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Mechanisms of Artificial Intelligence for the Preservation of Cultural Heritage

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Abstract:

Cultural heritage is considered a foundation for the renaissance of the United Nations, as it is believed to be an important link between the nation's present and its past. To protect, preserve, and revive it, Algeria has made significant efforts in numerous international endeavors through its relationship with UNESCO, the world's foremost supporter of its protection, and through its ratification of all international declarations, treaties, and agreements related to heritage, as well as its accession to the diverse international institution. At the national level, the Algerian state has established a set of means and methods to protect cultural heritage, including educational and legal ones, amending many relevant texts. Due to the development of advanced technology, the power of artificial intelligence has become evident in people's lives and has extended beyond it to cultural heritage by creating a set of mechanisms that artificial intelligence has successfully achieved.

Keywords: Cultural heritage, artificial intelligence, digitization, tangible heritage, and intangible heritage

INTRODUCTION:

Cultural heritage is considered a cornerstone in the advancement of nations, as it plays an important role in linking a nation’s present with its past. It is a shared legacy for future generations and constitutes an inseparable part of national identity. The loss of any part of it means losing a significant aspect of the priceless national identity. Therefore, it is essential to sustain this heritage through its protection, preservation, and distinguished management.

Its importance is not limited to its moral value alone; it also holds high economic and social value, as it is considered one of the factors of progress that yield beneficial returns on the development of infrastructure. Given its great moral and material value, and in light of the various dangers and threats it faces, it has received significant international care and attention.

As a result, many treaties, agreements, international recommendations, and decisions have emerged, along with the establishment of several governmental and non-governmental international organizations.

In addition, a number of regional efforts have been devoted to its protection in all aspects, as it is considered a shared heritage of humanity. These efforts have not been limited to the international level; rather, the protection of cultural heritage has become a core concern of states and their domestic legislation, as preserving these cultural treasures requires the combined efforts of both international and national bodies, through enacting national legislations aimed at protecting the heritage of each country individually.

Algeria is among the countries that have been blessed with a rich and diverse heritage, encompassing numerous relics of civilizations that have passed through it, stretching back to deeply rooted historical eras, to the extent that it is considered an open-air museum. However, this heritage is often subject to many violations and threats.

Therefore, in order to protect, preserve, and revive it, Algeria has engaged in many international efforts through its relationship with UNESCO the world's primary supporter of heritage protection and by ratifying all protocols, treaties, and international agreements concerned with heritage, as well as joining international bodies and institutions responsible for the protection of cultural heritage.

At the domestic level, the Algerian state has developed a set of mechanisms and tools aimed at protecting cultural heritage, including legislative mechanisms, through laws related to its protection and various relevant regulatory texts. In addition, there is the administrative protection mechanism, which consists of a set of restrictions, measures, and controls issued by the competent public authority to protect and preserve it.

With the tremendous scientific and technological advancement the world is witnessing—known as the digital culture everyone agrees that we are experiencing a digital transformation brought about by the digital revolution and its various forms in electronic spaces. This has enabled artificial intelligence to participate in decision-making, change life methodologies, and contribute to their development. This raises the question: How can artificial intelligence mechanisms preserve cultural heritage in its various forms?

Before answering this question, it is necessary to define some concepts and provide a historical overview of artificial intelligence.

First: Defining some concepts

1/ The concept of cultural heritage:

The concept of heritage is considered a flexible one that is difficult to confine within a comprehensive definition:

It refers to what previous and ancient civilizations have produced in all fields and domains, whether material or immaterial, and is closely linked to the history and identity of those peoples (Ahmed Samir, 2012) [1].

It also refers to everything produced by humans either by hand or intellect, or the remains they left behind, dating back more than a hundred years, including human, animal, and plant lineages, real estate antiquities, creative arts, and folk artifacts (Hafiza Mestawi, 2011, p. 15)[2].

It is also defined as everything that has reached us in writing from any branch of knowledge, or tangibly in any form of art, produced by thought and labor throughout human history. It is also described as the essence of what past generations have left to the present ones. It is a cultural science in its own right, concerned with a specific sector of culture and shedding light on it from various perspectives historical, social, geographical, and psychological (Sulah Al-Nasir, 2009, p. 7) [3].

The term has undergone significant change due to its association with both tangible and intangible aspects:

A. The concept of tangible heritage:

It includes all places, buildings, artifacts, and other items that are worthy of preservation and optimal protection for future generations [4] (Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972, p. 4).

B. As for intangible heritage:

It is the living spiritual heritage of humanity, representing living expressions inherited from ancestors and transmitted across generations, such as oral traditions, performing arts, rituals, festive events, knowledge and practices concerning nature and the universe, or the skills and know-how required for the production of traditional crafts (United Nations Educational, Scientific and Cultural Organization, Intangible Cultural Heritage, pp. 3–4) [5].

Despite its fragile nature, intangible heritage constitutes an important factor in preserving cultural diversity in the face of increasing globalization. It contributes to intercultural dialogue and promotes mutual respect, as it is characterized by being a living and contemporary heritage shared by diverse communities. It is also considered an inclusive and representative heritage through which skills and knowledge are transmitted among societies (Ben Omar Awaj & Mohamed Al-Arabi, 2022, p. 52).

2/ Digitization:

It is considered a form of electronic documentation, whereby the digitization process is carried out on an electronic medium. This transformation requires identifying all existing methods and techniques and selecting what suits the intended function. It has become a necessary process to solve many problems. It is defined as the conversion of information of various forms into a format readable by computer technologies, through the binary system, which represents information units as a set of binary digits. This process is carried out using a set of specialized technologies and devices. Digitization is considered a procedure for converting intellectual content stored on traditional physical media such as journals, articles, manuscripts, and books into digital form. This is the concept of digitization presented by Doug Hodges and adopted by the National Library of Canada [6](Soukal Iman, 2020, p. 85).

It is also considered an electronic process to produce digital or electronic symbols, either from a document or any physical item, or from analog electronic signals, where information is

converted from its real state into a digital form whether images, textual data, audio files, or any other format (Sameh Zainhom, 2006, p. 46) [7].

Digitization thus works to transfer heritage from the past through archives to the present using modern technological tools for preservation and storage, and into the future via the Internet and other modern digitization and innovation technologies, such as artificial intelligence [8] technology.

Artificial intelligence is a digital technology that facilitates the digital transformation of current operations, even those still carried out by human agents. Automation mechanisms have become possible thanks to the ability of AI algorithms to exploit collected data sets by training on them in order to make predictions about future data that are sufficiently close to the data used for training the algorithms.

Moreover, AI has demonstrated a certain degree of openness with regard to the types of data: it can be applied to audio, images, physiological data, or texts, to name a few. Progress in these areas, the openness of AI with regard to input data types, and the development of effective accompanying tools and services have led cultural institutions to question their capacity to benefit from AI technologies (Pasikowska-Schnaas, M., 2023) [9].

It is difficult to pinpoint the exact birth of artificial intelligence. Its roots may go back to the 1940s, specifically the year 1942. The term "artificial intelligence" was officially coined in 1956 when Marvin Minsky and John McCarthy hosted the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI).

This project, which marks the beginning of the AI spring, brought together those who would later be considered the founding fathers of AI. Initially, with the excitement of innovation and early successes, researchers made somewhat exaggerated statements, for which they were later heavily criticized. For example, in 1958, American Herbert Simon stated that within ten years, a machine would become the world chess champion if it were not barred from international competitions (Alya Atef, 2023, p. 43) [10].

3/ Artificial Intelligence:

It is the theory and development of computer systems capable of performing tasks that require human intelligence, such as perception, reasoning, learning, interaction with the environment, and creativity (Khawla Qamish, 2023, p. 354) [11].

4/ Digital Heritage:

It is the preservation of human tangible and intangible heritage through the use of multimedia technological innovations, making it accessible to everyone via the Internet, in line with the advancement of information technology (Soukal Iman, 2020, p. 85) [12].

3/ Mechanisms of Digitization and Artificial Intelligence:

A. Automated Scanning:

The use of 3D laser scanners today is one of the most accurate, fastest, and most effective methods for obtaining 3D model data of existing objects. The data obtained serve as a source

of information for converting real objects into accurate 3D digital replicas, which can capture spatial geometry and be used for various types of computer-based analysis and further processing.

Terrestrial laser scanning, also known as terrestrial surveying (Light Detection and Ranging – LiDAR) or topographic surveying, operates through a terrestrial laser scanning system, which is also a coordinate system for many points on the ground. Laser pulses are projected onto these points, and the target distance to the device is calculated. Laser scanning provides high precision when recording real-world objects. The result of the scan is a point cloud representing a three-dimensional image of the scanned objects.

However, with the advancement of devices and software performance, it has become possible to easily analyze dense point cloud models, while determining the accuracy of the scanning operations based on various factors, including the device's capabilities, the object's distance from the scanner, the angle of laser beam incidence, and surface materials. In addition, post-processing steps such as point cloud registration, filtering, and alignment may introduce unknown errors. Final accuracy assessment requires comparison with an ideal reference object, which is often unavailable, posing challenges in determining absolute accuracy (Lee, J., 2019, p. 242) [13].

3D laser scanning is one of the technologies of reverse engineering, which is also used in the digitization of elements of cultural heritage. Reverse engineering is a method by which the shape and geometry of a specific object can be obtained, and thus a 3D digital model can be created based on a physical model. The scientific and technological development of these methods brings many applicable advantages in the field of protecting and visualizing the entirety of cultural heritage.

B. Geographic Information Systems and 3D Modeling (GIS and 3D Modeling):

Geographic Information Systems (GIS) are considered among the most important technologies for 3D city modeling, which has become highly important and necessary for representing and conducting various analyses of cultural heritage, with the aim of finding solutions to problems within a virtual model framework of reality. In addition to the significant role of 3D GIS in urban planning and city organization, although many programs are capable of handling 3D objects, many of these applications require advanced techniques and sophisticated tools for representing and analyzing three-dimensional objects.

The 3D model objects represented in GIS are distinguished by their connection to a set of descriptive data that can be easily retrieved, a feature not available in other 3D modeling software.

The presented research aims to highlight the importance of procedural 3D modeling of cities within the GIS environment using the program ESRI City Engine. A set of architectural generation rules (CGA), programmed in the procedural modeling language, will be presented to generate a series of realistic 3D models capable of representing all elements of archaeological cities and their infrastructure, especially historical buildings.

This independent method relies on triangulation from two or more images to digitally reconstruct the object through the integration of technology and Geographic Information

Systems (GIS), proving the effectiveness of software, devices, and procedures for managing spatial data in terms of their usefulness in capturing, editing, analyzing, and representing data. It enables a more comprehensive approach to heritage preservation and facilitates the development of virtual collections and historical archives, while recognizing the integration of heritage sites with their surrounding landscapes (Yakar, M. & Doğan, Y., 2018, pp. 50, 55) [14].

Three-dimensional models of archaeological sites and structures are of great importance in the fields of archaeology and digital tourism. These models help archaeologists document the archaeological site and analyze the relationships between its components. They also serve as a tourist attraction, enabling visitors to explore archaeological sites and cultural heritage remotely in a virtual manner.

This study aims to propose a methodology for using some capabilities of computer-aided design systems and Geographic Information Systems in building a spatial and semantic database for archaeological sites and modeling them in 3D.

Users of this database can access all information related to the components of the archaeological site and navigate within it, thanks to the availability of animation generation capabilities within GIS. Then, the capabilities of the ArcGIS geographic information system are used to build the archaeological information system for the site and model it in three dimensions [15].

C. Virtual Reality Applications:

It is defined as an environment that simulates reality in a three-dimensional manner, through which users can explore and fully interact with a surrounding virtual reality as if it were a real one, perceiving its various aspects through their senses.

This virtual reality (VR) is designed using advanced hardware and software, and those wishing to immerse themselves in virtual reality wear helmets or glasses to interact with the surrounding environment and fully immerse themselves in the experience, allowing them to disconnect from their real surroundings and feel as though the virtual reality they have entered is actual reality and not merely a simulation of it.

Users create the corresponding decorative model using geometric elements in the foreground. There are also special programs for creating interactive 3D models in architecture, using multiple images to facilitate the process (Zara, J., 2004, pp. 101–102) [16].

This application also enables individuals to reconstruct archaeological sites that have been damaged or destroyed by natural causes. It allows users to wear headsets and walk through historically reconstructed environments rendered digitally in high precision, providing them with a realistic experience as if they were inside the site itself.

Virtual and augmented reality applications open new horizons in the field of heritage preservation and make it accessible to the public in an interactive and innovative way. Thanks to these technologies, people around the world can now explore cultural and historical heritage in a way that was never before possible, contributing to the dissemination of knowledge and enhancing global appreciation of human and cultural heritage.

D. Analysis and Restoration:

Recent developments in deep learning for image processing have led to the exploration of damage detection techniques using images and 3D point cloud data. Optical sensing techniques such as unmanned aerial vehicles and cameras have been used as alternatives to visual inspection to detect damage to heritage structures, with the aim of reducing human involvement. Intelligent damage detection techniques based on machine learning algorithms have gained significant attention.

Artificial intelligence, especially deep learning, has shown remarkable results in image-based damage detection. However, it can only identify two-dimensional surface damage in heritage structures. Therefore, other sensing technologies are integrated, such as 3D point clouds, infrared sensing, vibration response, and ground-penetrating radar. Artificial intelligence algorithms are used to enhance detection capabilities. There are also smart detection strategies for heritage preservation, focusing on various data types such as images, 3D point clouds, and dynamic responses.

However, the applicability of these technologies requires further validation, especially in cases with limited data, which necessitates urgent research into intelligent learning algorithms trained on small samples (Zhang, J. & Yuen, Y., 2022, p. 442) [17].

The study presents two techniques for damage detection in structural systems. The first technique uses dynamic behavior data as input variables and builds ten predictive models to estimate the location and severity of damage in a structure. The LS-SVM approach was found to be the most effective for building and projecting these models. The second technique involves the use of the MSEBI index to identify the damage location in the structure, and it employed the CBO algorithm with a suitable surrogate model to reduce the computational time required to detect damage severity.

4/ The Role of Artificial Intelligence in the Preservation and Promotion of Cultural Heritage:

The use of artificial intelligence and digitization contributes to the service of cultural heritage by enhancing research, excavation, and discovery efforts related to heritage and antiquities. It accelerates precise performance in detecting and identifying artifacts and enables accurate analysis of the knowledge extracted from them. It also improves the quality of restoration and preventive treatment efforts at appropriate times, based on predictive capabilities depending on the condition of the manuscript, model, or any other archaeological material. Furthermore, it rationalizes research and exploration efforts and reduces the cost of excavation and identifying the contents of discovered artifacts.

Artificial intelligence can be used in the field of heritage through the documentation and archiving of oral heritage, and the documentation of archaeological site discoveries accurately identifying, photographing, and recording their locations through aerial photography, laser scanning, and the use of drones to access difficult areas. AI-supported security software can provide protection for archived data, information, and artifacts by proactively dealing with threats and detecting any unusual activity in digital heritage storage and preservation locations. It can stop or alert about such threats before any danger occurs.

Digitization represents an effective means of preserving rare and valuable information resources, or those in physically fragile condition, which cannot be made available to users. It also helps reduce or eliminate access to the original sources by providing an alternative digital copy accessible to users and visitors.

Remote access to and exchange of information resources is also one of the fundamental features of digital collections. A library may provide another library with a digital copy of an information resource via network systems, and this process should be carried out reciprocally between libraries so that the user can view and compare, in a single location, all available information resources from several libraries or information institutions [18].

It also facilitates the collection of similar manuscript copies into a single version, especially those held outside the country, by utilizing electronic media such as email—without the need to travel to the locations where the heritage materials are kept.

This contributes to reducing the direct use of paper copies of artifacts in order to preserve originals such as manuscripts and minimize their handling by researchers. It also allows the researcher to identify types of Arabic scripts using computer tools and avoid health issues caused by direct contact with physical manuscripts, such as dust allergies or exposure to chemicals contained in the ink and paper due to aging, climatic conditions, and storage environments, etc.

Moreover, it enables scholars to carry out verification, comparison, and magnification of copies simultaneously, without the need to travel or endure the difficulty of comparing artifacts from one location to another (Aba Lahbib Hamza, 2014, p. 48) [19].

Digitizing cultural heritage offers innovative and effective solutions for preserving the past. By enhancing accessibility, protecting intangible cultural heritage, facilitating research and education, and safeguarding cultural diversity, virtual reality holds the potential to make cultural heritage accessible to people with physical disabilities or special needs. Through the provision of virtual museum experiences, individuals who may be unable to navigate physical spaces can now interact with cultural, natural, documentary, and historical heritage in a more inclusive manner.

The application of augmented reality in cultural heritage sites enhances visitor experiences through guided tours. Traditional guided tours often rely on audio guides or printed materials, which can be limited in terms of interaction and engagement. However, with augmented reality technology, visitors can now experience an entirely new level of immersion and interactivity. Augmented reality technology is also revolutionizing the way visitors interact with exhibits and installations at cultural heritage sites. Rather than passive observation, augmented reality allows for active participation and interaction with the content.

3D scanning technology enables the creation of highly accurate digital replicas of archaeological, cultural, and historical artifacts. These identical digital copies can be used for research, education, and even virtual reality experiences, bringing cultural heritage closer to people who might not have the opportunity to visit the actual site.

Mobile applications also provide virtual tours, language learning tools, and interactive learning experiences. These apps make it easier than ever to explore and appreciate tangible and

intangible cultural heritage, as well as the customs and traditions of different peoples—all now accessible to everyone.

With the help of technologies such as virtual reality, augmented reality, and mobile apps, innovative solutions can be delivered to engage users in ways that traditional learning methods cannot. By integrating game elements such as quizzes, scavenger hunts, and role-playing games, these technologies can bridge the gap between education and entertainment, creating exciting experiences for visitors and tourists.

Artificial intelligence also plays a role in fostering collaboration and partnerships in the field of cultural heritage by increasing resources, expanding access to new markets, enhancing innovation, and sharing costs and risks. Innovative solutions can be developed to advance the heritage industry, while also contributing to the preservation and promotion of our cultural heritage.

Artificial intelligence based on satellite technology can use satellite imagery to identify archaeological sites. Recent and significant developments in AI-powered satellite archaeology have revolutionized the way archaeologists explore and study ancient landscapes. The results indicate that it is a powerful and precise tool for reconstructing ancient landscapes.

Despite the importance of artificial intelligence technologies in the preservation of cultural heritage sites, there are concerns about applying these technologies to heritage locations. The implementation of such technologies remains restricted in many countries around the world due to their advantages and disadvantages.

Drones powered by artificial intelligence are useful for recording cultural heritage sites, providing 3D documentation of heritage locations, and supplying illustrative images of heritage sites. They are also used in surveying and mapping, which ultimately contributes to the preservation of cultural heritage sites.

Robots can also be used in the promotion and explanation of heritage and tourist sites, in planning tourist routes, and in providing visitors at heritage locations and hotel clients with tourism-related information.

Technology thus makes cultural heritage accessible to all, regardless of geographic location, through digital platforms such as virtual museums and others. AI tools play an important role in analyzing ancient texts, deciphering historical symbols, and translating manuscripts opening up new horizons for understanding ancient civilizations.

The use of modern technology is extremely important to keep pace with progress and to benefit from the achievements of the human mind in scientific fields, in order to apply them to the exploration, understanding, and effective protection of our archaeological sites.

Despite the importance of this process and the benefits it offers, it faces many challenges whether financial, related to budgets and allocated funds; or technical, such as adopting the best standards and formats for information resources resulting from digitization and artificial intelligence; or issues related to the technical infrastructure of the digitization project and agreements needed to overcome challenges related to authors’ and publishers’ rights.

CONCLUSION:

At the conclusion of our study on the mechanisms of employing artificial intelligence, digitization, and modern technologies and integrating them into the sectors of cultural heritage, museums, and the arts, there is great hope for enhancing visitor experiences and providing valuable insights into collections. It is essential to address the technical and ethical requirements associated with the applications of artificial intelligence in these fields.

Recent developments in AI and its acceptance by cultural heritage institutions and museums have created a positive environment for its dissemination. The urgent need to establish digital cultural heritage archives and digitize museums and heritage sites is imposed by threats such as wars and climatic and environmental conditions that affect archaeological sites and cultural heritage.

Artificial intelligence and computing technologies help improve the visitor experience and data management, and consequently, benefit future generations through this data. Good collaboration between cultural heritage specialists and information science professionals is essential to achieve the best results and avoid reliance on commercial software. Instead, open-source programs should be promoted, which can be developed with the help of heritage experts. The vision for digitization projects worldwide has become more objective, realistic, mature, and aware of the challenges, the paths to be followed, and the price to be paid. Digitization is essential for achieving proper preservation and for improving methods and ways of making knowledge accessible to all.

Recommendations:

- First: Work on integrating AI applications into the field of cultural heritage, developing communication infrastructure, and building a set of AI applications that would create a smart foundational structure.
- Second: Promote knowledge, training, and development to enable acceptance of AI use in the promotion of cultural heritage.
- Third: Enact a specific law on artificial intelligence, provided that computer scientists play a role in drafting its provisions. It is also necessary to take into account legal and ethical requirements.
- Fourth: Train the workforce to handle various AI technologies and raise awareness to increase the benefits of its advantages and avoid its downsides in achieving the objectives of protecting and promoting cultural heritage.

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