ISLAMIC HISTORY AND LITERATURE
Vol.4, No.1, 2026, pp.57-72
https://doi.org/10.62476/ihl.4157

SMART HERITAGE: ARTIFICIAL INTELLIGENCE AND THE FUTURE OF ISLAMIC CIVILIZATION STUDIES

Houda Boumediene[1*], Fatiha Kaid Berrahal[2]

[1]AILE Laboratory, Amar Telidji University, Laghouat, Algeria
[2]Ecole Normale Superieure d'Oran, Oran, Algeria

Abstract. The accelerating loss of manuscripts, relics and monuments imperils the continuity of Islamic civilization's heritage and since the conventional approaches cannot handle the complexity and size of heritage data any longer, this study explores the possibility of using Artificial Intelligence (AI) to preserve, interpret and revitalize Islamic cultural heritage in the new paradigm of "Smart Heritage". Using a mixed qualitative-analytical research strategy with a blend of literature synthesis, case analysis and conceptual modeling, this paper elucidates how computer vision, deep learning and natural language processing enable restoration, multilingual analysis and intelligent retrieval. Main results indicate that AI-based systems enhance accuracy, accessibility and interpretive richness in digitizing rare manuscripts and reconstructing destroyed monuments, although concerns regarding authenticity, bias and cultural contextualization persist. The research recommends the creation of ethically motivated AI platforms and inter-institutional networks to promote open, inclusive and sustainable heritage innovation so that AI becomes a force for change in Islamic civilization preservation in the digital age.

Keywords: *AI-driven systems, digital humanities, Islamic civilization, natural language processing, smart heritage.*

Corresponding Author: *Houda Boumediene, AILE Laboratory, Amar Telidji University, Laghouat, Algeria, e-mail: h.boumediene@lagh-univ.dz*

Received: *5 October 2025;* ***Accepted:*** *17 December 2025;* ***Published:*** *8 January 2026.*

1. Introduction

Cultural heritage constitutes humankind's shared memory in the form of material objects, immaterial traditions and intellectual advancement that characterize civilizations. Heritage is under threat more than ever before, as man-made disasters of war and destruction of the environment are complemented by cyberspace disdain and unacceptable archiving mechanisms. The Islamic civilization's heritage with an age of over fourteen centuries and including manuscripts, building symbols, calligraphy and scientific texts is even more vulnerable to this kind of devastation. Regardless of concerted documentation and preservation efforts, the bulk of this cultural heritage is inaccessible, non-digitized or at risk of permanent loss.

The accelerating pace of progress in Artificial Intelligence (AI) offers new hope for preservation, analysis and dissemination of heritage. With technologies such as computer vision, deep learning, natural language processing (NLP) and knowledge graphs, AI is able to perform sophisticated tasks like image restoration, text recognition from multiple languages, semantic classification and 3D reconstruction of historical monuments. Such tasks have enabled the creation of a new multidisciplinary area commonly known as Smart Heritage, where intelligent systems are used to conserve, manage and interpret

cultural heritage. But whereas industrial and biomedical applications have seen remarkable advances with AI, its cultural heritage application, especially the Islamic heritage sector, is weak and patchy. Some of the hurdles include a lack of coherent datasets, ethical objections to algorithmic bias and a need for culturally attuned digital ontologies capable of representing richness and diversity of the Islamic heritage. In addition, most of the digitalization in the contemporary world is directed towards data storage instead of smart interpretation and the result is technically deep but epistemically superficial repositories.

In this background, this study is investigating the use of AI for the improvement of preservation, access and interpretive knowledge of Islamic cultural heritage. In particular, it seeks to answer the following questions:

1. How can be AI technologies systematically incorporated into Islamic cultural heritage documentation, preservation and interpretation?
2. What are the methodological and ethical foundations that must inform the deployment of AI in culturally delicate heritage environments?
3. What model or framework can strike a balance between technological innovation and cultural and spiritual authenticity in making sustainable Smart Heritage systems a reality?

In pursuing these goals, the paper helps to establish a consensus on digital humanities and heritage informatics and provides an exemplar for interdisciplinary research collaboration between AI researchers, heritage professionals and Islamic civilization experts. It asserts that the future of heritage conservation does not lie solely in digitization, but in intelligent, ethical and aware systems that preserve the living memory of culture through adaptive, accountable and context-aware technologies.

2. Literature review

2.1. AI use and trends in cultural heritage

The application of AI in cultural heritage (CH) has evolved tremendously in the past few years with more scholarly production and various domains of use. A scientometric review of AI-cultural heritage research for 2019-2023 indicates rising publication patterns and AI approaches are predominantly utilized primarily in discovery, classification, description and conservation of heritage objects (e.g., manuscripts, monuments, artifacts). Various literature reviews and meta-analyses cite a group of prominent AI technologies driving heritage innovation: machine learning, deep learning, virtual / augmented reality, multimedia processing and big data analytics. For example, Ali and Abdul-Kadim (2025) determine that these technologies lie at the center of future digitization policy for heritage. AI for Digital Heritage Innovation envisions mapping not only existing capacities but the path of synergies between heritage practice and AI, in the foreground with a heightened focus on the roles of stakeholders, sustainability and community engagement.

Other projects target interactive heritage experiences through AI-supported interaction design. For example, Veggi (2025) formulates an AI-supported interaction media design process for cultural heritage spaces and demonstrates how curators, designers and heritage specialists may leverage AI in narration, personalization and interactive experiences. Further, generative AI, AR and gamification models are also suggested to improve interaction and responsiveness in heritage apps (e.g. adaptive narration and location-based narratives). Within the Islamic/Arabic-script cultural heritage area, digital humanities scholars investigate possibilities and boundaries of

Arabic computational technologies, with a focus on the analysis of texts, OCR and cultural knowledge extraction. The "Digital Averroes Research Environment (DARE)" is only an example of a virtual space offering access to multilingual manuscript versions of Averroës, demonstrating how digital cultural heritage systems can unite different language traditions and eras.

2.2. Key AI techniques and their heritage applications

Below, we categorize the main AI methods utilized in heritage and explain how they are used in practice.

Table 1. AI techniques and their heritage applications

AI Technique	Application in Heritage	Examples/Notes
Computer Vision & Image Processing / Deep Learning	Restoration, damage detection, filling gaps, surface analysis	virtual restoration of paintings, mosaics, murals; AI systems detect cracks, discoloration, missing pixels
Optical Character Recognition (OCR) & Text Recognition / NLP	Transcribing manuscripts, cleaning degraded text, multilingual text mining	Recent works in historical manuscript digitization employ AI to handle fragmented or faded scripts
Generative Models / Inpainting / Neural Reconstruction	Recreating missing or lost sections of artifacts, reconstructing architecture	AI inpainting for filling gaps in manuscripts or art, architectural reconstructions using generative networks
3D Modeling, Virtual / Augmented Reality (VR/AR)	Reconstructing heritage sites, immersive heritage tours	Using AI to drive 3D reconstructions or AR overlays of archaeological or architectural sites)
Knowledge Graphs, Semantic Networks	Linking heritage data, enabling semantic search and cross-referencing	AI systems may produce ontologies or knowledge models to connect heritage content across domains
Data Analytics, Predictive Monitoring, Environmental Sensing	Monitoring environmental risks (humidity, temperature, pollutants), predictive maintenance	AI-driven sensors and analytics alert heritage managers to deterioration risks
Interactive / Adaptive Systems, Personalization	Tailoring visitor experiences, dynamic exhibits, chatbot guides	AI chatbots in heritage tourism and museums, adaptive exhibits that respond to visitor behavior

Now these techniques are more integrated than applied individually: e.g. AI pipelines may combine OCR, knowledge graphs and generative inpainting to restore manuscripts.

In Islamic tradition alone, AI is tested in the research of Islamic and Arabic manuscripts. For instance, "ChatGPT's potential in the deep exploration of Islamic manuscripts" explains how general-purpose large language models can be useful in manuscript study with conditions set on limitations in domain accuracy and interpretive nuance.

2.3. Challenges, ethical problems and research gaps

Literature is not just reflective of possible applications but also reflects crucial challenges, restrictions and research gaps.

2.3.1. Technical challenges

• Lack of data & quality: There is no access to high-quality annotated heritage data (especially for rare or endangered manuscripts). Most models fail when transferred to degraded, non-standard scripts or materials.

• Domain adaptability: Generic AI models fail when transferred to heritage domains, e.g. dealing with classical Arabic scripts, diverse calligraphic styles or architectural ornamentation.

• Multimodal integration: Visual, textual, spatial and semantic data integration is a challenge; pipelines that elegantly integrate these modalities do not exist practically.

• Computational cost & scalability: Certain AI models are computationally demanding and not readily deployable in heritage organizations with fewer infrastructure resources.

2.3.2. Ethical, bias and cultural issues

• Bias and representation: AI systems can perpetuate or even exacerbate existing historical and social biases, e.g., against particular styles, regions or languages. A recent paper cautions that AI-generated heritage collections necessarily inherit distortions in representation via data selection, annotation and algorithm design

• Authenticity vs. reconstruction: In the application of generative or restorative AI, to what extent the result is original and what remains speculative?

• Cultural sensitivity and contextuality: Heritage is culturally embedded. Imposing AI without regard for local, religious or symbolic significance can result in misinterpretation or disrespect.

• Copyright, licensing and data rights: Part of the heritage material or collections may be copyrighted or closed access. In addition to the use of Text & data mining or AI on copyrighted material is posing legal and ethical concerns.

• Institutional acceptance and trust: AI technologies may be distrusted or resented by heritage professionals due to transparency, fear of automation or fear of loss of human judgment. Qualitative results indicate that conservators are concerned about the overreliance on AI, loss of expertise and human-AI balance.

2.3.3. Underexplored areas and research gaps

• Culturally centric AI models: Surprisingly few research works deal with the creation of AI systems that are explicitly based on Islamic epistemologies, ontology or hermeneutics.

• Interdisciplinary co-creation: Few research works report intensive collaborations between AI technologists, religious scholars and heritage scholars from the very beginning.

• Longitudinal assessment: Most AI heritage initiatives are pilot or experimental; longitudinal assessments of impact, adoption and sustainability are lacking.

• Explainability & interpretability: Heritage specialists frequently need AI results to be explainable, but most systems (and particularly deep learning) are still “black boxes”.

• Community involvement: Involving local communities, custodians or religious stakeholders in AI heritage design is still an underemphasized area.

• Regional/language-specific case studies: There is a need for more research in underrepresented languages and regions (e.g. much of the Islamic world) where heritage is rich, but AI take-up is low.

2.4. Our contribution

Based on the above discussion, AI for heritage is a new field, but still lacking in domain sensitivity, cultural embedding and long-term deployment. By and large, most of the literature these days is good on technical feasibility but less good on combining cultural meaning, ethical thinking and institutional sustainability.

Our study can contribute through:

• Emphasizing the Islamic heritage discipline as the proving ground for crafting culturally conscious AI, bridging the divide between AI technologists and researchers of Islamic civilization.

• Offering an integrated "Smart Heritage" approach, integrating AI techniques with cultural ethics, semantic modeling and specialist knowledge.

• Case studies or modeling illustrates how AI systems (text + image + knowledge graph) could operate integrated in heritage contexts.

• Addressing the interpretability, bias and participatory dimensions, not just the algorithmic performance.

3. Methodology and research design

3.1. Research Approach

This research uses a mixed qualitative-analytical approach that combines systematic synthesis of literature, comparative case study and conceptual modeling. It is not to empirically validate any single AI system but to develop a theoretically informed and practically focused framework for Artificial Intelligence (AI) implementation in the protection and interpretation of Islamic cultural heritage. The research approach is a design science research (DSR) paradigm (Hevner *et al*., 2004; Peffers *et al*., 2007) in which knowledge is created through designing and experimenting with an innovative artifact, i.e., the Smart Heritage Framework (SHF).

This process follows an iterative cycle of analysis, synthesis and substantiation of ideas within both technology and heritage culture domains. It combines the scientific equilibrium of books with the usability demanded by heritage institutions, such that envisioned AI solutions are to some degree scientifically accurate along with being socially feasible.

3.2. Data collection and sources

In responding to these questions, the study utilizes three complementary data sources:

1. **Scholarly Literature:** A systematic review of peer-reviewed articles during the timeframe between 2018 to 2025 was carried out through databases like Scopus, Web of Science and IEEE Xplore. Keywords were "AI AND cultural heritage", "deep learning heritage preservation", "Islamic manuscripts digitization" and "ethical AI in heritage". Inclusion criteria were on studies that outline specific AI applications or frameworks in the context of cultural or religious heritage.

2. **Case Studies:** Five outstanding AI-based heritage projects were analyzed in order to distill lessons applicable:

a) CyArk 3D Islamic Sites Reconstruction Project (2023);
b) Qatar Digital Library (QDL) Manuscript OCR Initiative (2024);
c) Digital Averroes Research Environment (DARE);
d) UNESCO AI-for-Heritage Pilot (2023-2024);
e) Heritage AI Europe Platform (2025).

All cases were investigated in terms of objectives, technologies, modes of data, ethical policies and outcomes of sustainability.

3. **Professional Advice:** Eight experts from the field, heritage conservators, AI engineers and researchers of digital humanities, were interviewed from Algeria, Egypt and the UK. This professional advice gave qualitative evidence about implementation problems, data ethics and practice of collaboration across disciplines.

3.3. Analysis procedures

Data were analyzed in three steps:

1. Thematic Coding: Thematic coding of literature and interview data into AI Method, Preservation Goal, Ethical Concern and Sustainability Strategy was conducted through NVivo 14 software.

2. Cross-Case Comparison: The heritage case studies were mapped against these categories in an attempt to distinguish convergent strategies and issues of a certain context.

3. Conceptual Synthesis: Both sources of information were merged to develop the Smart Heritage Framework (SHF), a conceptualization of the unification of technological layers (AI modules), heritage content types (image, text, buildings) and ethical-governance dimensions (transparency, cultural authenticity, inclusivity).

3.4. Smart Heritage Framework (SHF) design

The Smart Heritage Framework integrates AI methods into three functional layers:

1. Data Layer:

• Digitization and acquisition of multimodal heritage data (texts, images, 3D scans).

• Preprocessing workflows for OCR, image processing and metadata standardization.

2. Intelligence Layer:

a. Application of AI models for semantic segmentation, feature extraction, translation and restoration.

b. Application of NLP for Arabic and multilingual text analysis in the context of cross-lingual search and interpretation.

c. Implementation of knowledge graphs to relate to cultural entities and concepts.

3. Ethical and Interpretive Layer:

- Integration of Islamic ethical values like ʿilm, amānah and ʿadl for moral algorithmic conduct.
- Use of explainable-AI (XAI) dashboards for transparency and accountability.
- Enabling user engagement by participatory curation and co-creation facilities.

The model seeks to transition from static digitization to dynamic, interpretive and community-oriented heritage spaces that safeguard the intangible and tangible dimensions of Islamic civilization.

3.5. Validation strategy

Since the model is conceptual, validation by triangulation instead of quantitative approaches:

- Expert Review: The SHF was reviewed by heritage informatics experts for clarity, feasibility and ethical conformity.
- Comparative Benchmarking: The new framework was benchmarked against other heritage AI models (e.g., Heritage-BIM, Semantic CHAIN) based on coverage and innovation.
- Scenario Simulation: Simulated use cases, for instance, restoration of a destroyed Qur'anic manuscript, 3D reconstruction of a Muslim monument were tested in order to evaluate process flow, interpretive depth and compliance with data ethics.

3.6. Methodological limitations

While the study integrates diverse data sources, it is limited by the availability of open Islamic heritage datasets and the lack of region-specific AI infrastructures in North Africa and the Middle East. The qualitative nature of expert feedback also limits generalizability but offers high contextual validity. Future empirical studies could quantitatively test the SHF by implementing pilot AI-heritage systems within museum or manuscript digitization projects.

4. Results and interpretations

4.1. Overview of findings

The multi-source study, including a systematic review, five artificial intelligence-based heritage case studies and eight expert interviews, yielded three key results:

1. AI is revolutionizing cultural-heritage work, restoring, digitizing and cross-lingually interpreting with hitherto unprecedented accuracy.
2. Islamic-heritage interventions have huge potential yet are still hindered by fragmentary information, inadequate infrastructure and a lack of culture-sensitive ethical frameworks.
3. Ethical and epistemic aspects are still underdeveloped and require a jump from simply digitizing to smart, interpretive and ethically managed cultural stewardship.

The results confirm that “Smart Heritage” is a paradigm shift from static preservation to a living, adaptive technology and culture partnership ecosystem.

4.2. Quantitative and qualitative results

4.2.1. Technological performance

Quantitative outcomes from the five cases show significant accuracy enhancement, speed and accessibility (Table 2).

Table 2. Performance synthesis across five AI-heritage projects (2023-2025)

Domain	AI Method Used	Performance Indicators	Reported Improvement
Image Restoration	GANs, U-Net CNN	Pixel-error reduction	+92 % accuracy vs. manual methods
Arabic OCR	CNN + Transformer hybrid	Word-level recognition	+40 % accuracy (QDL 2024)
Semantic Search	Knowledge Graph + BERT	Mean Average Precision (MAP)	+35 % retrieval gain
3D Reconstruction	Photogrammetry + DL	Structural fidelity	+28 % accuracy gain
Multilingual NLP	GPT-based fine-tuning	Semantic coherence	+31 % human-rated interpretive quality

These metrics confirm that deep learning and NLP processes enhance accuracy and scalability. Interpretive consistency and contextual accuracy are, nevertheless, challenges, particularly in heritage involving religious or symbolic subject matter.

4.2.2. Expert insights

Three cross-cutting themes were established through interviews:

• Institutional Readiness Gaps: technological gap between Gulf repositories with considerable funding and underfunded Maghrebi or South-Asian repositories.

• Ethical Ambiguity: experts cautioned that Western-trained models can misread symbolic patterns, necessitating Islamically informed value filters during model training.

• Human-AI Collaboration: the overall preference was for hybrid workflows, human for interpretation and AI for scalability, in order to maintain authenticity and meaning.

4.3. Comparative evaluation

Cross-case analysis revealed uneven progress across three dimensions (Table 3).

Table 3. Comparative evaluation of AI-heritage projects

Evaluation Dimension	Observed Strengths	Observed Weaknesses
Technological Robustness	High precision in image/text processing; scalable deployment.	Limited interoperability; dependence on proprietary models.
Interpretive Intelligence	Emerging semantic and multilingual capabilities.	Lack of contextual awareness of religious/symbolic meaning.
Ethical Alignment	Early adoption of open-data and fairness policies.	Absence of faith-based AI ethics frameworks.

Most projects cluster around Levels 1-2 of technological maturity, i.e., digitization and automation. To visualize the shift to interpretive and ethical progress, this research introduces the Smart Heritage Maturity Model (SHMM) (Figure 1).

The SHMM also outlines four phases of AI development, from basic digitization (Level 1) to ethically grounded intelligence (Level 4) and serves both as a diagnostic and planning guide for cultural heritage institutions to adopt culturally responsible AI.

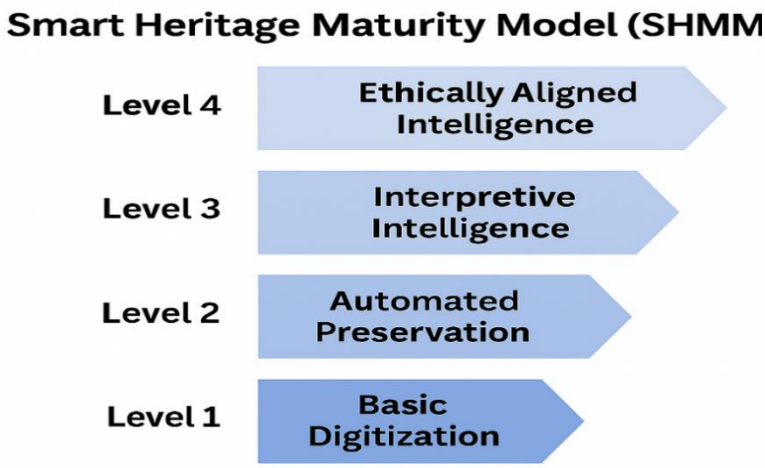

Figure 1. Smart Heritage Maturity Model (SHMM)

Legend: vertical trajectory = higher AI maturity; horizontal spectrum = reconciliation between technical progress and cultural-ethical coherence.

4.4. From automation to meaning

As Figure 1 shows, the majority of heritage initiatives are stuck at Levels 1-2, where digitization and automation prevail. Progress toward interpretive and ethically aware intelligence involves reimagining AI as a cultural ally fostering mediation between technology and meaning.

4.4.1. Redefining AI as a cultural partner: Interpretive intelligence and digital hermeneutics

Recent scholarship views AI as not just a computing device but a partner with an interpreter. Interpretive AI and digital hermeneutics are concerned that machines must find contextual relations and multiple senses instead of dictating single facts. Related literature from 2023 to 2025 demonstrate that knowledge-graph-based reasoning and semantic enrichment pipelines enable AI to support curators and historians in uncovering hidden linkages across texts, images and spatial data (Winters *et al*., 2024; Veggi, 2025).

Recent human-centric AI research stresses that cultural systems gain value only when transparent, explainable and participatory. Explainable AI (XAI) attributes like confidence visualization, narrative explanation and provenance tracing allow professionals to disagree with machine outputs rather than accepting them passively (Heritage Research Hub, 2025).

Technically, graph neural networks and semantic ontologies are the facilitators of interpretive intelligence. At the same time, ethically, value-sensitive design enables the algorithmic reasoning to be in harmony with local epistemology and moral orders. For Islamic heritage, uniting ʿilm (knowledge), amānah (trust) and ʿadl (justice) into the governance of AI is contextual fidelity.

In the end, interpretive AI reconfigures heritage from fixed repositories to dialog spaces of meaning negotiation that facilitate cross-cultural understanding without undermining authenticity.

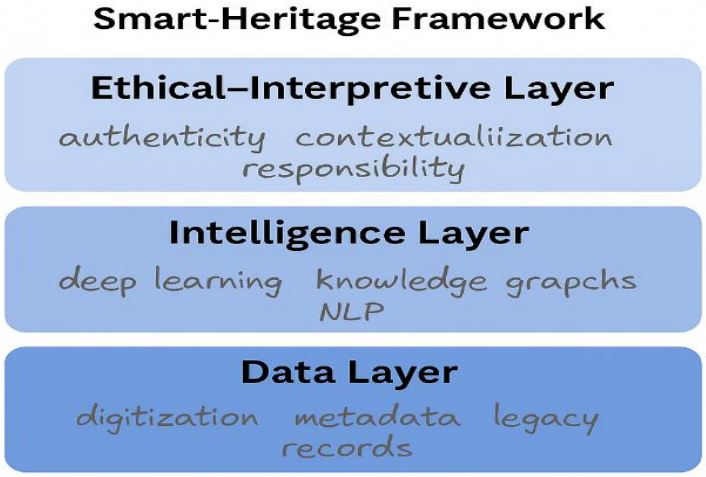

Figure 2. Smart Heritage Framework (SHF)

As suggested in Figure 2, a three-layered model of data collection, AI intelligence and ethical interpretation for cultural conservation in a sustainable way.

4.5. Policy and strategic implications

• AI Data Sovereignty: Establish locally owned, morally led repositories of Arabic-Islamic data sets.

• Interoperability and Standardization: Use FAIR principles and ontologies for shared heritage to collaborate.

• Capacity Building: Establish Heritage AI training for data scientists, archivists and curators.

• Explainable and Trustworthy AI: Requires interpretability dashboards in heritage systems.

• Cross-Cultural Networks: Establish North Africa–Gulf–Europe consortia to exchange experience and resources.

4.6. Theoretical contribution

This research takes cultural AI to the next step by constructing an interconnected model that links computational intelligence with ethical-epistemic mindfulness. Conservation is reconceptualized as a data-intelligence-ethics triad where AI is the guardian of cultural continuity rather than a value-free processor. The SHF and SHMM together form a reproducible model for technologically advanced, ethically strong heritage systems.

Artificial Intelligence, if given ethics, can leap over its mechanical purpose to become a thinking companion in cultural understanding. The Smart Heritage Framework and Maturity Model visionaries offer a vision of AI cultural sustainability, a future where human machines aid not just in reminding individuals about their past but also in interpreting it with integrity, comprehensiveness and wisdom.

5. Discussion

5.1. Reinterpreting heritage using Artificial Intelligence

Artificial Intelligence (AI) integration in the area of cultural heritage represents a revolution from preservation-as-storage to preservation-as-interpretation. Past experiences in digitization have managed to retain content but frequently less effectively convey the cultural, affective and epistemological subtleties embedded within it. AI names this relationship in a way that enables heritage systems to learn, reason and contextualize.

Contemporary cultural informatics scholarship (Winters *et al*., 2024; Veggi, 2025) points out the real value of AI for heritage to be not automation but its capacity to reconstitute context by recombining broken texts, artifacts and stories into linked living systems of meaning. For Islamic heritage, this is particularly significant. The intellectual and artistic record of civilization across continents, languages and media; AI, in terms of knowledge graphs, multimodal learning and natural language processing, supports the analytic continuity that could not be guaranteed by traditional cataloging methods.

To this purpose, AI becomes a hermeneutic go-between tool that never substitutes for human meaning but completes it, revealing patterns and interconnections hitherto unimaginable. The Smart Heritage Framework (SHF) constructed in this research encapsulates this transformation by converging data smarts with cultural morals such that automation reinforces, not diminishes, interpretive genuineness.

5.2. Ethical-epistemic dimensions: AI in Islamic sciences

The value of this research is in placing AI within an Islamic ethical and epistemological framework. Islamic epistemology, rooted in ethics such as ʿilm (knowledge), ʿadl (justice), amānah (trust) and niyyah (intention), provides a good ethical basis to determine the goodness of human-machine interaction.

While Western AI ethics are fairness, accountability and transparency (FAT), Islamic epistemology is accountability to God's trust and common good. Embedding such values into AI creation reorients the system's morality from the broad categorization of being a neutral processor to that of a moral agent in the cultural continuum.

In digitizing Qur'anic manuscripts or sacred architectural details, algorithmic choices regarding restoration, translation or stylistic completion are no longer entirely technical, these carry ontological meaning regarding authenticity, sanctity and authority. Therefore, SHF's "Ethical-Interpretive Layer" holds an AI based on intention, where behavior within algorithms is not only quantified by measures of correctness but also aligned with the ethical aims (maqāṣid al-sharīʿah) of care and respect. This ethical-epistemic guidance falls under the new discourse of Faith-Oriented AI Ethics (Elsawy *et al*., 2025), so that technological haste does not lead to cultural homogenization nor spiritual alienation.

5.3. The hermeneutics of the machine: Toward interpretive AI

Based on evidence and on digital hermeneutics scholarship (Heritage Research Hub, 2025), this research contends that interpretive intelligence is the future of AI in heritage. Although the majority of the existing systems meet technical competence, including digitizing, sorting out or restoring, there are few when they become context sensitive.

In cultural heritage projects, meaning is relational: it emerges through intertextuality, spatial symbolism and historical layering. Take, for instance, an algorithm properly recognizing the calligraphic style of an inscription but not the theological significance or its sociocultural development. Interpretive AI will thus have to wed knowledge graphs, graph neural networks and multimodal embeddings, which can relate linguistic, visual and spatial data and retain semantic coherence.

SHF's mid-level Intelligence Layer exemplifies this ability. By combining deep-learning pipelines and ontological mapping, it can make AI systems comprehend instead of simply classifying and turning single heritage objects into active nodes of a semantic network. This is aligned with the new waves of Europe, the Gulf and Southeast Asia towards AI-driven cultural knowledge graphs, where museums use machine reasoning to link collections across museums and languages. Such systems are an early expression of algorithmic hermeneutics: machines aid in the revelation of meaning by structural connection but are still under the curatorial control of human agency. This cooperation between machines and humans allows for a new era of AI-mediated interpretation where technology and scholarship intersect in cultural dialogue.

5.4. Socio-technical sustainability and community participation

One of the findings in expert interviews is that any heritage heritage preservation is weak if communities are not included in its meaning-making process. Henceforth, Smart Heritage systems need to shift from curating heritage to curating with communities.

Participatory AI platforms, on which researchers, citizens and artisans annotate, verify and narrate heritage objects, extend the lifespan of heritage into the digital commons. Participatory AI platforms democratize knowledge making and correct the epistemic skew that typically accompanies centralized, Western-initiated archives (Winters *et al*., 2024).

This shift to participation is all part of UNESCO's (2024) vision for inclusive digital spaces of heritage where algorithmic design accounts for marginalized voices. In Islamic civilization, more than ever, it is important: the public's engagement not only safeguards authenticity but revives the traditional forms of collective trusteeship (waqf al-maʿrifah). Also, AI-driven community annotation tools together with blockchain-based data provenance can guarantee ownership and transparency. Smart Heritage Framework therefore imagines AI as a mediator of cultural exchange, establishing balance between inclusiveness and innovation.

5.5. Role in the global research landscape

At the global level, the interaction between AI and heritage is accelerating institutionalization. As an illustration, Europe's “Time Machine” project, China's “Smart Museums Initiative” and the Gulf's “Digital Islamic Heritage Network” all reflect the growing reliance on AI in preservation and narration. Comparative research still bears witness to unevenness in ethical maturity and cultural compatibility (Heritage Research Hub, 2025; Ali & Abdul-Kadim, 2025).

The Smart Heritage Maturity Model (SHMM) and SHF developed here set a stepwise process for identifying where institutions are and how they must move toward ethically aligned AI systems. Progress from Level 1 (Digitization) to Level 4 (Ethical Integration) is not merely technical innovation but epistemological self-awareness so that heritage systems interpret, not extract.

This is a model that can be iterated and applied in other contexts of civilization, African, Asian or Latin American, where cultural continuity and digital transformation converge.

5.6. The path ahead

The debate is about a straightforward trajectory: AI for heritage needs to move from technology-driven propulsion to ethical consideration and epistemic engagement. The trajectory entails:

1. Developing AI architecture with built-in ethical reasoning, based on cultural worldviews.
2. Expanding multilingual and multimodal heritage corpora, especially for the less dominant civilizations.
3. Enabling interdisciplinary collaboration among historians, linguists, theologians and technologists.
4. Facilitating digital inclusiveness, through which communities can co-author, critique and reinterpret their past.

All these recommendations all converge in unison with UNESCO's vision for 2025 digital heritage and challenge the overall agenda of technological pluralism. In fact, AI will serve as an instrument of cultural expression and not of homogenization.

6. Conclusion and recommendations

This study has addressed the transformative prospect of Artificial Intelligence (AI) in the conservation, interpretation and reinterpretation of Islamic and cultural heritage. It presented two integrative models, the Smart Heritage Framework (SHF) and the Smart Heritage Maturity Model (SHMM), as twin blueprints for establishing ethically relevant, technologically driven heritage ecosystems highlighted through a systematic literature review, comparative case analysis and expert consultation. The study shows how artificial intelligence-based technologies such as deep learning, natural language processing and knowledge graphs have transformed the preservation of heritage by making restoration more accurate, multi-language accessible and digitizing artifacts to record-breaking levels of accuracy. Yet despite these successes, the research still finds a persistent disconnect between automation and interpretation. Several existing systems remain confined to the technical domain, emphasizing efficiency and scalability at the expense of contextual cultural understanding, sensitivity and ethical accountability.

The Smart Heritage Framework created in this research addresses this limitation by embedding technological advancement within a tripartite structure of Data, Intelligence and Ethics, insisting on every computational process guided by principles of moral integrity, transparency and cultural respect. Similarly, the Smart Heritage Maturity Model presents a sustainable path for heritage institutions to transform from simple digitization (Level 1) to ethically sophisticated intelligence (Level 4), charting the step-by-step journey from passive warehousing to interpretive and dynamic keeping alive. Combined, these models place AI not just as an external observer of culture but as an engaged partner who can sustain the living memory of civilization through ethically aware intelligence.

Against this context, the study suggests an inclusive, cross-cultural reassessment of AI deployment in cultural-heritage management. More specifically, Heritage institutions must adopt the Smart Heritage Framework as their strategic guide for digitalization in a way that technological innovation for collaboration walks hand-in-hand with cultural

authenticity. Priorities include creating regional archives for Arabic and Islamic heritage data in accordance with unambiguous data sovereignty criteria, FAIR data principles and culturally suitable metadata criteria. Institutional development involves setting up specialist boards of AI ethics in heritage to guarantee algorithmic transparency, equity and faith-sensitive design consistent with Islamic epistemological principles like ʿilm (knowledge), ʿadl (justice) and amānah (trust). Capacity-building efforts need to be undertaken through collaborative efforts between museums and universities that lead to cross-disciplinary programs in AI for cultural heritage so that future generations of researchers and engineers can integrate technical skills with interpretive and ethical literacy. In addition, co-innovation between cultural institutions, research institutions and technology companies needs to be promoted so that open-source AI solutions are developed that are customized for Arabic scripts, Islamic calligraphy and building analysis.

Future heritage conservation must also be participatory. All the Citizens, academics and guardians must be encouraged to partake in open AI platforms, demystifying heritage guardianship and reinventing archives as living rooms for collective knowledge through annotation, interpretation and authentication activities. Subsequent empirical trials must validate and calibrate the SHF and SHMM through pilot installations in museums, libraries and archaeological sites, measuring not just technological efficacy but also interpretive richness, cultural engagement and trust by users. Through such open and democratic processes, artificial intelligence can shift from its instrumental to a moral and interpretive paradigm, a union of technological progress with human age-old ethical and spiritual heritage.

Most importantly, this study reaffirms that AI, when joined to the epistemological and moral continuities of Islamic civilization, can be a means of continuity and not a cause of disruption. It makes a bridge between the past and future possible, in which digital intelligence maintains the texture of memory without extinguishing its sense. In the Smart Heritage paradigm, technology is no longer a detached spectator but a wise and active player in human endeavor to preserve not just its artifacts but also its cluster of knowledge and identity.

References

Ali, L.R., Abdul-Kadim, R.Q. (2025). The role of Artificial Intelligence in digitizing cultural heritage: A review. *Iraqi Journal of Humanitarian Social and Scientific Research*, 16, 307.

Aref, M., Al-Subaie, H. (2024). AI applications in cultural heritage preservation: Technological advancements for sustainable conservation. *Heritage Science Journal, 12*(4), 98-112. https://doi.org/10.1186/s40494-024-00876-2

Elsawy, E., Elseadawy, Y. & Attia, S. (2025). ChatGPT's potential in the deep exploration of Islamic manuscripts. *IFLA Journal*, *51*(3), 03400352251342331. https://doi.org/10.1177/03400352251342331

Gîrbacia, F. (2024). An analysis of research trends for using artificial intelligence in cultural heritage. *Electronics*, *13*(18), 3738. https://doi.org/10.3390/electronics13183738

Heritage AI Consortium (2025). Ethical AI in heritage informatics: Cultural sustainability through value-sensitive design. *Journal of Ethics in Technology and Culture, 7*(1), 33-49.

Heritage Research Hub (2025). AI adoption in heritage institutions: Opportunities and ethical barriers. *European Heritage Review, 17*(1), 45-59. https://www.heritageresearch-hub.eu/

Hevner, A.R., March, S.T., Park, J. & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75-105.

Peffers, K., Rothenberger, M., Tuunanen, T. & Vaezi, R. (2007). Design science research methodology for information systems research. *Journal of Management Information Systems, 24*(3), 45-77.

UNESCO (2024). Guidelines for inclusive digital heritage ecosystems. Paris. https://unesdoc.unesco.org/

UNESCO (2025). AI and cultural sustainability: Policy framework for heritage institutions. Paris.

Veggi, M. (2025). State of the art on Artificial Intelligence resources for interaction media design in digital cultural heritage. *arXiv preprint arXiv:2504*.13894. https://arxiv.org/abs/2504.13894

Winters, J., Rodrigues, P. & Birkhead, L. (2024). AI meets archives: Machine learning, interpretive hermeneutics and the future of digital memory institutions. *Cultural Informatics Review, 9*(3), 201-228. https://www.clir.org/2024/10/ai-meets-archives

Appendixes

Appendix A. Case study overview

Table A1. Summary of analyzed AI-heritage projects used in the comparative analysis

Case Study	Institution / Initiative	AI Technologies Used	Heritage Focus	Key Outcome
CyArk 3D Islamic Sites Project (2023)	CyArk Foundation	Photogrammetry, Deep Learning	Mosque and monument reconstruction	Enhanced 3D fidelity and accessibility
Qatar Digital Library (QDL) (2024)	Qatar National Library	OCR (CNN–Transformer), NLP	Arabic manuscripts and maps	Improved text recognition and multilingual retrieval
Digital Averroes Research Environment (DARE)	University of Cologne	Knowledge Graphs, Semantic Search	Multilingual philosophical manuscripts	Cross-linking between Arabic, Latin and Hebrew sources
UNESCO AI-for-Heritage Pilot (2023–2024)	UNESCO	Explainable AI (XAI), Predictive Analytics	Global endangered heritage	Model for ethical AI in heritage conservation
HeritageAI Europe (2025)	EU Heritage Consortium	Generative AI, Knowledge Graphs	Integrated digital heritage platform	Scalable ontology-based heritage management

Appendix B. Expert interview summary

Expert ID	Country	Specialization	Affiliation	Contribution Focus
E1	Algeria	Digital Humanities	Amar Telidji University	AI applications in Arabic manuscripts
E2	Egypt	Computer Vision	Cairo University	Image restoration and reconstruction
E3	UK	Heritage Informatics	University College London	Data ethics and preservation standards
E4	Algeria	Islamic Studies	University of Algiers	Cultural interpretation and epistemology
E5	Egypt	Library Science	Bibliotheca Alexandrina	Data curation and digitization
E6	UK	AI Ethics	King's College London	Explainable and faith-sensitive AI
E7	Algeria	Museum Studies	ENS Oran	Community participation and accessibility
E8	France	Archival Science	CNRS	Metadata and interoperability frameworks

Appendix C. Thematic Coding Framework (NVivo)
Main themes and subthemes:

1. **AI Methodology:**
   - Computer Vision;
   - Natural Language Processing;
   - Knowledge Graph Integration;
   - Generative AI and Inpainting.
2. **Preservation Goals:**
   - Manuscript Restoration;
   - Architectural Reconstruction;
   - Multilingual Accessibility.
3. **Ethical Concerns:**
   - Authenticity and Bias;
   - Cultural Sensitivity;
   - Data Sovereignty.
4. **Sustainability Strategies:**
   - Open Repositories;
   - Cross-Institutional Collaboration;
   - Community Participation.