Digital solutions for cultural heritage: preservation, interpretation, and engagement in line with the Venice charter principles

Alaa Ababneh[1,*,†]

[1] *Universitat Autònoma de Barcelona, Plaça Cívica, 08193 Bellaterra, Barcelona*

Abstract

This paper explores the application of digital technologies in conserving and managing cultural heritage sites, such as 3D laser scanning, VR, AR, GIS, high-resolution imaging, RTI, mobile apps, NLP, and AI. The research critically examines the principles of the Venice Charter considering the 'Venice Charter New Heritage Challenges (2024),' a revised framework that addresses the evolving needs and challenges of the heritage field in the 21st century. Established in 1964, the Venice Charter has long been a guiding document for preserving and interpreting cultural heritage. However, the rapid advancements in digital technologies and new challenges in the heritage field have necessitated a critical re-evaluation of the Charter's principles. The 'Venice Charter New Heritage Challenges (2024)' seeks to revisit these principles, acknowledging the significant shifts in the heritage landscape and the need to adapt to new societal, technological, and environmental concerns. By integrating digital technologies, heritage professionals can innovatively address the revised Venice Charter's core principles. For example, 3D scanning enables the creation of accurate digital representations of heritage structures, which can inform conservation and restoration efforts. VR and AR technologies can provide immersive experiences contextualizing heritage sites' historical and cultural significance, enhancing public understanding and appreciation. GIS, high-resolution imaging, and RTI can aid in the comprehensive mapping, analysis, and documentation of heritage sites, contributing to the Charter's diverse data collection and management principle. Mobile apps offer on-site interpretation and access to digital archives, promoting the Charter's principle of inclusive and accessible public engagement. NLP and AI technologies can support the Charter's research, interpretation, and knowledge dissemination principle. However, it's important to note that using these technologies in cultural heritage preservation is not without challenges and limitations. These may include data privacy and security issues, the need for specialized skills and training, and the potential for digital technologies to overshadow the physical experience of heritage sites. By demonstrating the synergies between digital technologies and the principles of the 'Venice Charter New Heritage Challenges (2024),' while also acknowledging these challenges, this research aims to empower heritage professionals to preserve, interpret, and disseminate cultural heritage in accessible, sustainable, and socially responsive ways, ultimately enhancing the public's engagement with and appreciation of these invaluable resources.

Keywords

Digital technologies, Cultural heritage, Preservation, Interpretation, Presentation and dissemination.

1. Introduction

Digital solutions have revolutionized numerous aspects of our lives, including the preservation, interpretation, and engagement of cultural heritage. As outlined in the Venice

VIPERC2024: 3rd International Conference on Visual Pattern Extraction and Recognition for Cultural Heritage Understanding, 1 September 2024

* Corresponding author.

† These authors contributed equally.

alaa.ababna@autonoma.cat (A.Ababneh)

0000-0002-7281-7373 (A. Ababneh)

Charter Principles, which provide guidelines for conserving and restoring historic monuments and sites, digital technologies offer innovative approaches to safeguarding and promoting cultural heritage for future generations. The Venice Charter, established in 1964 by the International Council on Monuments and Sites (ICOMOS), emphasizes the importance of preserving the authenticity and integrity of cultural heritage while ensuring its accessibility and relevance to contemporary society. It recognizes that cultural heritage is not static but an evolving entity requiring continuous care and adaptation (Trunfio et al., 2022; Erder, 1977).

Aligned with the Venice Charter Principles, digital solutions for cultural heritage preservation, interpretation, and engagement aim to maintain the authenticity and integrity of heritage while embracing technological advancements (Lercari & Jaffke, 2020). They complement traditional conservation practices and enable a dynamic and sustainable approach to cultural heritage management; digital technologies have recently been widely employed to document and monitor tangible heritage assets (Mishra et al., 2022). These technologies allow for the frequent tracking of changes in the form, function, and, at times, the location of heritage sites. However, it is essential to acknowledge that these tracking processes may involve subjective interpretations that require ongoing qualification, adjustment, and improvement over time.

Digital solutions provide a powerful toolkit for addressing the challenges posed by cultural heritage preservation, interpretation, and engagement; they facilitate the documentation, conservation, and restoration of historic sites and artifacts, allowing experts to capture detailed and accurate representations of tangible and intangible heritage (Hassan & Fritsch, 2019). High-resolution imaging techniques, 3D scanning, and virtual reality technologies create immersive digital replicas, allowing one to explore and study cultural heritage without risking physical damage (Kushwaha et al., 2020). Digital solutions enhance the interpretation and presentation of cultural heritage, making it more engaging and accessible to a broader audience; through interactive multimedia platforms, virtual exhibitions, and augmented reality applications, visitors can experience cultural heritage innovatively. Digital storytelling techniques enable the contextualization of historical narratives, fostering a deeper understanding of the significance and value of heritage sites (Martinez et al., 2021).

Importantly, digital solutions promote inclusivity and diversity in cultural heritage engagement; they break down physical access barriers, enabling individuals unable to visit sites in person to engage with cultural heritage remotely (Trillo et al., 2020). Digital platforms offer opportunities for communities to actively participate in preserving and interpreting their heritage, empowering them to share their stories and perspectives.

Digital technologies provide a cost-effective and low-risk solution for preserving and promoting cultural heritage assets; the increasing reliability and decreasing IT infrastructure costs, along with user-friendly information technology solutions, have led to the emergence of Digital Heritage (Marques et al., 2017). Museums and art galleries have embraced digitization through photography and 3D scanning, while collection management systems have been utilized to store and manage these digital assets. Additionally, applications such as virtual museums, augmented reality (AR), and virtual reality (VR) have been developed to engage end-users (Haddad et al., 2021). The widespread adoption of digital heritage has resulted in large collections of visual assets accompanied by metadata, forming big data repositories. Researchers (Moullou et al., 2023; Nurit et al., 2021) have recognized the potential of leveraging this data to address various cultural heritage challenges, including metadata retrieval, asset linkage discovery, and digital curation. Machine learning and semantic web technologies are often employed to tackle these challenges effectively.

Heritage plays a crucial role in achieving sustainable futures, as acknowledged by Agenda 2030 and the Habitat III UN conference. There has been shift towards a broader understanding

of heritage beyond its material aspects. Heritage has been included as a target in the Sustainable Development Goal for Sustainable Cities and Communities (SDG 11), highlighting the importance of protecting and safeguarding cultural and natural heritage (UN, 2020). The built environment, encompassing tangible and intangible heritage, is intrinsically linked to values such as cultural diversity, identity, and a sense of belonging; preserving and making these values available to future generations is vital for intergenerational justice and contributes to community resilience.

In this era of rapid technological advancements, integrating digital solutions within the framework of the Venice Charter Principles presents immense potential for the preservation, interpretation, and engagement with cultural heritage. By harnessing the power of digital technologies, we can safeguard our shared heritage, foster a deeper appreciation for cultural diversity, and ensure its relevance and significance for future generations, to leverage technology to ensure authentic conservation, inclusive interpretation, and meaningful engagement with cultural heritage while addressing the challenges and opportunities of the 21st century. The research aims to explore and demonstrate how digital technologies enhance the conservation, interpretation, and dissemination of cultural heritage sites in alignment with the principles outlined in the Venice Charter.

This research has demonstrated the significant potential of integrating digital technologies to address the core principles outlined in the updated "Venice Charter New Heritage Challenges (2024)". By critically examining the original Venice Charter, established in 1964, and the revised framework that aims to acknowledge the evolving needs and challenges of the 21st-century heritage field, this study has uncovered synergies that can empower heritage professionals to preserve, interpret, and disseminate cultural heritage in more accessible, sustainable, and socially responsive ways.

The research discusses the application of digital technologies, such as 3D laser scanning, VR, AR, GIS, high-resolution imaging, RTI, mobile apps, NLP, and AI, that help heritage professionals address the principles and challenges outlined in the "Venice Charter New Heritage Challenges (2024)".The paper aims to address a gap in the existing literature by critically examining the principles of the Venice Charter, which has long been a guiding document for cultural heritage preservation, in the context of the updated "Venice Charter New Heritage Challenges (2024)". To demonstrate the synergies between the integration of digital technologies and the principles outlined in the updated Venice Charter. The novelty of this research lies in its holistic approach to addressing the evolving needs and challenges of the cultural heritage field. By critically examining the principles of the Venice Charter, considering the "Venice Charter New Heritage Challenges (2024)," and showcasing the potential of digital technologies to address these principles, the study provides a comprehensive and innovative framework for heritage management and conservation in the 21st century.

2. 3D Laser scanning and modeling

Techniques such as terrestrial laser scanning and UAV photogrammetry have revolutionized data collection, offering efficient and accurate methods for creating detailed 3D models; 3D modeling and laser scanning technologies are invaluable in documenting and preserving cultural heritage. Laser scanners are known for their wide field of view and precise data capture capabilities from minor artifacts to large architectural structures; these technologies enhance immersive experiences, support research and conservation efforts, and provide permanent documentation of significant objects and locations (Kushwaha et al., 2020). Laser scanning has become an indispensable tool in numerous cultural heritage projects, ensuring the preservation of our heritage for future generations.

Laser scanning has been used in heritage conservation, showcasing many notable applications such as the Notre Dame Cathedral in Paris (Ali et al., 2019), the Opera House Theater in Rhode

Island (Haddad et al., 2021), the Royal Palace in Madrid (Kushwaha et al., 2020), and the Statue of Liberty in New York City (Marques et al., 2017). Laser scanning enables the digital reconstruction of sculptures, architectural pieces, and artworks, facilitating the production of molds and duplicates for outdoor cultural heritage artifacts that require preservation (Hassan & Fritsch, 2019). Laser scanning technology effectively creates replicas; laser scanners measure distances without physical contact, they are well-suited for monument documentation, as they have no adverse impact on the original structure (Moullou et al., 2023).

Architectural documentation is critical in preserving built heritage by supporting conservation efforts; traditional physical documentation methods are susceptible to fragmentation and loss over time. By incorporating digital technologies, such as 3D parametric modeling, the documentation of built heritage can be enhanced, and many projects use laser scanning Technology. Ababneh et al. (2022) used laser scanning to scan the Gadara Tunnel in Jordan; it has suffered from deterioration and damage over time, posing a significant threat to tourists. The study utilized LiDAR to generate highly accurate 3D models of the tunnel; the analysis established the aqueduct's structural integrity and identified the most threatening areas.

Figure 1: Laser scanning scan Gadara Tunnel (Ababneh et al., 2022)

The Royal Academy of Engineering (RAEng) Jordan is a collaborative research endeavor that aims to develop a comprehensive collection of virtual models, including 3D models and Building Information Modeling (BIM) objects; it aims to establish a library of 3D models showcasing exemplary Jordanian heritage and traditional buildings. These models promote Jordan's tourism image (Trillo et al., 2020).

Current international research focuses on creating BIM libraries for built heritage based on laser scanning data, with a key challenge being the modeling of complex or unique shapes that represent specific construction components of each asset. This approach generates parametric families of architectural geometry to effectively manage and represent heritage buildings (Aburamadan et al., 2022). The primary platform of the Herit-IT Jordan project, along with its

associated library, offers a range of digital outcomes related to the Jordanian House of Art in Amman and Qaqish House in As-Salt, which serve as pilot heritage buildings. These outcomes include virtual tours, point clouds, Heritage Building Information Modeling (H-BIM) models of the buildings, and H-BIM families of architectural features. A multi-level workflow was applied to develop an HBIM library for the vaulted systems of Palazzo Magio Grasselli in Italy, integrating different data types and software tools while exporting the models into the GIS environment (Aburamadan et al., 2022).

The original Venice Charter emphasized fundamental principles such as authenticity, minimal intervention, and the importance of preserving heritage sites' historical and cultural context. The updated "Venice Charter New Heritage Challenges (2024)" builds upon these tenets, while also acknowledging the need to adapt to new realities, including the growing role of technology, the imperative of environmental sustainability, and the drive for greater inclusivity and public engagement.

The application of digital technologies has been shown to support these evolving principles directly. 3D laser scanning, for instance, enables the creation of high-fidelity digital representations that can aid in conservation and restoration efforts while preserving the authenticity of the original structure. Virtual and augmented reality experiences, in turn, allow visitors to engage with heritage sites in immersive and contextual ways, strengthening their understanding and appreciation of the historical and cultural significance. Furthermore, using GIS, high-resolution imaging, and RTI technologies facilitates the comprehensive documentation and mapping of heritage resources, supporting the Charter's emphasis on holistic conservation.

Figure 2: Jordan Digital Heritage Platforms

The Aerial Photographic Archive for Archaeology in the Middle East (APAAME) project successfully conducted comprehensive 3D documentation of the extensive archaeological site of Ajloun Castle. By utilizing dense 3D point clouds, the project achieved high geometric accuracy and photorealistic representation, effectively meeting surveying and archaeological requirements. The resulting 3D digital model of Ajloun Castle seamlessly integrated as a building layer within Google Earth (Al-Fugara et al., 2016).

3. Virtual reality (VR) and Augmented reality (AR) Technologies

VR and AR technologies have revolutionized how we engage with and experience cultural heritage. VR allows users to immerse themselves in digital environments, allowing remote exploration of historical sites and artifacts; AR, on the other hand, overlays virtual elements in the real world, offering additional information and interactive features to enhance visitor experiences (Marques et al., 2017). These technologies have wide-ranging applications in preservation, education, and storytelling, making cultural heritage more accessible and fostering a deeper connection with history and culture. AR has gained popularity in museums and cultural sites, where it provides augmented reality guides and experiences.

Initially, virtual reality (VR) applications in educational settings for cultural heritage utilized gamification as a learning technique. Today, educational proposals incorporate heritage-focused games, including pre-existing video games like Assassin's Creed and its educational versions, as well as Class craft and Minecraft Education Edition (Andrea et al., 2021). In heritage education, there is a notable rise in the use of geolocation-based applications, augmented reality (AR), and virtual reality (VR) (Bozzelli et al., 2019). Specific digital platforms, virtual museums, and even in situ experiences utilizing GPS and QR codes enable these possibilities (Arias-Espinoza et al., 2018).

Figure 3: ARtGlass of augmented reality (AR) tour at Mount Vernon

Other devices like Virtual reality glasses or VR goggles as Smart Glass or similar visors can be utilized to enhance the immersive experience. Currently, advancements in technology such as 3D and 360° imagery, GPS, GoPro cameras, drones, and photogrammetry are revolutionizing education in heritage (Maietti et al., 2020; Maietti et al., 2018). These technological developments are reshaping our interaction with cultural assets, expanding knowledge, improving understanding, increasing global accessibility, and introducing new approaches and methodologies for engaging with heritage.

A notable example is the Olympia archaeological site in Greece, where the Archeoguide outdoor AR system brings archeological monuments, artifacts, and elements from the ancient world back to life. Another example is the old town of Chania in Crete, Greece, where mobile augmented reality can virtually restore destroyed parts of ancient monuments such as the Glass Mosque, the Saint Rocco temple, and the Byzantine Wall (Ali & Hamed, 2019). In some cases, complete physical restoration and reconstruction may be unattainable, while others face risks to

their historical value due to current conditions (Malinverni et al., 2019). The 'The Ara It Was' project at the Pacis Museum in Rome explores the impact of AR and VR on visitor experience, satisfaction, and service model innovation in cultural heritage museums (Trunfio et al., 2022).

AR technology provides an immersive and guided experience of the palace, Qasr al-Abd, at Iraq al-Amir, Jordan. Visitors use handheld or wearable devices to access an AR app that guides them to the palace and provides audio information. At the same time, a virtual avatar enriches their experience with historical narratives about the site (Ali & Hamed, 2019).

The creation of 3D cultural heritage archives requires solutions for interoperability between models within the archive and external sources. AR applications enhance the tourist experience at heritage sites, incorporating information into the natural environment through device displays (e.g. Virtual Time Travel) or audio guides (e.g. museum audio guides) (Longo, 2017). Virtual or Augmented Heritage and 3D GIS Cultural Heritage are emerging fields that utilize information technology to digitally capture and represent various forms of cultural data, including 3D objects such as artworks, buildings, and entire landscapes (Maietti et al., 2020). The cultural heritage community has transitioned from static 2D documentation to interactive 3D digital tools, incorporating the dimension of time (4D); this transformation has accelerated the adoption of virtual heritage, as it offers significant advantages over traditional methods, the widespread acceptance of new technologies in the cultural heritage field indicates their superior capabilities and potential for dissemination (Marques et al., 2017).

Projects like Inception demonstrate the integration of 3D representations into a European cultural heritage database, promoting heritage comprehension through innovative devices and methodologies. Educational innovation projects like Form apps focus on enhancing digital competence through virtual spaces, networks, and devices (Moullou et al., 2023). The Baética project fosters learning communities by conducting multidisciplinary research on archaeological sites, resulting in virtual hypotheses and 3D digitalizations of monuments (Longo, 2017). The SmartMarca project from Italy aims to transmit AR and VR content on cultural heritage to provide students with interactive learning methods and content creation opportunities (Malinverni et al., 2019).

The heritage project also aims to improve the level of understanding of Mediterranean UNESCO cultural heritage by using augmented reality (AR), virtual reality (VR), and mixed reality (MR). Immersive technologies, such as Emily Gal, Virgo, and Smart Coolture resources, offer virtual exploration, cataloging, and exhibition creation to promote and preserve heritage while increasing accessibility (Maietti et al., 2020).

Figure 4: Example of VR and AR: iHERITAGE project & Inception Project

The ArkaeVision project utilizes VR and AR technologies to enhance the exploration of cultural assets, incorporating digital fiction, storytelling, and gamification to boost engagement

and understanding (Pietroni et al., 2023). The e-Archeo project focuses on multimedia solutions to enhance knowledge of Italian archaeological sites, providing integrated and multi-channel experiences using scientific, narrative, and emotional languages (Bozzelli et al., 2019).

Augmented reality (AR) and augmented reality (AR) technologies technology allow the virtual restoration and reconstruction of ancient structures in their original settings; by overlaying 3D models of historical buildings onto their existing ruins, visitors can visually experience and visualize the appearance of these structures in their ancient state.

4. Geographic Information System (GIS) mapping

Geographic Information System (GIS) mapping combines geographic and attribute data to analyze and visualize spatial information. In cultural heritage, GIS mapping aids in documenting, managing, and preserving heritage sites, allowing for inventory creation, significance analysis, vulnerability assessment, and conservation planning. It also integrates cultural heritage data with other geographic information, enabling a holistic approach to heritage management within the broader environmental context.

The Geographic Information System (GIS) is tool that captures, analyzes, manages, stores, and presents spatial or geographical data. It allows for creating detailed maps and analyzing various data types within a geographic context. GIS plays a significant role in archaeology by enabling researchers to manage, analyze, and visualize spatial data related to past human activities and landscapes. Archaeologists utilize GIS to map excavation sites, record the distribution of artifacts, and analyze the topography of ancient settlements (Moullou et al., 2023).

The Digital Archaeological Atlas of the Holy Land (DAAHL) is a comprehensive database of archaeological sites and project metadata from the Levant region, aiming to create the first online digital atlas for the Holy Land. Part of the more extensive Mediterranean Archaeological Network (MedArch-Net) project, DAAHL contributes to the preservation and dissemination of archaeological knowledge in the region (Trillo et al., 2020).

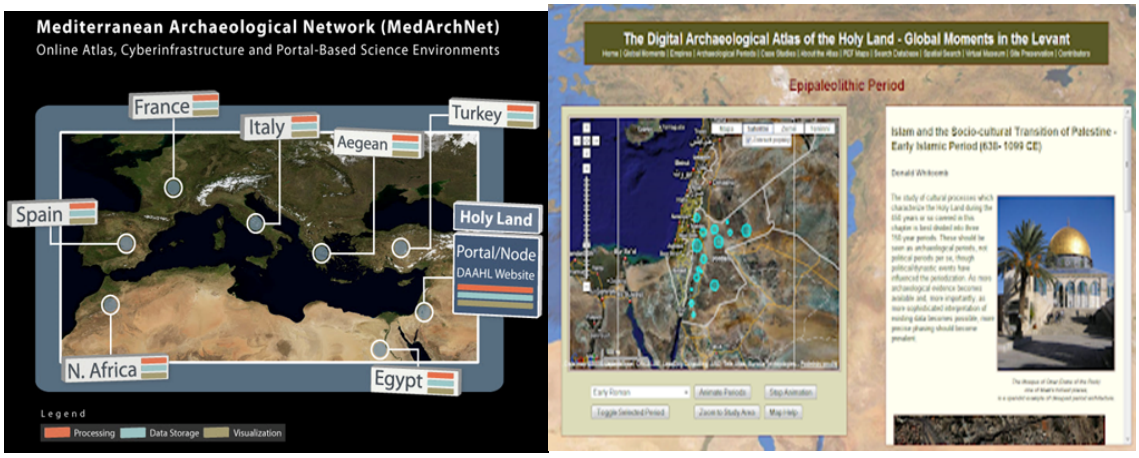

Figure 5: Example of Mediterranean GIS project Webpage: Archaeological Network (MedArch-Net) and Digital Archaeological Atlas of the Holy Land (DAAHL)

In the past two decades, architectural laser scanners have emerged as powerful tools for capturing highly detailed information from the surrounding environment. These scanners can capture millions of points, which are then used to generate a point cloud, providing accurate site documentation. This computer-controlled method can be combined with GNSS (Global Navigation Satellite System) and unmanned aerial vehicle (UAV) photogrammetry techniques to produce comprehensive 3D models of the site (Moullou et al., 2023).

The Aerial Photographic Archive for Archaeology in the Middle East (APAAME) is an openly accessible archive on Flickr. It is part of a long-term research project focused on discovering,

recording, and monitoring archaeological settlements in the Near East, with a particular emphasis on Jordan; it conducts annual helicopter missions to capture high-resolution aerial images of ancient settlements and landscapes. The photographs are georeferenced or geolocated, providing precise spatial information for research and analysis (Trillo et al., 2020).

By integrating different data sources like satellite imagery, historical maps, and field surveys, GIS helps archaeologists identify patterns, locate potential excavation sites, and gain insight into the historical context of events, for a critical perspective on using GIS, mapping, and spatial thinking in archaeology.

5. High-Resolution Imaging and Reflectance Transformation Imaging (RTI)

RTI is a flexible and non-contact imaging technique that captures surface texture information for subjects of various sizes using a portable toolkit. It involves moving a light source around the subject while the camera remains stationary, recording the light's position in each image. This method provides valuable surface texture details. Additionally, combining sensors operating in the visible and shortwave infrared spectrum, multispectral imaging can analyze construction materials and identify pathologies in cultural heritage elements, offering spatial and spectral information (Del Pozo et al., 2017).

RTI is used as a method of digital preservation for many projects worked antler from Star Carr, in north-east Yorkshire; project Daytime survey of prehistoric rock art at Roughting Linn, Northumberland, and project Extreme RTI at Ughtasar rock art site, Armenia (Duffy et al., 2018). The AHRC RTISAD project has developed and tested various techniques for collecting and processing reflectance transformation imaging (RTI) data (Earl et al., 2011). The developed method, HD-RTI, combines RTI and HDR imaging techniques adaptively to enhance the relighting quality and characterization of local angular reflectance. The application of HD-RTI to industrial samples with heterogeneous surfaces demonstrates improved visual saliency maps and robustness for visual quality assessment tasks, particularly for glossy and heterogeneous surfaces. This digitization approach aligns with the principles of Industry 4.0 and enables comprehensive characterization of surface visual properties (Nurit et al., 2021).

The archaeological site of Stobi, situated near Gradsko in the Former Yugoslav Republic of Macedonia (FYROM), served as a case study to showcase the synergistic effectiveness of Reflectance Transformation Imaging (RTI), photogrammetry, and virtual tour imaging. A diverse selection of nine inscription sets from the site were specifically chosen to exemplify the broad range of applications for these combined techniques (Longo, 2017).

Infrared (IR) photographic documentation, while advantageous, has limitations. However, retrospective photogrammetry offers an alternative approach by utilizing historical photographs or images to extract 3D geometric and geospatial information from the past. This technique involves analyzing old photographs and using them to reconstruct the three-dimensional geometry of depicted scenes or objects. It entails identifying reference points or features in the photographs and employing software and mathematical algorithms to reconstruct spatial information. Retrospective photogrammetry finds applications in historic preservation, archaeology, and urban planning, enabling the understanding of changes over time and the creation of accurate 3D models or maps of historical sites or structures.

High-resolution imaging, multispectral imaging, and RTI are advanced techniques used in cultural heritage documentation and analysis, enabling detailed artifact study, revealing hidden features, and creating interactive digital representations. These non-invasive methods contribute to research, conservation, and public access to cultural heritage.

6. Natural Language Processing (NLP) and Artificial Intelligence (AI)

AI technologies, including computer vision and NLP, enhance visitor experiences through interactive platforms like chatbots, providing instant information and personalized recommendations based on visitor preferences. AI algorithms extract insights from diverse data sources, supporting decision-making for cultural institutions.

AI has revolutionized cultural heritage by advancing documentation, preservation, and public engagement; through machine learning and computer vision, AI excels in digital preservation, restoring and enhancing visual quality; it also aids in artifact analysis by recognizing patterns, styles, and materials (Mishra et al., 2022). NLP is crucial for analyzing textual data, enabling digitization, and facilitating sentiment analysis and semantic search; NLP promotes cross-cultural understanding through language translation, analyzing and understanding textual data in cultural heritage (Belhi et al., 2019), enabling digitization through techniques like OCR and handwriting recognition while facilitating analysis of large text corpora (Andrea et al., 2021), sentiment analysis (Shubita & Saleh, 2020), and semantic search (Dou et al., 2018), ultimately enhancing the accessibility and discovery of cultural heritage content.

NLP and AI techniques have empowered heritage professionals to preserve, interpret, and share cultural heritage in a more accessible and engaging manner. Projects like the one led by DISI at the University of Trento and the CNR-IMATI's work within the GRAVITATE project demonstrate the use of AI in analyzing the emotional impact of artworks and automating the assembly of fragmented artifacts; these advancements enhance understanding, visitor experiences, and archaeological analysis (Andrea et al., 2021).

Deep learning, a powerful machine learning technique based on neural networks, has revolutionized computer vision and cultural applications. Recent advancements in computing hardware and algorithms have significantly improved its performance; convolutional neural networks like AlexNet have achieved high accuracy in tasks like image classification. Deep learning enables cultural data classification, annotation, and curation using visual features, while language processing techniques extract metadata from textual descriptions; it also aids the automatic population of ontologies for preserving and exchanging digital representations of cultural assets (Maietti et al., 2020).

The CEPROQHA team has leveraged deep learning to enhance cultural heritage analysis and preservation, developing annotation and classification approaches demonstrating excellent performance; their frameworks have been validated on diverse datasets from prestigious institutions (Belhi et al., 2019).

Deep learning techniques in cultural heritage rely on large and well-structured datasets; institutions collaborate with data scientists to publish benchmark datasets and tackle data-oriented challenges (Dou et al., 2018). Open data sources like WikiArt and museum collections provide valuable resources. Convolutional neural networks (CNNs) are effective in visual classification, but incorporating additional information, such as textual data, improves accuracy; multimodal classification approach combining visual and textual data outperforms traditional approaches using only visual input (Belhi et al., 2019).

Machine learning (ML) has seen widespread application in various fields, including archaeology; ML algorithms simulate human learning processes by analyzing data and making predictions. In archaeology, ML techniques have created training datasets for Dutch Named Entity Recognition (NER), semantic search in excavation reports, and automatic annotation of heritage and archaeological concepts. Cloud-based tools have been developed to process textual archaeological records and generate semantic metadata. ML has proven to be a valuable tool for archaeologists, enabling more efficient analysis and understanding of archaeological data (Moullou et al., 2023).

Machine learning (ML) has been widely employed in archaeology, focusing on image analysis and object recognition. ML techniques, such as deep neural networks, have been utilized to extract structural elements of buildings and detect ancient rock carvings; neural networks have also extracted architectural features from images and pottery sherds from drone-acquired imagery (Belhi et al., 2019). ML uses a Random Forest algorithm to automatically detect shipwrecks and segment petroglyphs from 3D digitized rock surfaces; the availability of large-scale LIDAR, satellite, and aerial images has transformed archaeology, particularly in mapping and site searching. ML techniques offer promising archaeological research and exploration advancements, enabling efficient site searches in various locations (Moullou et al., 2023).

Digital preservation, as the UNESCO Charter outlines, utilizes digital technologies (DTech) to record, preserve, and provide access to historic buildings and sites' cultural and historical significance. It involves non-destructive methods like 3D scanning and modeling, virtual reality (VR), and visualization to document architectural heritage accurately (Li et al., 2023). Digital preservation is characterized by non-destructiveness, convenience, and the maintenance of authenticity; these methods enable real-time data sharing, non-destructive restoration, and the preservation of architectural heritage's authenticity (Andrea et al., 2021). Digital technologies also play a crucial role in protecting architectural heritage from disasters and climate change events, aligning with the United Nations' Sustainable Development Goals (SDGs) (Moullou et al., 2023). Laser scanning, drones, digital photography, GIS, and AI safeguard architectural heritage and support conservation. Digital technologies have fueled research and practices in digital preservation across various countries.

7. Mobile applications

Mobile applications have become instrumental in bringing cultural heritage closer to people and enhancing their engagement and interaction with cultural artifacts, historical sites, and heritage resources; they offer a range of features and functionalities that provide users with immersive experiences, educational content, and convenient access to cultural heritage information.

Numerous apps have emerged to meet visitors' needs exploring cities and monuments, offering real-time, enriched content and interpretations of the past through ambient computing and deep learning (Arias-Espinoza et al., 2018). Projects like Time Machine aim to digitally reconstruct historical places in 4D, combining them with various data types accessible through augmented reality interfaces (Lercari & Jaffke, 2020). Monugram enables real-time monument information based on image recognition, while Woolysses provides interactive chatbot tours with personalized multimedia content tailored to the user's needs; Eagle facilitates the automatic recognition of Greek/Latin epigraphs and the dissemination of associated information (Andrea et al., 2021).

The use of Geographic Information Technologies (GIT) in Cultural Heritage (CH) involves analyzing heritage value through Digital Representations (DR), considering mental spatial cognition and physical perceptions. This field focuses on 3D data acquisition, modeling, visualization, and integrating 3D GIS with AR in mobile platforms. Trials and products, such as the case study of Lisbon's Aqueduct, demonstrate the application of these techniques to refine solutions and develop mobile applications for cultural heritage (Marques et al., 2017).

Many Tools as Mobile applications, such as iDig is a digital tool designed for archaeologists, offering wireless connectivity and visualization capabilities to enhance excavation work and recording; it has been successfully implemented at the Athenian Agora Excavations, providing immediate digital records and optimizing workflows through the iDig iPad app (Boyd et al., 2021).

A new freeware digital system based on Google/Android platforms allows recording, managing, and sharing archaeological survey data through smartphone/tablet with two

ArcheoSurvey and LithicsOTG applications. It offers data collection, artifact analysis, and measurements, with storage in device memory and a cloud-based database, providing researchers with a customizable solution for their projects (Cascalheira et al., 2017).

Dig@IT is a versatile virtual reality tool that enables immersive archaeological data analysis and curation. Its implementation at the UNESCO World Heritage site Çatalhöyük demonstrates the feasibility of digital methods for processing and curating 3D stratigraphic data (Lercari et al., 2018).

During the 2012 field season of the Pyla-Koutsopetria Archaeological Project in Cyprus, a custom mobile application called PKapp was created. This application showcased various opportunities for utilizing digital workflow in archaeological research (Fee, 2016).

The development of mobile apps tailored for site stewardship effectively mitigates adverse human effects on cultural landscapes and improves our ability to document and monitor cultural heritage sites. One such app is the Citizen Preservationist, an open-source hybrid software for mobile and desktop use. This app promotes the preservation and utilization of archaeological sites and historic parks. Its viability was demonstrated through a user study conducted at Bodie, California State Historic Park (Lercari & Jaffke, 2020).

These apps aim to leverage technology to make historical knowledge more accessible and bridge the gap between the digital and physical worlds.

8.Discussion

At the core of this research lies the critical examination of the principles espoused by the iconic Venice Charter. This guiding document has shaped the preservation and interpretation of cultural heritage since its inception in 1964. In the face of rapidly evolving societal, technological, and environmental challenges, the "Venice Charter New Heritage Challenges (2024)" emerges as a revised framework that acknowledges the need for a more holistic and responsive approach to heritage management.

By exploring the integration of cutting-edge digital technologies, this study has uncovered compelling synergies between these innovations and the principles outlined in the updated Venice Charter. The ability of 3D scanning, VR, and AR to create accurate digital representations and immersive experiences aligns with the Charter's emphasis on conservation, restoration, and public engagement. Similarly, the comprehensive mapping, analysis, and documentation capabilities afforded by GIS, high-resolution imaging, and RTI technologies resonate with the Charter's call for diverse data collection and management. The provision of on-site interpretation and digital archives through mobile apps and the potential of NLP and AI to enhance research, interpretation, and knowledge dissemination further demonstrate the Charter's principles being operationalized digitally.

. The rapid advancement of tools and techniques, from virtual reality to 3D scanning and AI-powered analysis, has opened unprecedented opportunities to revolutionize how we interact with and safeguard our shared cultural treasures. Yet, all researchers are acutely aware of the need to ensure that our innovative solutions remain firmly grounded in the timeless principles of the Venice Charter. The 1964 Venice Charter and its 2024 update serve as the cornerstone for conserving and restoring monuments and sites, outlining fundamental tenets that must guide our actions. At the heart of the Venice Charter are the principles of authenticity, integrity, and stewardship – essential to preserving the essence and significance of cultural heritage. These principles call for a reverent approach to intervention, emphasizing the importance of respecting each heritage site's unique character and historical context and promoting the careful documentation of all conservation work.

By cultivating a deep understanding of the Venice Charter's principles and continuously exploring innovative ways to apply them, we can ensure that our digital solutions serve as empowering enablers rather than disruptive forces. Only then will the full transformative power of technology be unlocked while upholding the fundamental tenets that have guided the conservation of cultural heritage for generations.

Looking to the future, the seamless integration of digital technologies with the revised Venice Charter holds great promise for the continued evolution and improvement of cultural heritage management and conservation. As technology advances, heritage professionals will be increasingly equipped to address emerging challenges, such as remote monitoring and assessment of heritage sites, developing interactive educational platforms, and leveraging AI-powered tools for predictive analysis and decision-making. By embracing this digital transformation, the heritage sector can ensure the long-term preservation and accessibility of these invaluable cultural assets while fostering greater public engagement and appreciation.

8. Conclusion

Thinking in reflecting on the transformative role of digital technologies in cultural heritage preservation, interpretation, and public engagement, we stand at a pivotal juncture. The rapid advancement of tools and techniques, from virtual reality to 3D scanning and AI-powered analysis, has opened unprecedented opportunities to revolutionize how we interact with and safeguard our shared cultural treasures. Yet, as the external observer and rapporteur for this process, I am acutely aware of the need to ensure that our innovative solutions remain firmly grounded in the timeless principles of the Venice Charter. The foundational tenets of authenticity, integrity, and stewardship, as outlined in the landmark 1964 Venice Charter and its 2024 update, must guide our actions, even as we harness the power of digital innovation. Throughout this exploration, we have witnessed the immense potential of these technologies to enhance accessibility, deepen public understanding, and foster cross-cultural dialogue. Virtual tours can transport audiences to remote heritage sites, immersive experiences can breathe new life into ancient artifacts, and AI-powered analysis can uncover hidden insights that inform preservation efforts. However, the accurate measure of success lies in our ability to seamlessly integrate these digital tools and techniques with the reverence and care demanded by the Venice Charter. Only then can we unlock the full transformative power of technology while upholding the fundamental principles that have guided the conservation of cultural heritage for generations. By cultivating a deep understanding of the Venice Charter's principles and continuously exploring innovative ways to apply them, we can ensure that our digital solutions serve as empowering enablers rather than disruptive forces.

9. References

[1] Cuy, S., De Oliveira, D., Gerth, P., Kleinke, T., Schierenbeck, J., & Watson, J. (2017). iDAI. field 2: A Modern Approach to Distributed Fieldwork Documentation. In Proceedings of the 22nd International Conference on Cultural Heritage and New Technologies 2017. CHNT 22, 2017. Museen der Stadt Wien–Stadtarchäologie.
[2] Trunfio, M., Lucia, M. D., Campana, S., & Magnelli, A. (2022). Innovating the cultural heritage museum service model through virtual reality and augmented reality: The effects on the overall visitor experience and satisfaction. Journal of Heritage Tourism, 17(1), 1-19.
[3] Lercari, N., & Jaffke, D. (2020). Implementing Participatory Site Stewardship through Citizen Science and Mobile Apps: The Case of Bodie, California. Advances in Archaeological Practice, 8(4), 337-350.
[4] Fee, S. B. (2016). 2.1. Reflections on Custom Mobile App Development for Archaeological Data Collection.
[5] Lercari, N., Shiferaw, E., Forte, M., & Kopper, R. (2018). Immersive visualization and curation of archaeological heritage data: Çatalhöyük and the Dig@ IT App. Journal of Archaeological Method and Theory, 25, 368-392

[6] Cascalheira, J., Bicho, N., & Gonçalves, C. (2017). A Google-based freeware solution for archaeological field survey and onsite artifact analysis. Advances in Archaeological Practice, 5(4), 328-339.
[7] Patrik, A., Utama, G., Gunawan, A. A. S., Chowanda, A., Suroso, J. S., Shofiyanti, R., & Budiharto, W. (2019). GNSS-based navigation systems of autonomous drone for delivering items. Journal of Big Data, 6, 1-14.
[8] Mishra, M., Barman, T., & Ramana, G. V. (2022). Artificial intelligence-based visual inspection system for structural health monitoring of cultural heritage. Journal of Civil Structural Health Monitoring, 1-18.
[9] Boyd, M. J., Campbell, R., Doonan, R. C., Douglas, C., Gavalas, G., Gkouma, M., ... & Renfrew, C. (2021). Open area, open data: advances in reflexive archaeological practice. Journal of Field Archaeology, 46(2), 62-80.
[10] Parfenov, V., Igoshin, S., Masaylo, D., Orlov, A., & Kuliashou, D. (2022). Use of 3D laser scanning and additive technologies for reconstruction of damaged and destroyed cultural heritage objects. Quantum Beam Science, 6(1), 11.
[11] Hassan, A. T., & Fritsch, D. (2019). Integration of Laser Scanning and Photogrammetry in 3D/4D Cultural Heritage Preservation–A Review. International Journal of Applied, 9(4), 16.
[12] Kushwaha, S. K. P., Dayal, K. R., Sachchidanand, Raghavendra, S., Pande, H., Tiwari, P. S., ... & Srivastava, S. K. (2020). 3D Digital documentation of a cultural heritage site using terrestrial laser scanner—A case study. In Applications of Geomatics in Civil Engineering: Select Proceedings of ICGCE 2018 (pp. 49-58). Springer Singapore.
[13] Martinez Espejo Zaragoza, I., Caroti, G., & Piemonte, A. (2021). The use of image and laser scanner survey archives for cultural heritage 3D modelling and change analysis. ACTA IMEKO, 10(1), 114-121.
[14] Trillo, C., Aburamadan, R., Mubaideen, S., Salameen, D., & Makore, B. C. N. (2020). Towards a systematic approach to digital technologies for heritage conservation. Insights from Jordan. Preservation, Digital Technology & Culture, 49(4), 121-138.
[15] Marques, L. F., Tenedório, J. A., Burns, M., Romão, T., Birra, F., Marques, J., & Pires, A. (2017). Cultural Heritage 3D Modelling and visualisation within an Augmented Reality Environment, based on Geographic Information Technologies and mobile platforms. ACE: Arquitectura, Ciudad y Entorno.
[16] Haddad, N. A., Fakhoury, L. A., & Sakr, Y. M. (2021). A critical anthology of international charters, conventions & principles on documentation of cultural heritage for conservation, monitoring & management. Mediterr. Archaeol. Archaeom, 21, 291-310.
[17] Ali, J. M. A., & Hamed, H. M. (2019). Employing augmented reality for reviving heritage sites: an AR vision for Qasr al-Abd in Jordan. American Journal of Tourism Research, 8(1), 1-10.
[18] Belhi, A., Gasmi, H., Al-Ali, A. K., Bouras, A., Foufou, S., Yu, X., & Zhang, H. (2019, August). Deep learning and cultural heritage: the CEPROQHA project case study. In 2019 13th International Conference on Software, Knowledge, Information Management and Applications (SKIMA) (pp. 1-5). IEEE.
[19] Andrea, G., Russo, M., & Roberta, S. (2021). REPRESENTATION CHALLENGES. Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain. DISÉGNO-OPEN ACCESS, 1-432.
[20] Dou, J., Qin, J., Jin, Z., & Li, Z. (2018). Knowledge graph based on domain ontology and natural language processing technology for Chinese intangible cultural heritage. Journal of Visual Languages & Computing, 48, 19-28.
[21] Shubita, A., & Saleh, Y. (2020). The application of artificial intelligence technology in cultural heritage development. International Journal of Recent Technology and Engineering, 8(5), 1140-1146.

[22] Moullou, D., Vital, R., Sylaiou, S., & Ragia, L. (2023). Digital Tools for Data Acquisition and Heritage Management in Archaeology and Their Impact on Archaeological Practices. Heritage, 7(1), 107-121.4
[23] Al-Adamat, R., Al-Shawabkeh, Y., Al-Kour, O., & Al-Shabeeb, A. R. (2016). A multi-resolution photogrammetric framework for digital geometric recording of large archeological sites: Ajloun Castle-Jordan. International Journal of Geosciences, 7(3), 425-439.
[24] Malinverni, E. S., Pierdicca, R., Di Stefano, F., Gabrielli, R., & Albiero, A. (2019). Virtual museum enriched by GIS data to share science and culture. Church of Saint Stephen in Umm Ar-Rasas (Jordan). Virtual Archaeology Review, 10(21), 31-39.
[25] Longo, I. E. (2017). ThreeDimensional Epigraphic Recording at Stobi (Former Yugoslav Republic of Macedonia): Creating a Virtual Lapidarium.
[26] Aburamadan, R., Trillo, C., Cotella, V. A., Di Perna, E., Ncube, C., Moustaka, A., ... & Awuah, K. G. B. (2022). Developing a heritage BIM shared library for two case studies in Jordan's heritage: The House of Art in Amman and the Qaqish House in the World Heritage City of As-Salt. Heritage Science, 10(1), 1-21.
[27] Li, Y., Du, Y., Yang, M., Liang, J., Bai, H., Li, R., & Law, A. (2023). A review of the tools and techniques used in the digital preservation of architectural heritage within disaster cycles. Heritage Science, 11(1), 199.
[28] Maietti, F.; Di Giulio, R.; Medici, M.; Ferrari, F.; Ziri, A.E.; Turillazzi, B.; Bonsma, P. (2020). Documentation, Processing, and Representation of Architectural Heritage through 3D Semantic Modelling: The INCEPTION Project. In Impact of Industry 4.0 on Architecture and Cultural Heritage; IGI Global: Hershey, PA, USA, 2020; pp. 202–238.
[29] Maietti, F.; Piaia, E.; Mincolelli, G.; Di Giulio, R.; Imbesi, S.; Marchi, M.; Giacobone, G.A.; Brunoro, S. Accessing and Understanding Cultural Heritage through Users Experience within the INCEPTION Project. In Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection: EuroMed. Lecture Notes in Computer Science, Nicosia, Cyprus, 29 October–3 November 2018; Ioannides, M., Fink, E., Brumana, R., Patias, P., Doulamis, A., Martins, J., Wallace, M., Eds.; Springer: Cham, Switzerland, 2018; Volume 11196.
[30] Arias-Espinoza, P.; Medina-Carrión, A.; Robles-Bykbaev, V.; Robles-Bykbaev, Y.; Pesántez-Avilés, F.; Ortega, J.; Matute, D.; Roldán-Monsalve, V. e-Pumapunku: An Interactive App to Teach Children the Cañari and Inca Indigenous Cultures During Guided Museum Visits. In Proceedings of the 2018 Congreso Internacional De Innovación Y Tendencias En Ingeniería (CONIITI), Bogota, Colombia, 3–5 October 2018; pp. 1–5.
[31] Bozzelli, G., Raia, A., Ricciardi, S., De Nino, M., Barile, N., Perrella, M., ... & Palombini, A. (2019). An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The ArkaeVision project. Digital Applications in Archaeology and Cultural Heritage, 15, e00124.
[32] Pietroni, E., Menconero, S., Botti, C., & Ghedini, F. (2023). e-Archeo: A Pilot National Project to Valorize Italian Archaeological Parks through Digital and Virtual Reality Technologies. Applied System Innovation, 6(2), 38.
[33] Duffy, S. M., Goskar, T., Backhouse, P., & Kennedy, H. (2018). Multi-light Imaging Highlight-Reflectance Transformation Imaging (H-RTI) for Cultural Heritage. Historic England. https://historicengland. org. uk/images-books/publications/multi-light-imaging-heritage-applications.
[34] Earl, G., Basford, P., Bischoff, A., Bowman, A., Crowther, C., Dahl, J., ... & Piquette, K. E. (2011). Reflectance transformation imaging systems for ancient documentary artefacts. Electronic visualisation and the arts (EVA 2011), 147-154.
[35] Del Pozo, S., Rodríguez-Gonzálvez, P., Sánchez-Aparicio, L. J., Muñoz-Nieto, A., Hernández-López, D., Felipe-García, B., & González-Aguilera, D. (2017). Multispectral imaging in cultural heritage conservation. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 155-162.

[36] Nurit, M., Le Goïc, G., Lewis, D., Castro, Y., Zendagui, A., Chatoux, H., ... & Mansouri, A. (2021). HD-RTI: An adaptive multi-light imaging approach for the quality assessment of manufactured surfaces. Computers in Industry, 132, 103500.
[37] Erder, C. (1977). The Venice Charter under Review. Journal of Faculty of Architecture, METU, Ankara, 25, 24-31.
[38] How ARtGlass is Reimagining Museums and Historical Sites with Augmented Reality. https://www.bizjournals.com/richmond/inno/stories/fundings/2019/01/29/how-artglass-is-reimagining-museums-and-historical.html). (Last Access: 14\2\2024)
[39] ARtGlass to Expand Offerings in 2020. https://www.culturalheritagepartners.com/artglass-to-expand-offerings-in-2020/# (Last Access: 14\2\2024)