PRESERVING CULTURAL HERITAGE USING ARTIFICIAL INTELLIGENCE

Khabzoaui Abdelkarim[1], Cherifi Mourad[2]

[1]*University of Souk Ahras, Algeria*
[2]*University of Médéa, Algeria*

Abstract: *This study examines the pivotal role of artificial intelligence (AI) in preserving cultural heritage. This underscores AI's applications in digital documentation, artefact restoration, visitor engagement, and cultural data management. This paper highlights how AI technologies, including 3D scanning, machine learning, and predictive modelling, have enhanced conservation efforts. Additionally, it examines the potential of AI in preserving intangible cultural heritage and creating global repositories of cultural information. The text concludes by addressing the ethical considerations associated with the use of AI in cultural heritage conservation. It emphasises its increasing significance in safeguarding the cultural legacy for future generations.*

Keywords: *Cultural Heritage; Artificial Intelligence; Digital Documentation; 3D Scanning; Preservation; Conservation.*

Introduction

Cultural heritage, encompassing both tangible and intangible elements, represents the collective memory and identity of societies. As globalisation poses challenges to heritage preservation, artificial intelligence (AI) has emerged as a tool for safeguarding these cultural assets. This study examines the role of AI in cultural heritage conservation, exploring its applications and the associated ethical considerations.

AI has transformed heritage preservation through digital documentation, artefact restoration, visitor engagement and data management. The integration of 3D scanning, machine learning, and predictive modelling has enhanced conservation efforts, enabling precise and noninvasive preservation approaches.

AI-driven 3D scanning creates high-resolution digital replicas, supporting documentation, and virtual access to cultural heritage across geographical boundaries. In artefact restoration, AI algorithms offer solutions for image analysis and reconstruction. Machine learning can analyse patterns, reconstruct damaged areas, and predict deterioration, thereby enabling preventive conservation measures.

AI has enhanced museum experiences through personalised recommendations and virtual tours, thereby improving accessibility and engagement within museums. These technologies have the potential to preserve intangible heritage and create global cultural repositories. However, ethical considerations include maintaining object integrity, ensuring process transparency, and protecting heritage from its misuse.

1. The Importance of Preserving Cultural Heritage and Its Challenges in the Modern Era

Cultural heritage encompasses a diverse range of both tangible and intangible elements that collectively represent a society's history, values, and achievements. Tangible heritage encompasses physical artefacts, including monuments, buildings, archaeological sites, and artworks, which serve as tangible reminders of past civilisations and cultural practices. In contrast, intangible heritage encompasses traditions, rituals, performing arts, oral traditions, and traditional knowledge systems that are transmitted across generations. Additionally, natural landscapes, which often hold cultural significance and influence human interactions with the environment, constitute an essential component of cultural heritage. Together, these elements create a rich tapestry of human experience and creativity that links past, present, and future generations. (Nomishan & Sule Sani, 2023)

The preservation and promotion of cultural heritage are crucial for preserving cultural diversity and promoting social cohesion. By safeguarding these cultural assets, communities can reinforce their unique identities and values while adapting to the challenges presented by modernisation and globalisation. This process not only strengthens social bonds within communities but also facilitates intercultural dialogue and understanding on a global scale. Cultural heritage sites and practices often serve as focal points for tourism and economic development, thereby contributing to sustainable growth and the well-being of communities. Furthermore, the study and appreciation of diverse cultural heritages can lead to innovative solutions for contemporary challenges, drawing inspiration from traditional knowledge and practices. As societies continue to evolve, the dynamic nature of cultural heritage ensures that it remains a living, breathing entity that reflects the ongoing narrative of human civilisation.(Billore, 2021)

The incorporation of advanced technologies in the preservation of cultural heritage has initiated a transformative era of accessibility and engagement. The application of 3D scanning techniques enables the creation of highly detailed digital replicas of artefacts and historical sites, allowing researchers to examine intricate details without compromising the integrity of the original objects. Virtual reality experiences enable users to explore reconstructed ancient environments, providing immersive educational opportunities that were previously inconceivable. These digital tools not only support more comprehensive documentation but also promote the dissemination of cultural knowledge across geographical boundaries, dismantling barriers to access and fostering a global appreciation for diverse cultural legacies (Lin et al., 2025).

The transition towards community-led conservation initiatives represents a notable shift from conventional top-down approaches to heritage management. By engaging local communities in decision-making processes and daily conservation activities, these initiatives harness a wealth of indigenous knowledge and practices that have often been overlooked. This participatory approach not only ensures that conservation strategies are culturally appropriate and sustainable but also enhances the connection between communities and their heritage. As local stakeholders assume leadership roles in preserving their cultural assets, they cultivate a more profound sense of ownership and responsibility, which is crucial for the long-term protection and vitality of cultural heritage sites and traditions.(Zain El Shandidy, 2023)

2. Digital Documentation and 3D Techniques for Preserving Cultural Heritage

The use of digital documentation and three-dimensional techniques has become essential for the preservation of cultural heritage. These approaches offer numerous advantages:(Owda et al., 2018)

- **Accurate recording:** High-resolution 3D scanning and photogrammetry make it possible to precisely capture the details of artifacts, buildings, and sites.
- **Non-invasive documentation:** These digital techniques ensure thorough documentation without physical contact, thereby reducing the risk of deterioration.
- **Virtual access:** 3D models allow researchers and the general public to study and interact with cultural heritage remotely.
- **Conservation planning:** Detailed digital records facilitate the monitoring of changes over time and the implementation of conservation efforts.
- **Digital reconstruction:** 3D modeling enables the recreation of damaged or lost elements of heritage sites.
- **Data archiving:** Digital documentation constitutes a permanent record that can be easily stored and shared (Fu et al., 2023).

2.1. Key Techniques:

- **Laser scanning:** Generates extremely accurate 3D point clouds for objects and structures.
- **Photogrammetry:** Uses multiple photographs to create 3D models.
- **Structured light scanning:** Projects light patterns onto objects to capture surface details.
- **CT scanning:** Reveals the internal structures of artifacts without causing damage.
- **Virtual and augmented reality:** Enhances engagement with cultural heritage through immersive experiences (Bernstein et al., 2021)

2.2. Challenges and Considerations:

Data storage and management: Large files require robust storage solutions.

- **Technological obsolescence:** Ensuring long-term accessibility of digital data.
- **Ethical considerations:** Balancing preservation efforts with cultural sensitivities.

- **Training and expertise:** Developing the necessary skills in digital documentation techniques.
- **Cost:** The initial investment in equipment and software can be substantial.

The integration of these digital techniques can significantly enhance cultural heritage preservation efforts, providing valuable tools for documentation, research, and public engagement.(Parkhurst & Shogren, 2008)

3. Artificial Intelligence in the Restoration of Damaged Artifacts

Artificial Intelligence (AI) has emerged as a powerful tool in the field of artefact restoration, offering innovative solutions to preserve and reconstruct damaged historical objects. This technology has revolutionised traditional restoration methods by providing more accurate, efficient, and non-invasive approaches.(Zhang, 2024)

3.1. Key applications of AI in artifact restoration include:

A. Image analysis and reconstruction:

AI algorithms can examine broken or worn-down objects, identifying patterns and determining which parts are missing or damaged. Machine learning systems can then rebuild the damaged areas by using the information that's still there and comparing it to similar historical objects. This helps restore artefacts that have been damaged over time.

B. 3D modelling and printing:

AI-powered 3D scanning techniques:

- Use advanced artificial intelligence to create highly detailed digital versions of historical objects or artefacts
- Capture the object's shape, size, and surface details accurately Uses of these digital models:

Virtual restoration:

- Digitally repair or reconstruct damaged parts of the artefact
- Visualise how the object might have looked when it was new or complete.(Lee et al., 2024)

Physical reconstruction:

- Guide the creation of real, physical copies using 3D printing
- Help in reproducing missing parts or entire replicas of artefacts

This technology enables the better preservation, study, and reproduction of important historical objects without compromising the originals.

C. Material analysis:

AI systems can analyse the materials from which ancient objects are made. This helps experts select the appropriate materials to repair and restore these objects. By using

compatible materials, the restored objects will last longer and maintain their authenticity. This approach ensures that restoration work is more accurate and effective in preserving historical artefacts.(Khalid et al., 2024)

D. Predictive conservation:

AI algorithms analyse patterns to predict how artefacts might deteriorate over time. This enables conservators to take preventive measures before significant damage occurs, thereby helping to protect and preserve important objects.

AI systems can also organise and store large amounts of information about artefacts and how they are restored. This makes it easier for people to access the information and use it for future research or restoration work.

These technologies help museums and other institutions take better care of historical objects and artworks, ensuring they last longer for future generations to study and enjoy (Khalid et al., 2024) .

3.1. Challenges and considerations:

The text outlines four main challenges in using AI for historical artefact restoration:

1. Ethical considerations: Balancing technological intervention with historical integrity and maintaining transparency.
2. Data limitations: Acquiring sufficient, diverse, and relevant data to train AI systems.
3. Interdisciplinary collaboration: Facilitating practical cooperation between AI experts, conservators, and historians.
4. Technological constraints: Addressing complex materials and designs that may exceed current AI capabilities (Doni et al., 2024)

3.2. Future prospects:

The text outlines three key developments in AI-driven artefact restoration:

1. Advanced algorithms for more accurate, context-sensitive restoration
2. Integration with augmented reality to enhance restoration processes
3. AI systems that can adapt to various cultural and historical contexts

These advancements in AI technology are significantly improving cultural heritage preservation, with the potential for even more sophisticated solutions in the future.

4. Using Artificial Intelligence to Enhance Visitor Experience in Museums

Museums are finding innovative ways to enhance the visitor experience, leveraging technology to make visits more enjoyable and accessible. For instance, many museums now offer systems that suggest exhibits based on visitors' preferences, making each visit feel more personalised. Interactive displays allow visitors to engage with the exhibits through chatbots and augmented reality, creating a more immersive experience. Museums

are also making it easier to manage crowds by tracking how people move through spaces, ensuring smoother visits. To help everyone enjoy the museum, they have added language translation services and assistive tools for those with disabilities.

Additionally, technology is helping to preserve artefacts, with systems that monitor their condition and support conservation efforts. The design of exhibits is also improving, as museums utilise visitor feedback to enhance the engagement of their exhibits. Virtual tours enable people to explore collections from anywhere in the world, and educational tools are making learning more engaging and interactive. All of these innovations are designed to make the museum experience better and more inclusive, encouraging even more people to connect with art, history, and culture.(Siri, 2024)

5. Challenges and Opportunities in Integrating Artificial Intelligence into Cultural Heritage Preservation:

The text outlines several ways in which museums are utilising Artificial Intelligence (AI) to enhance visitor experiences and improve operational efficiency. AI systems provide personalised recommendations by suggesting exhibits based on the individual interests of each visitor. Interactive technologies, such as chatbots and augmented reality, are incorporated into displays, enabling a more engaging and immersive experience. Crowd management is enhanced by analysing visitor movement patterns to optimise the flow of people through the museum. Accessibility is enhanced with language translation services and assistive tools for visitors with disabilities, ensuring everyone can fully participate in the experience. (Rani et al., 2023)

AI-powered monitoring systems are used to assess the condition of artefacts, aiding in their preservation. Data-driven insights inform exhibit design, refining displays to match visitor preferences. Virtual access through remote tours allows people to explore collections from anywhere in the world. AI-powered educational tools create more interactive and engaging learning experiences for visitors.

These AI applications aim to modernise museum operations, improve visitor engagement, and increase access to cultural heritage. However, challenges remain, including concerns about data privacy related to visitor tracking and personalisation. Museums also face the challenge of balancing the integration of technology with traditional museum experiences. It is essential to ensure that AI systems are inclusive and do not perpetuate biases. Additionally, staff training is crucial for effectively using and maintaining AI technologies. Securing funding for the implementation and ongoing maintenance of AI systems is another challenge. Finally, concerns may arise about potential job displacement among museum staff as automation and AI become more prevalent.(Rani et al., 2023)

Opportunities for further AI integration in cultural heritage preservation include advanced conservation techniques that utilise AI-powered analysis and prediction, enabling more precise and efficient restoration. Additionally, AI can enhance artefact authentication and provenance tracking, ensuring the accuracy and origin of cultural objects. Digital archiving and cataloguing of collections can be significantly improved with AI, making it easier to organise and access vast amounts of cultural data. AI-assisted research can uncover historical connections that were previously difficult to identify,

offering new insights into the past. For remote visitors, personalised online experiences can be provided, enabling them to explore museum collections from anywhere in the world. Furthermore, collaborative AI platforms can facilitate the sharing of knowledge between institutions, encouraging cooperation in preserving cultural heritage.

To maximise the benefits of AI and address potential challenges, museums should develop clear ethical guidelines for the use of AI in cultural contexts. Collaboration with AI experts, ethicists, and diverse stakeholders is crucial to ensure the responsible implementation of AI. Transparency in AI usage and data management should be a priority to maintain trust. Ongoing staff training and development are necessary to ensure that AI technologies are used effectively. Museums should regularly assess the impact of AI on visitor experiences and preservation efforts to ensure its positive influence on these areas. Ultimately, AI must complement, rather than replace, human expertise and curation, thereby ensuring a harmonious integration of technology with traditional practices.(De Bernardi et al., 2019).

6. Future Directions for Using Artificial Intelligence in Preserving Cultural Heritage

Cultural heritage preservation has long been a significant challenge due to factors such as environmental degradation, ageing, and human intervention. The emergence of artificial intelligence (AI) presents new opportunities for addressing these challenges, offering enhanced accuracy, efficiency, and sustainability in preserving valuable cultural assets. This section will explore the future directions in which AI can contribute to preserving cultural heritage, highlighting key technological innovations and potential applications.

6.1. AI-Driven Digitization and Documentation:

One of the most important aspects of preserving cultural heritage is the accurate and comprehensive documentation of artefacts, buildings, and intangible cultural heritage. AI technologies, such as machine learning and deep learning algorithms, can aid in automating the digitisation process, converting physical objects and documents into high-resolution digital formats. The future of AI in this field lies in enhancing these processes by:

Improving the accuracy of 3D scanning techniques for better digital models of artefacts.

Automating the transcription of historical texts using AI-driven optical character recognition (OCR) and natural language processing (NLP).

Developing AI systems that can detect subtle damage or wear and tear in artefacts that human eyes might miss, ensuring comprehensive documentation.(Wang & Zhou, 2025)

6.2. Restoration and Conservation using AI:

AI can play a crucial role in the restoration of damaged or deteriorating cultural artefacts. Using AI, it is possible to replicate missing parts of artefacts or reconstruct damaged ones based on historical data. Future trends may include:

- AI algorithms analyse the original materials and digitally reconstruct damaged artefacts before physical restoration occurs.
- AI-based predictive models simulate how artefacts might degrade over time, enabling conservators to develop strategies for preserving them for more extended periods.

Integration of AI with robotics for precise restoration work, where AI helps guide robotic systems in applying restoration techniques with incredible accuracy.(Tzouganatou, 2021)

6.3. Enhancing Visitor Engagement through AI:

AI has the potential to redefine the visitor experience in museums, galleries, and heritage sites. Future directions in this area include:

- AI-powered virtual tours that offer personalised experiences based on individual interests, with AI chatbots answering questions in real-time.
- Augmented reality (AR) and virtual reality (VR) applications, powered by AI, enable visitors to interact with artefacts in a more engaging and informative manner.

AI-driven systems that help visitors explore the history of artefacts and cultural sites in greater detail through immersive storytelling, providing context and enhancing educational value.(Rani et al., 2023)

6.4. AI for Preserving Intangible Cultural Heritage:

Intangible cultural heritage, such as oral traditions, music, dance, and folklore, is just as important as tangible heritage but can be harder to preserve. AI can assist in preserving these forms of heritage by:

- Using AI to document and analyse oral histories, transcribe, and translate them into multiple languages.
- Employing AI-driven music recognition systems to capture and preserve traditional music and performances, even from endangered cultures.
- Analysing cultural patterns and rituals using AI to predict potential threats to their continuity and develop proactive preservation strategies .(Bi & Nasir, 2024)

6.5. AI and Big Data for Cultural Heritage Management:

As the world continues to collect vast amounts of data related to cultural heritage, the use of AI in managing this data will become increasingly important. Future AI applications may include:

- Developing AI systems capable of processing large-scale cultural data to identify patterns, trends, and risks, and improving decision-making for heritage managers.

- Integrating AI with big data analytics to create global repositories of cultural heritage, where data on artefacts, sites, and practices can be continuously updated and accessed by stakeholders around the world.
- Implementing AI to predict and monitor environmental impacts on cultural heritage sites, thereby helping to prevent damage from climate change or human activities. (Tsipi et al., 2023)

6.6. Ethical Considerations and Challenges:

While the potential of AI in cultural heritage preservation is vast, there are ethical challenges that need to be addressed:

- Ensuring the accuracy and reliability of AI-driven restorations and digital reproductions, and maintaining the integrity of the original cultural objects.
- There is a need for transparency in AI algorithms, particularly in how data is used and how decisions are made in the preservation process.
- Protecting cultural heritage from potential misuse or commercialisation, ensuring that AI applications respect cultural sensitivities and community ownership.

The future of artificial intelligence in cultural heritage preservation holds enormous potential for both tangible and intangible assets. From AI-driven digitisation and restoration to enhancing visitor experiences and managing cultural heritage data, the possibilities are vast. However, careful consideration of the ethical implications and challenges surrounding AI integration is crucial to ensure that these technologies enhance the preservation of cultural heritage in a responsible and meaningful way. As AI technologies continue to evolve, they will undoubtedly play a pivotal role in safeguarding cultural heritage for future generations .(Greco et al., 2024)

Conclusion

Artificial intelligence (AI) has emerged as a transformative tool in cultural heritage preservation, offering solutions for digital documentation, restoration, and data management. This paper examines the role of AI in protecting tangible and intangible cultural assets through 3D scanning, machine learning, and predictive modelling. AI-driven digitisation creates high- resolution digital replicas for documentation and virtual access. AI algorithms analyse patterns for artefact restoration, while 3D technologies assist in reproducing missing parts. AI enhances visitor experiences through personalised recommendations and virtual tours, while also preserving intangible heritage by documenting oral histories and analysing cultural patterns. The integration of AI with big data analytics enables the creation of global cultural repositories and enhances heritage site monitoring. However, ethical considerations regarding object integrity, transparency, and cultural protection must be addressed. As AI advances, collaboration between experts, conservators, and stakeholders is essential to maximise benefits and address challenges.

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KHABZOAUI Abdelkarim

University of Souk Ahras, Algeria

ORCID https://orcid.org/0009-0009-0604-6644

a.khabzaoui@univ-soukahras.dz

Cherifi Mourad

University of Médéa, Algeria

ORCID https://orcid.org/0009-0009-2195-7374

cherifi.mourad@univ-medea.dz

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Abstract and Keywords in Bulgarian

Резюме: *Това изследване разглежда ключовата роля на изкуствения интелект (ИИ) в съхранението на културното наследство. То подчертава приложенията на ИИ в дигиталната документация, реставрацията на артефакти, взаимодействието с посетителите и управлението на културни данни. Статията акцентира върху това как технологиите на ИИ, като 3D сканиране, машинно обучение и прогностично моделиране, са увеличили усилията за съхранение. Освен това, се разглеждат потенциалните възможности на ИИ за съхраняване на нематериалното културно наследство и създаване на глобални хранилища на културни данни. Текстът завършва с обсъждане на етическите съображения, свързани с използването на ИИ в съхранението на културното наследство, и подчертава неговото нарастващо значение за опазване на културното наследство за бъдещите поколения.*

Ключови думи: *Културно наследство; изкуствен интелект; дигитална документация; 3D сканиране; съхранение; реставрация.*

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