

Cultural Heritage Preservation in the Era of Digital Transformation: New Approaches, Challenges, and Directions Forward.

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1.INTRODUCTION

Combining digital technology and cultural heritage has resulted in a paradigm shift in the manner in which preservation is done, making it significantly easier for us to access our heritage. The paradigm shift in cultural preservation can be associated with technological innovations in computing technologies that allow for collecting, storing, restoring, analyzing, and representing the heritage assets. The digitization of artefacts, artwork, and documents ensures that they will be available even without the presence of geographical boundaries (Wagner & Clippele, 2023). Moreover, the digital era has opened up some new ways of conducting research on the culture and new opportunities for participation in the preservation of culture by the general. Furthermore, the use of artificial intelligence, virtual reality, augmented reality, and 3D scanning technology will revolutionize cultural preservation (Ba'ai & Aris, 2024; Vicol, 2025).

These innovations may be quite helpful to the conservationists as far as providing documentation, virtual restoration, and immersive learning resources that may enable creating better links to the heritage. On the other hand, it is necessary to admit that there is one more dimension that is associated with using these innovations, namely the dimension that concerns the ethics of cultural representation, privacy and data security, and cultural commodification (Oladokun et al., 2024; Siliutina et al., 2024). An adequate strategy taking into consideration all these aspects is required in order to get desirable outcomes. In the following sections of this research paper, it is intended to concentrate on discussing the newest technological developments in relation to their ability to revolutionize cultural heritage conservation and the challenges arising from this process. For instance, the increasing use of generative artificial intelligence technologies may be regarded as one of the signs of the upcoming age of greater possibilities of heritage conservation in terms of the digital twin maps, archiving, and conservation itself (Ghaith & Hutson, 2024). With the continuous advancement in technology, which includes 2D/3D digital scanning technology, image processing and reproduction technologies, and advancements in immersion techniques, the level of complexity and sophistication in the delivery of cultural heritage continues to increase. Specifically, through these technological advancements, there is an ability to perform accurate digitization and reconstruction of historical buildings, hence the conservation and immersion into history. Furthermore, through digitization and digital mapping, virtual restoration of objects as well as the development of predictive models of object decay is possible (Bocheńska et al., 2023).

This paper aims at exploring the multiple impacts of digitalization on the preservation of heritage through analyzing the opportunities for innovation and the challenges posed by the process of digitalization. In addition, this study will look at the changes that digitalization brings about with regard to heritage preservation, identify challenges and suggest some possible solutions. Case studies/projects in this area, other than those covered in Melnyk et al., (2025), will be reviewed. Ethical implications of digitalization of cultural heritage will be explored.

New Approaches in Cultural Heritage Protection Through Digital Technologies Using Artificial Intelligence in Heritage Documentation and Interpretation

Artificial Intelligence has brought about many advancements in documentation and interpretation of cultural heritage through advanced analytical methods that are beyond ordinary ways of processing data. AI technology is helpful in processing huge amounts of data related to cultural heritage, generating documentation, maintaining records, and connecting people through high-quality digital media. The above mentioned AI uses help in creating digital replicas of the cultural property, which are helpful for monitoring, maintenance and restoration. These digital replicas contain data gathered through 3D scanning, LIDAR scanning and IoT devices, providing

information on the state of the structure, material, and environmental threats to cultural heritage (Geng et al., 2025; Pasupuleti, 2025).

Applications of Virtual and Augmented Reality for Enhancing Experiences

The application of virtual reality and augmented reality in connection with the heritage opens great possibilities for achieving highly immersive experiences regarding the culture and eliminating the constraints that come from space and time issues. The use of technologies makes it possible to restore ruined and damaged heritage sites and provide virtual visits to the reconstructed heritage sites and learning about the cultural artifacts. In addition to this, VR and AR can be used for presenting various historical situations and impacts on the heritage sites to get a better understanding of their history and what they are prone to (Slater & Sánchez-Vives, 2016). Moreover, immersive virtual reality can be used for interpretation of heritage in an interesting way.

3D Scanning & Digitization for Conservation of Heritage Objects

Geomatics methods, including photogrammetry and LiDAR, have an important role in forming 3D images of historic objects and sites, which is critical for their preservation and study. The application of these technologies makes it possible to form thorough digital replicas of the sites, which will be used as a source of information for further preservation and virtual restoration of the objects if the damage is done to artistic pieces. It is made possible by creating a thorough digital image, which, in addition to protection against any degradation, can be used for future AI analysis (Pansoni et al., 2023).

Technology of Blockchain for Ensuring Authenticity and Data Integrity

Blockchain technology is a powerful tool to make sure that digital cultural heritage data will be authentic and will not be changed in the process of its transmission. This technology ensures the creation of a trusted environment, which can be used for data storage and sharing of the information about the provenance of digital cultural artefacts. This ability makes it possible to prevent any illegal activities related to cultural heritage items. Furthermore, using smart contracts, which can be created on blockchain, it becomes possible to control intellectual property rights regarding digital cultural heritage (Wang et al., 2021).

Obstacles Associated with Digital Cultural Heritage Preservation

Technical and Infrastructure Obstacles

Despite the high potential for these technologies in the field of cultural heritage preservation, there are a number of technical and infrastructure challenges that need to be surmounted in order to realize success. These challenges include a highly expensive financial investment in the acquisition of sophisticated technological equipment and software, as well as the challenge of data management, interoperability and digital curations. Moreover, the constant changes in the technological field pose the problem of obsolescence of devices and software in use, requiring the institution to constantly migrate its technological system in order to ensure the digital heritage preservation. (Surti et al., 2024; Hedstrom, 1997).

Problems Related to Fidelity and Data Obsolescence

The fidelity of digital reconstructions in relation to the original objects, as well as the need to guarantee that the digital nature of these reconstructions is preserved in light of the fast changes in the technological environment, poses serious challenges related to the preservation of evidentiary qualities of the cultural heritage that has been converted into digital form. Moreover, there is an issue of data obsolescence owing to rapid changes in the standards for storing and formatting data (Amico & Felicetti, 2024).

Economic Issues and Financing

As the high prices of obtaining highly developed digital technology for preservation, along with costs of maintenance and training, impose substantial economic burden upon heritage institutions, especially the ones that exist in developing countries, it results in the partial digitization of archives due to global inequality in heritage conservation. In addition, the proposed financing method can cause discrepancy between the interests of the organization and the external digitization process (Griffin et al., 2023).

‘Digital Divide’ and ‘Accessibility’

The unequal availability of technology and internet access becomes an additional challenge that leads to digital divide in the global society. This means that because of the above-mentioned factors, people from disadvantaged communities cannot have equal access to the digitized cultural heritage. Digital divide problem is not only about the barriers in education and research, but also exclusion of disadvantaged cultures from the global context (Yüksek & Sökmen, 2021).

Ethical Issues in Digital Heritage

Digital heritage is faced with some ethical considerations regarding the specific culture and values of the people, and this has to be considered too for preserving cultural heritage and its diversity. Besides, representation and ownership issues arise due to the use of digital technologies in the preservation of cultural heritage in case of digitizing cultural heritage of indigenous or marginalized peoples by people who have not obtained full consent or participation of these peoples. (Hill & DeHass, 2018).

Representation of Cultural Sensitivity

Therefore, there should be an adoption of ethical principles and practices in digital heritage that promote community involvement, informed consent and cultural sensitivity to avoid perpetuating colonial perspective or misunderstanding about cultural significance. This practice also requires considering the power dynamics arising in digital curation for ensuring representation of different communities according to their own heritage. There could be imposition of epistemological perspective of Western world in digital heritage through using digital infrastructure of the West. (DeHass et al., 2025)

Issues of Intellectual Property Rights and Ownership

There are various problems related to intellectual property rights and ownership in the digital environment because of ownership and conventional laws and regulations, particularly, with regard to intangible cultural assets or owned-by-community objects in whose case the current copyright schemes may not be useful. This calls for the development of legal instruments enabling the incorporation of various cultural notions of ownership and information exchange that need to consider the interests of individual creators and also the preservation of the community legacy. (Rouhani, 2023).

Privacy of Data and its Security

It is necessary to make sure that confidential cultural data are not accessed or altered and destroyed in any way because the reliability of digital heritage databases depends on the security of data stored in these databases. In particular, there have to be security arrangements designed to prevent cyberattacks, while international data privacy regulations should also be followed in the case when cultural heritage data contain personal data. Ethics are relevant here with respect to "digital colonialism" risks in case when the digitizing entity is an outsider organization (DeHass & Taitt, 2018; Quintero et al., 2019).

Future Path and Strategic Initiatives**Development of an Effective Strategy for Digital Preservation**

One of the key strategies that will contribute to the development of sustainable approaches to digital preservation involves international collaboration, digital preservation laws, continuous innovations, and commitment to ensuring longevity of cultural digital memories across the globe. This strategy would address challenges such as the language barrier and lack of funding in the region, particularly in Arab countries and developing states, and would promote inclusivity of the digital media infrastructure. One of the major aspects of sustainability is monitoring digital formats and using open standards in order to avoid digital obsolescence (Sousa, 2023).

Building Collaborations and Partnerships

Productive collaboration and partnerships between cultural organizations, technology companies, governments and local communities need to be promoted in order to develop sustainable digital preservation strategies. Collaboration allows sharing of knowledge and resources and development of culturally relevant and technologically advanced preservation frameworks. In addition, collaboration between these different entities is essential in order to build capacities of local professionals engaged in managing digital content and metadata (Farouk, 2024).

Community Participation and Participatory Approaches

The involvement of the concerned communities in all the stages of digital heritage creation, from selection to digitization, interpretation, and dissemination of the cultural heritage resources, is important for ensuring their authenticity and validity. The reason being that participation guarantees that the digitalized versions represent properly the cultural heritage of the community. It is even more important in disadvantaged settings where only community-based strategies can help overcome the issues connected with infrastructural problems and lack of funding (Beyene, 2007; Borin & Rossato, 2023; Daoudi et al., 2011).

Policies and Regulations

Effective policies and regulations are needed to enable proper collection, storage, and access to digital cultural heritage resources in order to address disparities of developing nations. They are supposed to address issues such

as data sovereignty, intellectual property, and equitable access to ensure digital inclusiveness and prevent digital disparities. These policies should also contribute to capacity building and digital literacy programs to ensure local communities' and organizations' participation in digital cultural heritage management (Motshekga et al., 2003; Kasozi & Nabasira, 2008).

The paper has convincingly shown what a revolution digital technology can bring in terms of preserving our cultural heritage; on the other hand, several problems were raised that require appropriate reaction. Actions need to be taken for overcoming the above mentioned obstacles of ethics, technology, and resource availability sustainably. The actions should not only be taken within the framework of economically prosperous societies but also in disadvantaged ones which do not have enough means to protect their cultural heritage (Daoudi et al., 2011; El-Khairi et al., 2000; Maseko, 2009). A multifaceted strategy involving new technologies, local participation and development of appropriate policy measures will be essential for accomplishing the above stated goal. Future research might include developing culturally aware digital infrastructure. Such a measure would be especially relevant in the regions such as rural Uganda and Morocco, where low digital literacy and poor infrastructure make it difficult to conduct preservation activities. Another possible area of future research could be analysis of alternative funding sources and cooperation in order to ensure sustainability of such projects in the regions under consideration. The research into the way the employment of creativity and digital tools in living labs may contribute to better initiatives towards the food cultural heritage may result in new ways to accomplish the objective (Soldato & Massari, 2024).

First and foremost, the main findings imply that while digital transformation provides unique opportunities for the preservation of cultural heritage, there are a number of problems, such as authenticity, obsolescence, costs, and digital divide, that complicate the process. Besides, it is necessary to pay special attention to the necessity for models that focus on data preservation and security, rather than technological innovations and user convenience. Thus, future studies need to be conducted in the direction of developing an ontology-based framework to support interoperable and sustainable digital cultural heritage data (Sudrajat et al., 2023). Such an approach would make it possible to provide semantic interoperability of digital data repositories and enhance their accessibility and usability to both academics and general public audience. In other words, it is important to implement effective solutions to ensure data quality and management in order to keep its historical and consistent nature in spite of the growing popularity of digital data (Chun et al., 2025).

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