AUTHENTICITY UNDER QUESTION: ETHICAL REFLECTIONS ON 3D TECHNOLOGIES IN SCULPTURE CONSERVATION

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ABSTRACT

This paper examines the ethical challenges posed by the integration of 3D technologies—such as photogrammetry, laser scanning, and additive manufacturing—into the conservation of sculptural heritage. While these tools offer novel possibilities for documentation, replication, and interpretation, they also raise concerns regarding authenticity, reversibility, and material compatibility. The convergence of physical and digital practices necessitates a reassessment of existing conservation ethics that were originally developed for analogue interventions. Drawing on a comparative analysis of ethical frameworks—including the London and Seville Charters, the Nara Document, and ICOMOS guidelines—and three representative case studies (the Arch of Palmyra, the Tlingit Killer Whale Hat, and multisensory museum interfaces), this study evaluates how traditional ethical principles translate into the digital realm. Key issues such as intellectual property, data longevity, and community agency are critically examined. The article proposes an expanded ethical model for digital interventions that incorporates participatory and care-based approaches. It argues that 3D technologies should not be treated as neutral tools but as culturally embedded practices requiring transparency, contextual sensitivity, and shared responsibility. This reframing allows 3D applications to enhance, rather than compromise, the long-term integrity and meaning of heritage artefacts. The aim is not to resist technological change, but to articulate conditions under which 3D interventions can support—not undermine—the long-term integrity and cultural value of heritage artefacts.

Keywords: 3D technologies, conservation ethics, authenticity, digital heritage, digital reconstruction

1. INTRODUCTION

The integration of 3D technologies into the conservation of sculptural heritage has opened new possibilities for documentation, interpretation, and audience engagement. (Soulioti and Chatzidaki 2021). Tools such as photogrammetry, laser scanning, and additive manufacturing now allow conservators to record, replicate, and disseminate cultural artefacts with unprecedented precision and flexibility. (Di Giuseppantonio Di Franco, Galeazzi, and Vassallo 2018). These developments have led to a significant methodological shift: from object-focused interventions to data-driven, reproducible, and often dematerialised forms of conservation. Yet alongside these technical innovations arise critical ethical questions. (Giombini 2018).

While 3D technologies are often introduced under the banner of accessibility or innovation, their use can challenge foundational conservation principles—authenticity, reversibility, minimal intervention, and material compatibility. As the field increasingly embraces hybrid workflows that combine digital data with physical restoration, the boundaries between documentation, intervention, and interpretation become blurred. In this context, established ethical frameworks such as the Venice Charter (1964), the Nara Document on Authenticity (1994), and ICOMOS principles offer only partial guidance. Likewise, domain-specific documents like the London and Seville Charters propose digital best practices, but often fail to account for the philosophical and material complexities involved in 3D-mediated heritage conservation.

This article addresses the ethical gap between traditional conservation standards and the evolving realities of digital practice. It argues that while 3D technologies offer valuable tools, they must be applied with critical

awareness of their representational, ontological, and socio-political implications. In particular, the visual authority of digital surrogates, the long-term sustainability of digital assets, and the question of cultural authorship raise unresolved tensions.

The paper draws on theoretical literature, conservation charters, and case-based examples to examine how ethical principles may be reinterpreted in light of these challenges. By reframing authenticity and proposing care-based and participatory approaches, the article seeks to contribute to the development of more comprehensive and context-sensitive ethical guidelines for 3D technologies in sculpture conservation.

2. ETHICAL FRAMEWORKS FOR DIGITAL CONSERVATION

The ethical foundations of conservation practice have historically been articulated through international charters and institutional guidelines, such as the ICOMOS Charter (2003), which emphasize principles like authenticity, reversibility, minimal intervention, and respect for original context. Core principles—such as authenticity, reversibility, minimal intervention, and respect for original context—remain central reference points. However, their interpretation in digital environments is not straightforward. Digital interventions, while often non-invasive in appearance, can carry ontological and representational implications that require reconsideration of these foundational norms[1].

Among the most influential documents in this domain is the London Charter (Denard, 2009), which advocates for intellectual transparency, methodological rigour, and the use of paradata to explain decisions made in digital visualisation. While the Charter was initially conceived for virtual reconstructions, its principles are broadly applicable to conservation contexts that involve 3D modelling or replication. Nevertheless, its impact in practice remains inconsistent. Projects often fail to provide adequate metadata or distinguish between evidence-based reconstruction and interpretive speculation, undermining the Charter's call for epistemic transparency (Di Giuseppantonio Di Franco et al. 2018).

The London Charter's call for transparency could be operationalised by embedding explanatory layers within digital exhibitions.

The Seville Charter (López-Menchero & Grande, 2011) complements the London Charter by emphasising interdisciplinary collaboration and the responsible integration of digital technologies in archaeology and heritage management. It foregrounds scientific accuracy and public accessibility, advocating for rigorous documentation and long-term preservation. Although designed for virtual archaeology, its principles are transferable to the conservation of sculptural objects—particularly in cases where digital reconstructions serve interpretive or communicative functions.

The Nara Document on Authenticity (1994) introduced a significant conceptual shift by framing authenticity as context-dependent rather than materially fixed. This has profound implications for digital conservation: it legitimises forms of representation that diverge from material continuity but retain historical or cultural resonance. However, the flexibility offered by the Nara framework can also lead to ethical ambiguity, especially when used to justify speculative or politically motivated reconstructions (Luxen 1994). Labadi (2010) extends this line of critique by arguing that heritage authenticity must evolve beyond rigid frameworks toward a more relational, dynamic, and community-informed model. She introduces the notion of "post-authenticity," which foregrounds lived experience and interpretive multiplicity over essentialised or object-focused definitions.

Brumann (2020) critiques the underlying assumptions of international heritage governance, arguing that concepts of authenticity used by bodies like UNESCO are often shaped by Eurocentric ideals. He calls for a more anthropological approach to heritage ethics—one that recognises cultural pluralism and resists homogenised standards of value.

1 ICOMOS Charter: Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage (2003) Ethics of Digitizing Public Heritage (Najam Ul-Assar, 2021)

As Cameron (2015) notes, the Nara Document emerged from cross-cultural debates about the Eurocentric limits of the Venice Charter, pushing the field toward a more pluralistic and context-sensitive understanding of authenticity.

The ICOMOS charters, particularly the Venice Charter (1964) and the Charter on the Interpretation and Presentation of Cultural Heritage Sites (The Ename Charter), (ICOMOS 2008), remain essential ethical benchmarks. Though not originally designed for digital interventions, their emphasis on authenticity, documentation, and interpretive clarity aligns with the challenges posed by 3D technologies. Yet, these documents tend to prioritise material conservation and often lack explicit provisions for born-digital or hybrid heritage objects. As a result, conservators are frequently required to extrapolate traditional guidelines to novel digital contexts.

In summary, while existing ethical frameworks provide a valuable foundation, they exhibit notable limitations when applied to 3D technologies in sculpture conservation. They often fall short in addressing the unique risks associated with digital surrogates, such as symbolic overreach, loss of material reference, or insufficient documentation of modelling processes. As digital tools increasingly shape the future of conservation practice, there is a pressing need to revisit and expand these frameworks to ensure they remain relevant, inclusive, and adaptable.

Younger scholarship, particularly in contemporary art conservation, has begun to challenge such limitations by reframing replicas not simply as degraded substitutes, but as autonomous manifestations entangled in complex ontologies of meaning, interpretation, and reception (Soulioti and Chatzidaki 2021). This shift invites conservators to move beyond materialist biases and engage with replicas as conceptually situated artefacts whose authenticity may lie in intention or context rather than physical continuity.

3. EMERGING ETHICAL CHALLENGES

While international charters and institutional guidelines offer a foundational ethical framework for conservation, the accelerating development of digital technologies introduces novel challenges that exceed the scope of existing norms. The application of 3D technologies—particularly when used for modelling, replication, and dissemination—raises critical questions around digital ownership, long-term viability, representational authority, and stakeholder inclusion. These emerging ethical concerns call for expanded, dynamic approaches that can accommodate both the technological specificity and sociocultural implications of digital heritage practices.

4. INTELLECTUAL PROPERTY AND DIGITAL AUTHORSHIP

The digitisation of cultural artefacts complicates traditional understandings of ownership and authorship. Although physical custodianship may rest with a museum or institution, the creation of a digital model often involves interpretive labour—such as post-processing, segmentation, or enhancement—that may introduce new claims to copyright. When outsourced to commercial platforms or third-party providers, the ethical control over these models can become obscured. Moreover, the re-use and remixing of 3D models on open platforms like Sketchfab, sometimes detached from their original context, raises the risk of digital decontextualisation or cultural appropriation. These challenges are particularly acute in the case of indigenous or sacred artefacts, for which Western legal frameworks provide limited protection (Brown and Nicholas 2012).

Cronin (2015) argues that digital reproductions challenge traditional notions of ownership by divorcing the perceived value of heritage from its material form, especially when digital surrogates are viewed as equally legitimate vessels of cultural meaning.

5. SUSTAINABILITY AND DIGITAL LONGEVITY

Unlike physical artefacts, digital surrogates are subject to rapid technological obsolescence. File formats, software environments, and metadata standards evolve quickly, rendering earlier data potentially unreadable or inaccessible. Without dedicated strategies for long-term digital preservation—including open-source formats, regular migration, and institutional infrastructure—3D documentation efforts risk becoming ephemeral. This fragility contradicts conservation's commitment to enduring value and underscores the need to treat digital files as heritage in their own right (Ioannides and Quak 2014). Conservation ethics must therefore expand to include care for digital matter and the systems required to maintain its integrity over time.

Yet the reliability of 3D data is itself contingent upon technical parameters: optical distortion, environmental conditions, and surface reflectivity can all introduce inaccuracies that complicate the use of such models for long-term conservation (Bugeja et al. 2022). These constraints underscore the need for critical evaluation of digital outputs and caution against treating scans as inherently objective representations.

Recent strategic agendas, such as the R&D roadmap proposed by Münster et al. (2024), underline the need for interdisciplinary infrastructures to support the ethical, sustainable, and inclusive use of AI in cultural heritage. These frameworks advocate not only for technical robustness and data longevity, but also for transparency, institutional responsibility, and alignment with societal values. By integrating AI in a way that supports curation, engagement, and preservation, heritage institutions can proactively address ethical challenges posed by digital transformation and automation in conservation work.

As Immonen and Malinen (2021) point out, the rapid evolution of 3D digitisation tools presents not only technical but also ethical challenges for heritage institutions. Without long-term planning and institutional frameworks for sustainable use, digitisation risks becoming a resource-intensive yet short-lived practice. They also highlight that large-scale 3D archives can strain storage infrastructure and increase energy consumption, complicating alignment with sustainability goals.

6. EPISTEMIC TRANSPARENCY AND VISUAL AUTHORITY

One of the most pressing issues in digital conservation is the epistemic weight carried by high-resolution visualisations. Digital reconstructions—particularly those presented in immersive, interactive, or visually compelling formats—often convey a sense of factual accuracy, even when based on partial or speculative data. This "aesthetic realism" risks misleading viewers and undermines the interpretive ambiguity inherent in heritage materials. Scholars have called for the integration of paradata and metadata into digital models, allowing users to distinguish between documented, inferred, and speculative elements (Spiegel, Hallerman and Kulik 2017). Without such transparency, digital surrogates may inadvertently assume unjustified authority within public discourse, policy decisions, or educational contexts.

As Vyhnánková (2025) argues, ethical responsibility in digital conservation does not end with the accurate production of a 3D model. It also includes the way digital interventions are communicated to both professional and public audiences. Rather than evaluating ethics solely in terms of material or technical accuracy, this perspective highlights the importance of transparency, cultural sensitivity, and interpretive framing in the presentation of digital surrogates.

Stobiecka (2020) expands this argument by drawing on Walter Benjamin's concept of aura, suggesting that digital mediation inevitably alters the ontological status of heritage objects. The experiential immediacy of original material is replaced by a new form of aesthetic presence—seductive but disembodied. This substitution challenges not only perception but the very terms on which authenticity is negotiated in digital environments.

7. PARTICIPATORY AND CARE-BASED ETHICS

Traditional conservation frameworks tend to be institutional and technocratic in nature. However, emerging scholarship advocates for a more relational and care-based approach to digital heritage, foregrounding attentiveness, empathy, and shared responsibility. Care ethics shift the focus from abstract principles to situated relationships—between objects, communities, and professionals—and call for participatory design processes that recognise the agency of source communities and non-expert stakeholders (Giombini 2023). In practice, this may involve collaborative digitisation protocols, co-curation, and cultural consent mechanisms. By embedding care into digital workflows, conservation moves closer to ethical inclusivity and social accountability.

This resonates with Giombini's proposition that conservation ethics should be reoriented from mere material integrity toward the preservation of meaning, especially when heritage is embedded in the social and emotional relationships of communities. (Giombini 2018). This position is echoed in Vyhnánková's (2025) proposal that participatory approaches in 3D conservation not only redistribute decision-making power but also help reframe the conservator's role as a mediator of cultural relationships rather than a neutral technician.

8. CASE STUDIES AND ETHICAL DILEMMAS

The ethical dimensions of 3D technologies in conservation become particularly salient when examined through real-world case studies. These examples reveal how digital interventions, even when well-intentioned, can generate unintended consequences—both conceptual and political. The following case studies illustrate different types of ethical dilemmas related to authorship, representation, community agency, and digital colonialism.

8.1 The Arch of Palmyra: spectacle, surrogacy, and symbolic politics

Perhaps the most widely discussed case of digitally reconstructed heritage is the 3D-printed replica of the Arch of Triumph in Palmyra, unveiled in London's Trafalgar Square in 2016. Created by the Institute for Digital Archaeology using photogrammetric data and CNC-milled stone, the replica was presented as a gesture of defiance against cultural terrorism. However, critics noted that the project lacked consultation with Syrian stakeholders and bypassed UNESCO frameworks. The monument's relocation to Western capitals sparked accusations of cultural appropriation and "digital colonialism"—the symbolic extraction of heritage for political spectacle. While technically impressive, the project exemplified how digital surrogates can reinforce unequal power dynamics and instrumentalise heritage for ideological ends. (Khunti 2018, Foley n.d., Labadi 2010). Fig. 1

As recent scholarship has shown, the politics of digital surrogacy and restitution must also be framed within broader transformations in ethical and legal frameworks concerning colonial objects. The shift from legalistic ownership claims to relational ethics—grounded in the rights of communities and intergenerational responsibilities—represents a paradigmatic turn in the way heritage is understood, claimed, and restored (Stahn 2023). In this context, even well-intentioned digital interventions must be evaluated not only for their technical merits but for their alignment with these evolving ethical standards. What should museums or conservators consider in similar cases?

8.2 The Killer Whale Hat: indigenous consent and data sovereignty

The digitisation of the sacred Tlingit Killer Whale Hat—a ceremonial object held at the Smithsonian Institution—offers a valuable example of collaborative heritage practice shaped by community values. In this case, the scanning and digital reproduction were carried out in consultation with tribal leaders and with cultural sensitivity, including the use of locally sourced materials and approval by community representatives (Cieslik 2020). However, the broader circulation of the resulting 3D model has raised ongoing concerns regarding cultural consent, digital rights, and community control over access. The case underscores the limitations of

equating legal custodianship with moral or cultural authority and highlights the need for culturally responsive digitisation strategies. These include protocols for consultation, controlled access, and Indigenous agency in defining metadata and reproduction rights. This case highlights the need for clear provenance and context annotation when exhibiting 3D reconstructions of conflict-damaged heritage.

8.3 The Regolini-Galassi Tomb: interpretation, immersion, and epistemic ambiguity

The immersive 3D visualisation of the Regolini-Galassi tomb in Cerveteri, developed as part of the Ancient Itineraries project, offers insight into the tension between educational accessibility and epistemic transparency. While the virtual tour enables audiences to explore a reconstructed version of the tomb, it does not always clearly demarcate which elements are factual, hypothesised, or entirely speculative. The use of rich visual effects and atmospheric soundscapes further enhances the illusion of completeness. Such representations can obscure the provisional nature of archaeological knowledge and may unintentionally mislead users. This case illustrates the epistemological risks of aesthetic realism and supports calls for the systematic inclusion of paradata in public-facing visualisations. (Pietroni and Ferdani 2021).

8.4 The Wages of Sin: authorship, instability, and institutional responsibility

A compelling example of ethical decision-making in contemporary art conservation is the case of The Wages of Sin (1987) by Mike Kelley. Originally created as a wax-based sculptural installation comprising candles embedded in a sphere, the work was damaged during transit and handling in the context of a major retrospective. In response, the Whitney Museum and the Mike Kelley Foundation collaborated to produce an exhibition copy that would replace the original component while preserving its visual and spatial effect (Nagy 2022).

The process involved detailed 3D scanning, modelling, and casting in durable synthetic materials to mimic the original's formal qualities. While technically faithful, the replica inevitably altered the work's material presence and conceptual logic—particularly as the original medium (wax) was inherently ephemeral and symbolically charged. The decision to replicate rather than restore or reinterpret raises important questions about the boundaries of authorship, the ethics of substitution, and the role of the museum as an arbiter of meaning.

This case illustrates the unique challenges of contemporary materiality and highlights the growing relevance of digital and material replication strategies. It also signals the need for transparency and critical reflection in exhibition contexts, especially when the reproduced object deviates significantly from the artist's chosen materials or intent.

8.5 Multisensory museums and the ethics of embodied engagement

Museums increasingly employ 3D technologies not just for visual display but for embodied, multisensory engagement. Projects that recreate artefacts through 3D printing for tactile exploration—particularly for visually impaired audiences—exemplify the inclusive potential of digital tools. However, they also raise new ethical questions: What are the implications of allowing touch where original materials would prohibit it? Who determines the threshold between interpretation and misrepresentation? These projects demonstrate that even seemingly benign applications of 3D technologies can challenge established museological norms and require careful ethical reflection. (Di Giusepantonio Di Franco et al. 2015)Fig. 3

As Beerkens (2007) notes, the use of replicas in museums has long sparked debate about authenticity, especially when reproductions become central to the interpretive experience. Rather than undermining authenticity, such interventions may offer alternative forms of engagement, particularly when the original object is fragile or inaccessible.

8.6 Digital preparedness and institutional responsibility: The Ain Fouara statue

The 3D documentation of the Ain Fouara statue in Sétif, Algeria, offers a compelling example of how digital technologies can be leveraged in anticipation of—not merely in response to—physical damage. The marble statue, created in 1899 by Francis de Saint-Vidal, has long been a symbolic and controversial presence in public space, and was vandalised in a high-profile incident in December 2018. (Mechiche & Zeghlache, 2020). Remarkably, a high-resolution 3D scan of the monument had been created a year earlier by the Italian heritage start-up Scan the World[2], allowing the damaged parts to be accurately reconstructed from pre-existing data. (Khodja et al., 2019).Fig. 2

This case demonstrates the strategic potential of digital heritage tools as part of risk preparedness. Unlike other examples where reconstruction efforts are based on incomplete or post-destruction documentation, the Ain Fouara scan enabled the creation of physically faithful replacements using 3D printing and CNC milling technologies (Khodja et al., 2019) However, the case also illustrates that technological readiness is not ethically sufficient in isolation. Questions emerged around the legitimacy of reproducing contested public monuments, the role of the state in symbolically restoring a colonial-era statue, and the absence of community consultation in determining the form and meaning of the reconstruction (Mechiche & Zeghlache, 2020).

From an ethical standpoint, the case exemplifies the importance of institutional responsibility in integrating digital strategies into long-term heritage management. The availability of 3D data was a fortunate by-product of an external initiative, rather than the result of systematic conservation planning. Furthermore, the public discourse surrounding the statue remained largely disconnected from the technical processes involved in its restoration, despite the attention the incident received in international media. This disconnect underlines the risk of overemphasising technological solutions without engaging with broader cultural, political, and social dimensions.

In this context, the Ain Fouara statue invites a rethinking of digital preparedness not merely as a technical protocol, but as an ethical commitment—to transparency, community dialogue, and the cultural conditions under which digital heritage is created, stored, and activated.

9. PRACTICAL RECOMMENDATIONS FOR ETHICAL 3D USE

Based on the preceding discussion, this section outlines a set of practical recommendations for the ethical integration of 3D technologies into sculpture conservation. These principles are intended as a flexible framework to guide practitioners, institutions, and stakeholders in navigating the evolving challenges of digital heritage.

9.1 Embed ethical planning from the outset

Ethical considerations should not be treated as retrospective justifications but as integral to the design and implementation of any project involving 3D technologies. This includes defining the purpose, scope, and limitations of the intervention early on.

9.2 Ensure transparency through documentation and paradata

All stages of 3D processing—scanning, modelling, editing, and printing—should be accompanied by thorough documentation. Paradata should be clearly presented to distinguish between factual, interpretive, and speculative elements.

2 Scan the World. (2016). Ain Fouara Fountain, Sétif, Algeria – 3D scan. MyMiniFactory. Retrieved from https://www.myminifactory.com/object/3d-print-ain-fouara-fountain-setif-algeria-175370

9.3 Adopt inclusive, care-based approaches

Engage with source communities, user groups, and non-expert stakeholders through participatory methodologies. Ethical practice in digital conservation must be relational and responsive to cultural contexts and sensitivities.

9.4 Plan for digital sustainability

Long-term preservation of 3D data requires institutional commitment to open formats, metadata standards, and periodic maintenance. Digital files should be treated as dynamic heritage objects requiring ongoing care.

9.5 Respect cultural authorship and data sovereignty

Institutions should develop policies that address the ownership and control of digital models, especially for sacred, indigenous, or contested objects. Cultural consent should guide access, reuse, and dissemination strategies.

9.6 Critically reflect on visual authority and public impact

When 3D technologies are used in public-facing contexts—such as exhibitions, education, or digital tourism—it is vital to consider their rhetorical power. Visual realism should not override critical engagement with ambiguity and interpretation.

By following these principles, conservation professionals and institutions can move beyond a reactive or purely technical engagement with digital tools, and toward an ethical paradigm that foregrounds transparency, care, and shared responsibility.

10. KEY FINDINGS

1. Digital technologies challenge traditional conservation ethics by shifting the notion of authenticity from material permanence to contextual relevance.

2. Community agency and epistemic diversity are essential in evaluating the legitimacy of digital reconstructions.

3. Participatory and care-based models offer viable frameworks for ethically informed 3D interventions.

4. Case studies show that the cultural value of digital replicas depends on transparency, purpose, and contextual sensitivity.

11. DISCUSSION

The examined case studies illustrate that the ethical use of 3D technologies in sculpture conservation is not simply a matter of technical execution or best-practice compliance. Rather, these interventions operate within a complex ethical terrain shaped by shifting notions of authenticity, authorship, cultural agency, and material presence. While existing frameworks provide valuable orientation, they often fall short in addressing the nuanced challenges that arise when physical heritage is transformed into digital and hybrid forms.

One of the most persistent tensions concerns the ontological ambiguity of digital surrogates. Unlike physical replicas, which occupy a fixed material space, digital models exist in a fluid, reproducible, and contextually malleable state. They can be visualised, manipulated, and reproduced in ways that traditional conservation cannot accommodate. As a result, digital objects resist stable categorisation: they are at once records, tools,

simulations, and re-creations. This ontological hybridity complicates questions of authenticity, especially when digital reproductions acquire institutional or symbolic authority independent of their material referents.

Closely related is the issue of epistemic authority. High-fidelity models, especially when embedded in immersive or educational settings, often convey a sense of empirical completeness that may not correspond to the fragmentary or uncertain status of the original artefact. The aesthetics of precision and visual coherence can conceal layers of interpretation and assumption. Unless explicitly communicated, such omissions risk misleading users and reinforcing the illusion of historical certainty. This calls for more robust implementation of paradata—not merely as metadata annotations but as integral components of digital transparency.

The discussion also highlights the need to move beyond institutional or preservationist paradigms towards participatory and care-based ethics. Digital interventions affect not only objects but also the communities and epistemic traditions to which these objects belong. Ethical practice must therefore be relational: attentive to the values, voices, and rights of stakeholders, especially in contexts involving indigenous, marginalised, or postcolonial heritage. This shift requires more than guidelines; it demands a change in institutional culture and professional sensibility.

Finally, the political dimension of digital heritage must not be overlooked. As the Palmyra Arch example illustrates, 3D technologies can be mobilised for ideological purposes—whether to promote resilience, assert ownership, or construct narratives of civilisation and destruction. The ethical challenge lies in ensuring that such interventions do not instrumentalise heritage or silence the communities most directly affected. In this light, digital conservation must be understood not only as a technical practice but as a form of cultural authorship that carries social and political weight.

In sum, the integration of 3D technologies into sculpture conservation compels a re-examination of core ethical assumptions. It reveals that authenticity is not a fixed property, but a negotiated condition; that documentation is not neutral, but mediated; and that conservation is not only about preserving matter, but also about sustaining meaning. A responsive ethical framework must therefore be plural, reflexive, and open to voices beyond the disciplinary mainstream.

The philosophical implications of digital reproduction find resonance in Walter Benjamin's seminal essay The Work of Art in the Age of Mechanical Reproduction (1969). Benjamin argued that technical reproduction erodes the "aura" of original works by detaching them from their historical and spatial context. In the context of 3D modelling, this loss of aura is intensified by the seamless realism and interactivity of digital surrogates, which may mask their derivative nature. While digital tools offer unprecedented access and preservation potential, they also replicate the same tensions Benjamin identified nearly a century ago: between mass accessibility and the dilution of authenticity, between visual authority and ritual presence.

12. CONCLUSION

The integration of 3D technologies into sculpture conservation has generated a profound shift in how authenticity, authorship, and materiality are negotiated. This article has critically examined the ethical dimensions of applying photogrammetry, additive manufacturing, and related digital tools within conservation contexts, drawing on theoretical literature, international charters, and emblematic case studies. It has shown that these technologies are not merely functional enhancements but epistemologically active instruments that reshape conservation practice and perception alike.

Through the case of the vandalised Ain Fouara Fountain, the internationally circulated replica of the Arch of Palmyra, and the multi-sensory replica of the Tlingit Killer Whale Hat, this study has demonstrated that digital interventions not only enable physical reconstructions but also participate in narrative framing, cultural diplomacy, and the redefinition of heritage value. These examples reveal tensions between technological optimism and critical heritage concerns, especially when digital outputs are divorced from local communities

or ethical oversight.

At the normative level, the article has reviewed key documents—including the London and Seville Charters, the Nara Document on Authenticity, and recent ICOMOS declarations—arguing that while these frameworks offer relevant principles, they often fail to address the granular complexities posed by digital practices. Topics such as long-term digital preservation, the instability of file formats, the delegation of decision-making to software algorithms, and the risk of cultural misappropriation require a more nuanced and operational ethical response than current guidelines typically provide.

To meet this challenge, the paper advocates for a reframing of conservation ethics that moves beyond the binary of analogue versus digital. It proposes an approach grounded in care ethics, participatory governance, and epistemic humility. Conservation must be understood as a process of stewardship that acknowledges both material and immaterial heritage values, especially in contexts involving sacred, colonially entangled, or politically charged artefacts. This entails not only technical expertise but also social responsibility and ethical literacy on the part of conservators, curators, and digital technicians.

The study suggests concrete steps for improving ethical practice: 1) embedding ethical assessment into the early planning stages of digital conservation projects; 2) ensuring community consultation and, where applicable, consent; 3) adopting transparent documentation protocols, including data provenance and contextual interpretation; and 4) training professionals in the social, legal, and philosophical dimensions of digital heritage work. Institutions must recognise that 3D interventions do not occur in a cultural vacuum, and that digital reproductions—especially those exhibited without explanation—can eclipse the aura, material presence, and original significance of heritage artefacts.

Rather than resisting digital transformation, this article calls for a deeper engagement with its implications. It reframes 3D technologies as ethically charged mediators rather than neutral tools and emphasises the need to design conservation strategies that are both technologically competent and ethically grounded. By shifting the conversation from what we can do with 3D technologies to what we should do, the field of conservation can better safeguard the long-term cultural value, narrative integrity, and relational meaning of the objects in its care.

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15. LIST OF FIGURES

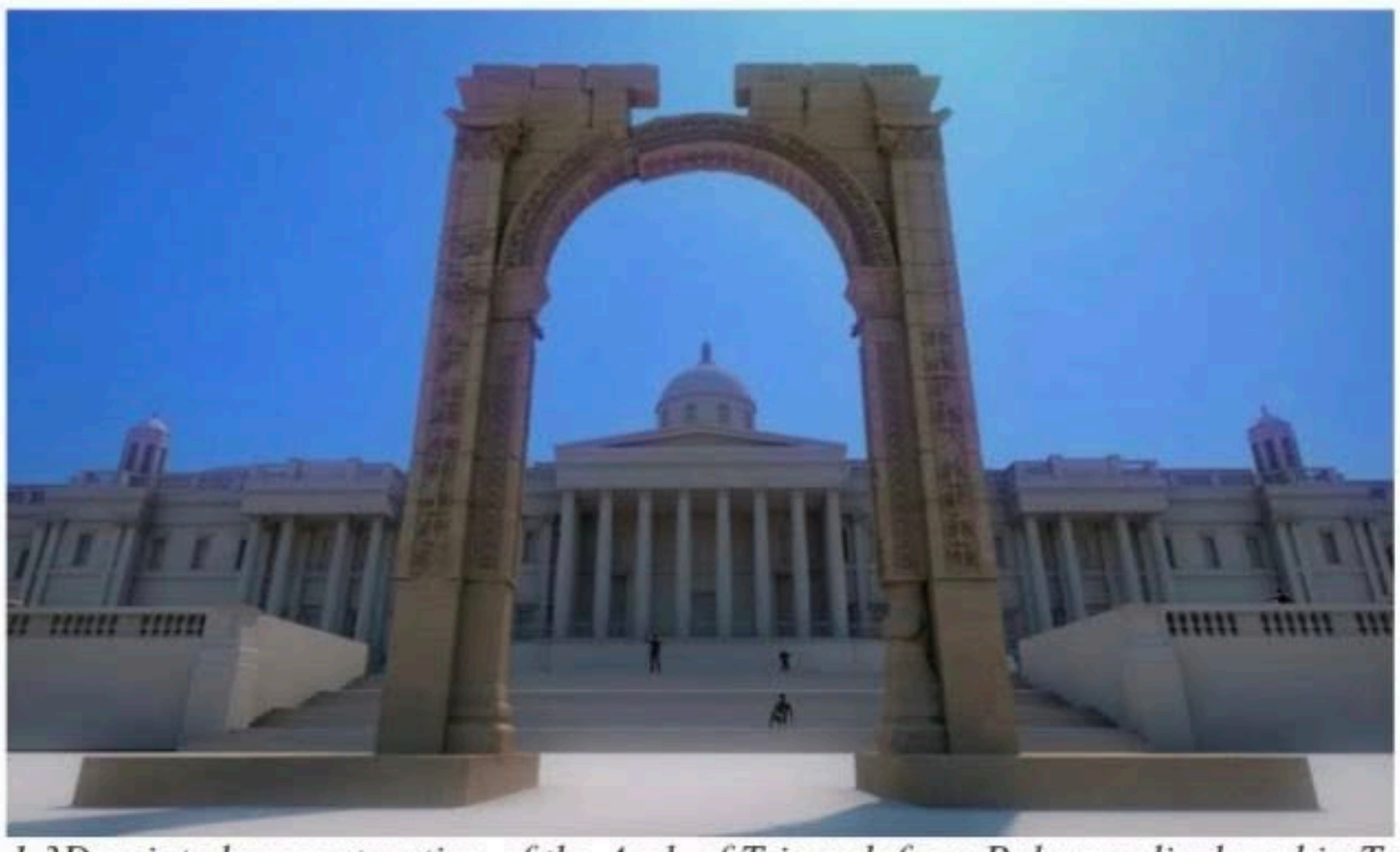


Fig. 1 3D-printed reconstruction of the Arch of Triumph from Palmyra displayed in Trafalgar Square, London (2016). Created by the Institute for Digital Archaeology, the replica—carved from Egyptian marble—was presented as a symbol of resilience. However, it also ignited debates around authenticity, context, and digital colonialism. Author's compilation based on images published in Foley, P. (n.d.). The (In)Authenticity of 3D-printed Heritage. Retrieved January 12, 2023, from https://www.academia.edu/31453322/The_In_Authenticity_of_3D_Printed_Heritage

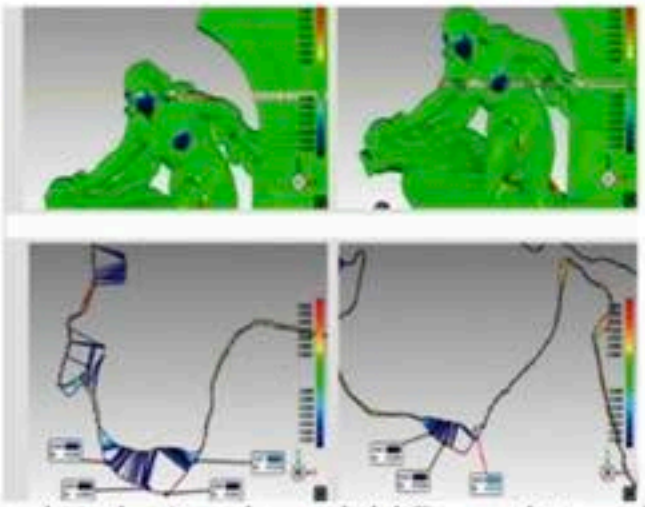


Figure 2: 3D deviation analysis showing colour-coded differences between the damaged and pre-destruction states of the Ain Fouara statue. The visualisation was instrumental for high-precision reverse engineering after vandalism in 2018. Adapted from Khodja, N. A., Zeghlache, H., Benali, F., & Guani, O. (2019). The use of new technologies in the restoration and conservation of built cultural heritage: The case of the statue of Fouara, Setif, Algeria. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W11, 43–46. https://doi.org/10.5194/isprs-archives-XLII-2-W11-43-2019



Figure 3: Comparison of original artefacts and 3D-printed replicas used in a multisensory perception study. The replicas enabled tactile exploration by visually impaired visitors and enhanced interpretive engagement. Adapted from Di Giuseppantonio Di Franco, P., Camporesi, C., Galeazzi, F., & Kallmann, M. (2015). 3D printing and immersive visualization for improved perception of ancient artifacts. Presence: Teleoperators and Virtual Environments, 24(3), 243–264. https://doi.org/10.1162/PRES_a_00229

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