo's sculptures. Using machine learning techniques, this would allow for digital documentation at scale enabling automated amelioration of visual defects and synthesis of missing parts for artefacts. A corollary to this change in digitization is how large volumes of artifacts are curated and managed by heritage institutions (Pavlidis 2023). Furthermore, high-resolution imaging enables the documentation of fine details that would be lost in traditional photography and would be at risk of disappearing over time as cultural heritage.

2. Recovery and Reconstruction

AI-based tools have ushered in a new era into these practices by providing efficient and noninvasive approaches. Novelties, like deep learning models, i.e., auto encoders and generative adversarial networks, are applied to identify anomalies of ancient objects and contribute to their renovation. For instance, AI has been used to restore the surfaces of ancient stone steles and even complete missing portions of ancient mosaics (Moral-Andrés et al. 2022). The advantages of these techniques are two, from a practical perspective, they help professionals in the restoration domain with advanced and complementary tools that may help efforts to cut time and costs related to manual restoration, and AI systems can operate on limited sample data, deriving missing information from in-tact portions of the artifact using learned patterns. This ability is not without its challenges, but, the AI-generated reconstructions come concerns surrounding their authenticity and cultural accuracy.

3. Predictive Conservation and Environmental Analysis

Predictive conservation is a new area of preservation, machine learning can be used to modify historical environmental data and material properties to forecast future degradation events, making it possible for conservators to respond proactively. Sensors and IoT (Internet of Things) equipment can be used to gather data on real-time environmental characteristics such as humidity, temperature, and pollution for heritage organizations. Then all this data is analyzed by algorithms that can detect signals of early trouble. Such prediction models serve to conserve cultural heritage sites by: (i) prolonging the life of valuable artefacts; (ii) assisting in resources assignment demanded by conservation projects.

4. Classification and Typology of Artifacts

Classification and typology of artefacts were determined manually by experts from visual appearance and source of history. Automation of the

classification process can be achieved by the application of AI. This feature is especially welcome in museums and in cases of archaeological analysis, where amounts of data involved are simply too large to be managed with conventional classification tools. AI's capacity to generate and analyze vast amounts of visual data with very little chance of error is therefore regarded as a significant step in the digitization and preservation of our cultural heritage.

5. Ethical Issues in AI-Powered Preservation

The application of AI to cultural heritage protection encounters some challenges. The most important is the ethical concern of authenticity. The technical prowess to be able to use AI to restore and reconstruct heritage objects, has the potential to transform the cultural meaning of heritage objects (Ghaith 2024). Therefore, it is crucial that these technological interventions respect the integrity, and preserve the authenticity of the original artifacts. There are also questions of authenticity, identity, bias and representation. Data privacy is also a major issue, managing the digitization of sensitive cultural material in a way in which both the rights of the community and intellectual property are protected.

6. Notable Case Studies

By combining AI with photogrammetry, the Vatican has also been able to reconstruct a photorealistic 3D digital model of the interior of St. Peter's Basilica, as a way of increasing the personal engagement of visitors and informing conservation efforts in time for the Jubilee of 2025 (Vatican News, March 2024) This effort is emblematic of how AI-driven methods can seamlessly combine scientific accuracy with the cultural narratives job to the top-notch of heritage sites. The conservation of the Miao Batik Culture in China is also a particular case worthy of special mention. A mixture of knowledge graphs and DL methods was utilized to protect the rich batik designs along with their cultural contextual meaning. Through connecting semantic information to high level pattern analysis they were able to achieve a high level of accuracy in classification demonstrating the AI system's potential to retain cultural meaning, and not just the physical characteristics that are present in artifacts.

METHODOLOGY

A ten multiple-choice questionnaire was shared online using Google Forms, and 104 people answered it. The questions focused on different aspects of AI use in cultural heritage, like how familiar people are with AI and their opinions. The answers were collected and analyzed in diagrams with google charts to understand public views on AI in this field.

RESULTS

The results of the questionnaire provide robust evidence that artificial intelligence is transforming cultural heritage preservation in several meaningful ways.

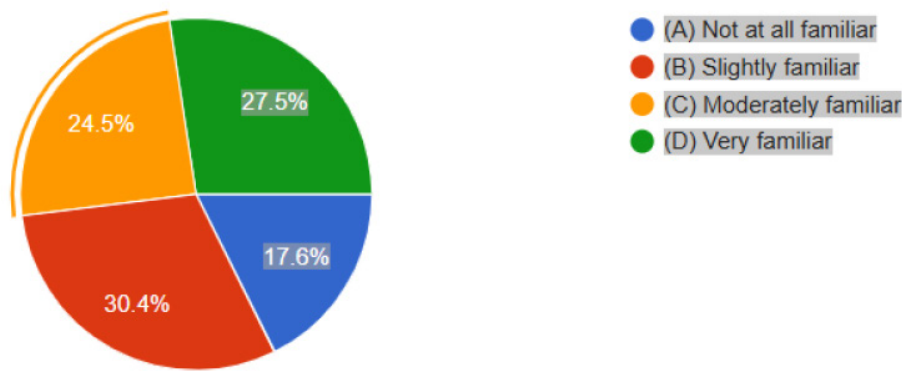


Fig. 1. Familiarity with the Use of AI in Cultural Heritage

The majority of participants show moderate familiarity with the use of AI in cultural heritage preservation.

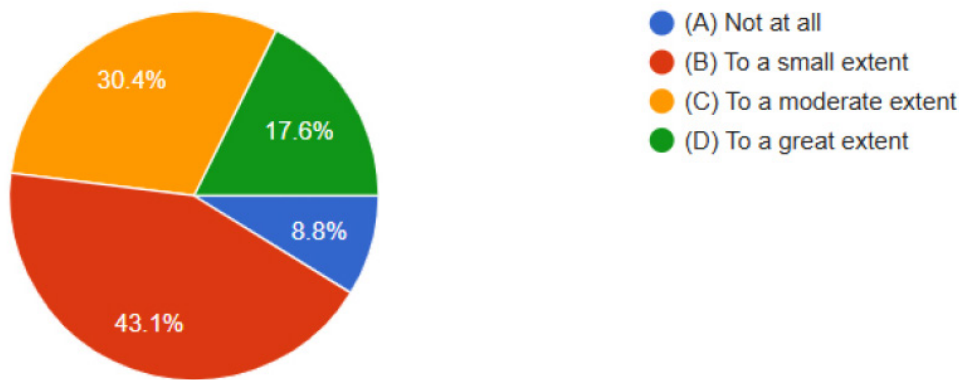


Fig. 2. Accuracy in Digital Documentation Using AI

Most participants believe that AI significantly enhances the accuracy of artifact documentation, particularly through 3D modeling technology.

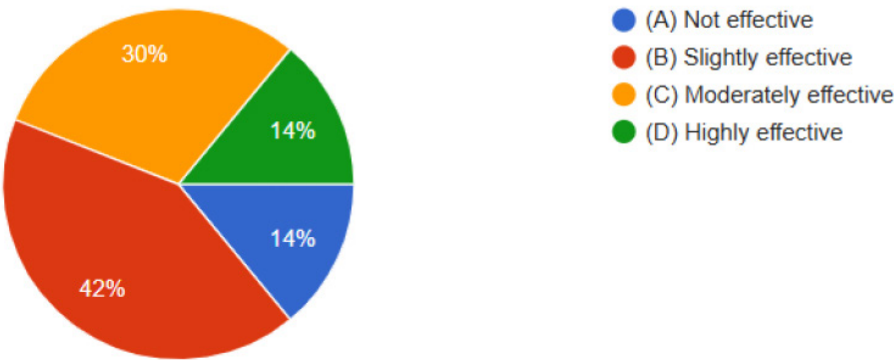


Fig. 3. Effectiveness of AI-Powered Restoration Methods

The majority of participants find AI restoration methods effective in repairing damaged artifacts.

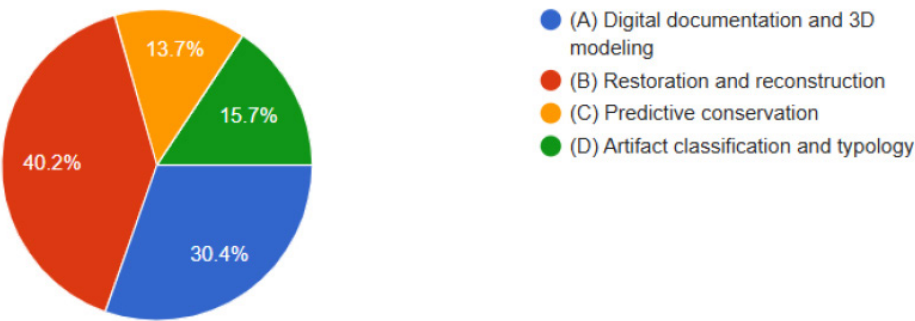


Fig. 4. Area of Interest in AI Applications for Cultural Heritage

Most participants are most interested in AI applications related to digital documentation and restoration. This suggests that the public perceives AI primarily as a tool for preservation and restoration.

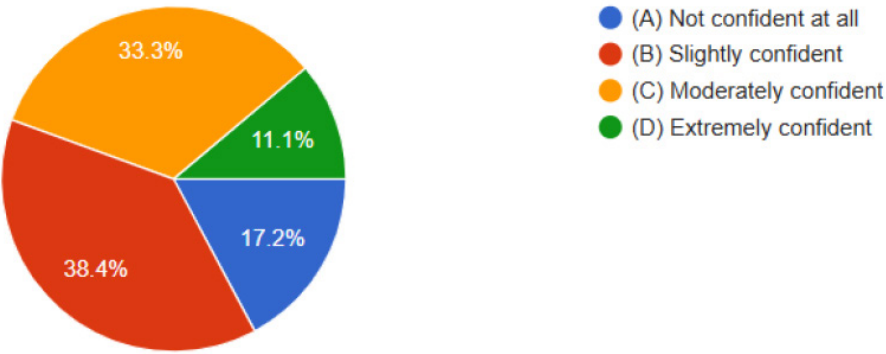


Fig. 5. Authenticity of Cultural Heritage Items

The majority of respondents are confident that AI methods maintain the authenticity of cultural heritage items.

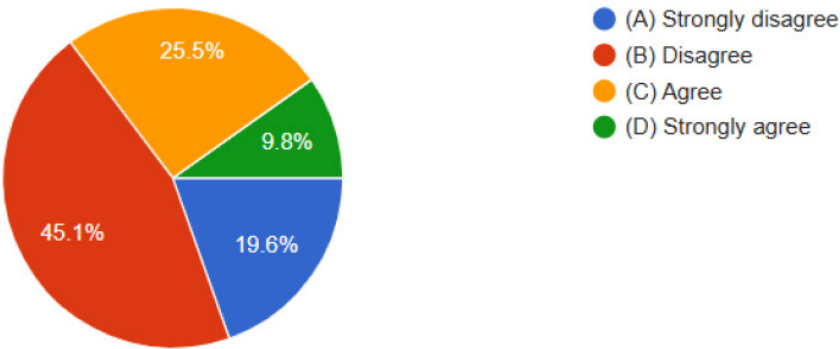


Fig. 6. Risk of Bias in Representing Cultures

Despite the generally positive perception of AI, there are concerns about the potential for bias in representing certain cultures through these technologies.

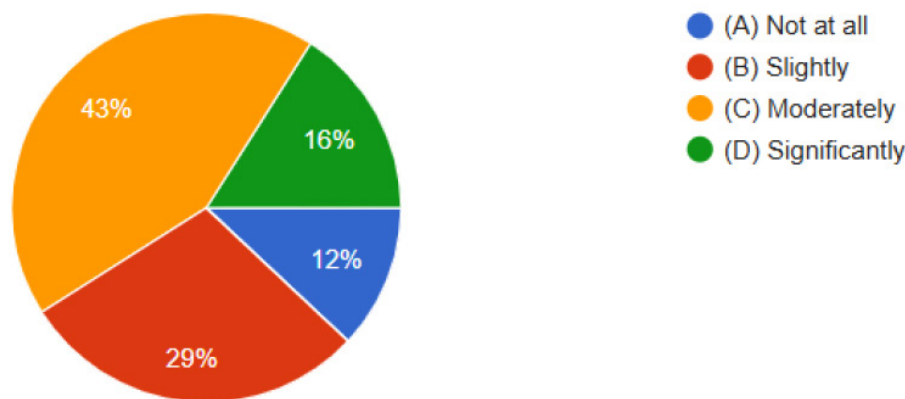


Fig. 7. Visitor Experience at Cultural Heritage Sites

Most participants believe that AI enhances the overall visitor experience at cultural heritage sites.

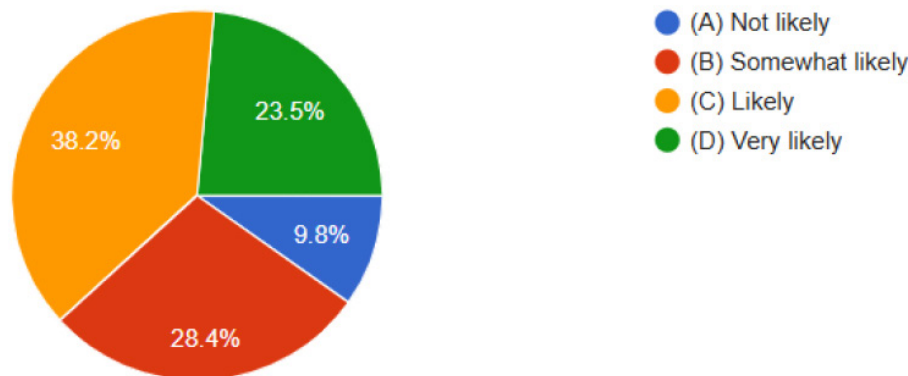


Fig. 8. Likelihood of Recommending AI-Enhanced Cultural Heritage Sites

Many respondents would be likely to recommend a cultural heritage site that employs AI-driven interactive exhibits to others.

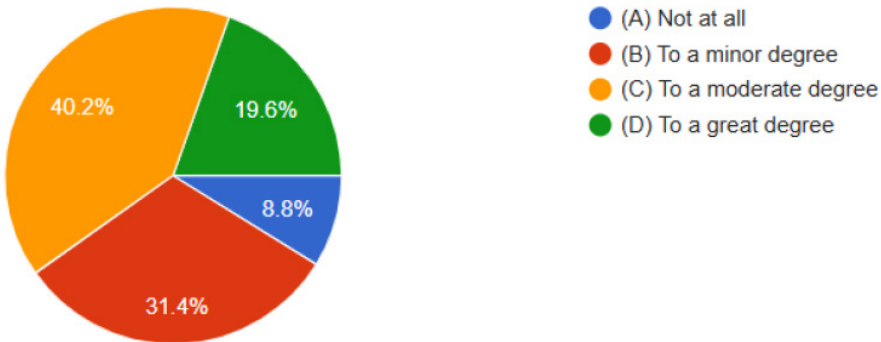


Fig. 9. Contribution of AI to Future Advancements in Cultural Heritage Conservation

Participants are generally optimistic about AI’s contribution to future advancements in cultural heritage conservation. While most believe AI will play a significant role in the sector’s progress, there is still a need for its further integration in conservation and other areas of cultural heritage.

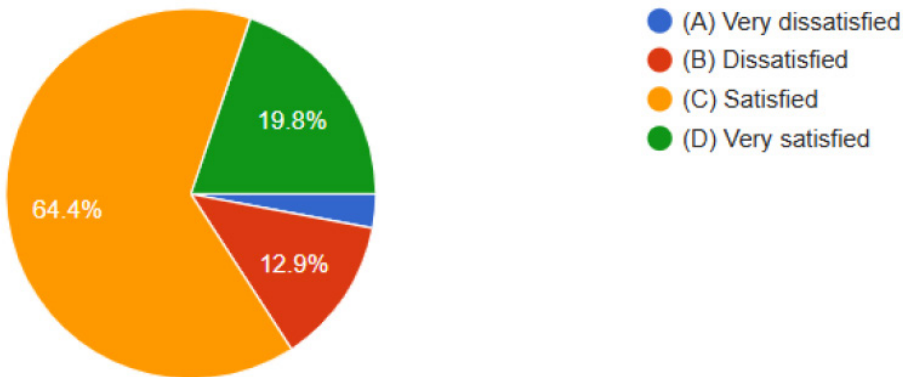


Fig. 10. Satisfaction with Current Use of AI in Cultural Heritage Preservation

The majority of participants report being satisfied with the current use of AI technologies in preserving cultural heritage.

DISCUSSION

This study aims to fill in some gaps by surveying what people think about using AI in cultural heritage. It looks at ten important points like how familiar people are with AI. How accurate they believe the digital records are, how AI preserves heritage and how satisfied people are with the current uses. Combining ideas from theory and survey results, the study hopes to give a clearer picture of how people see and value AI in this area.

CONCLUSION

In this article, we have conducted a research on the contribution of artificial intelligence to cultural heritage preservation. Through the fusion of modern technologies and traditional conservation approaches, AI introduces new tools for digital documentation, restoration, predictive conservation, and automated artifact classification. Integrating these technologies not only increases preservation efficiency and accuracy but also offers new opportunities for research, education and public engagement.

An effective AI appropriation in the context of the cultural heritage field should necessarily be an interdisciplinary one, which integrates technological innovation with deep cultural sensibility and ethical responsibility. The structured survey-based quantitative data corroborates that people embrace the interactive possibilities offered by AI-driven displays, even as they express reservations about balancing challenges of authenticity, bias, and representation. Finally, the progress of AI in the cultural heritage preservation offers an interesting concept of intersections between technology and tradition. Using the capabilities for machine learning, computer vision, and advanced data analytics, heritage institutions are transforming the way that they are protecting and promoting our shared cultural heritage. The intention of such an article would be to stimulate additional research, and civic partnerships, and to inspire innovation in a manner that respects the ethical and cultural values associated with the preservation of heritage.

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ИЗКУСТВЕН ИНТЕЛЕКТ В ОПАЗВАНЕТО НА КУЛТУРНОТО НАСЛЕДСТВО: ТЕОРЕТИЧНИ РАМКИ И КОЛИЧЕСТВЕН АНАЛИЗ

Резюме: Докладът предлага пътешествие в използването на изкуствения интелект (ИИ) за опазване на културното наследство. Чрез използване на постиженията в машинното обучение, компютърното визуално представяне и разнообразни подходи на ИИ, областта на културното наследство се променя по безпрецедентен начин по отношение на документирането, реставрацията, прогностичната консервация и класификацията на обекти (както движими, така и недвижими) и места с историческо и художествено значение. Концептуалният модел включва четири основни области: дигитална документация и дигитализация на артефакти, реставрация и реконструкция на повредени елементи, прогностична консервация чрез анализ на околната среда и материалите, и автоматична категоризация на културни артефакти. ИИ се използва за високорезолуционно сканиране и 3D моделиране на обекти, които се използват за създаване на интерактивни дигитални архиви, насочени както към академични изследвания, така и към споделяне с широката публика. Методологически изследването ползва количествен метод чрез провеждане на структуриран въпросник с 10 въпроса с избор от няколко възможни отговора, насочен към посетители на обекти от културното наследство. Целта на този инструмент за измерване е да оцени ефекта и възприемането на подходи за съхранение на културното наследство, базирани на ИИ.

Ключови думи: изкуствен интелект; културно наследство; количествен анализ; устойчивост; опазване

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