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AI-DRIVEN TRANSFORMATIVE INNOVATIONS IN ARCHAEOLOGICAL RESEARCH –RESHAPING HISTORICAL LANDSCAPES

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Article Info

Abstract
Artificial intelligence has revolutionised contemporary archaeological studies and historical research. The research uses a qualitative examination of the instruments and methods that are currently being employed in AI in different historical settings such as the use of robots with humanoids and hologram projections, advanced designs for neural networks and 3D modelling to discover challenging territory and maritime archaeological resources, as well as the role AI plays in cataloguing human bones to offer socio-historical observations. The study's importance stems from its ability to transform archaeology traditions by providing improved reliability and effectiveness in digging, evaluation, and presentation methods. The benefits of AI for archaeologists include better dynamic and instructive interactions in exhibits, faster and more accurate data handling, and the capacity to analyse huge databases. But AI can also cause problems with computerised interpretive reliability, excessive dependence on AI and the possible disappearance of conventional historical expertise. The research aims to analyse AI transformative innovations as well as their possible challenges and prospects in the contemporary era. Though technologies are inevitable in the contemporary world, there is a dire need for an indispensable balance in Artificial Intelligence integration into archaeological research to harness its advantages and mitigate its demerits.

Keywords:
AI, Archaeology, Innovations, Historical Research.

Introduction

The word archaiologhia is derived from the Greek words archaios, which means ancient, and loghia, which means speech. In the early nineteenth century, the term archaeology came to mean studying artefacts from antiquity, such as sculptures, paintings, and buildings and interpreting them according to aesthetic standards without considering the context in which they were created. The first significant European public museums, like the Louvre in Paris, were founded around the same time and often included an archaeological component with bas-reliefs and antique sculptures. However, throughout time, the history of classical art gave rise to a more independent definition of the word archaeology, which now refers to the process of excavating using certain methods in order to look for artefacts from earlier civilizations. Archaeology nowadays is just as interested in and passionate about a "miraculously" intact statue as it is in a basic vase crock. The concept that the finding is examined to gain further insight into the historical, political, economic, and cultural context of the era to which it belongs has evolved into a more accurate and novel one throughout time. Moreover, archaeology draws on other fields that are deemed "related" or "auxiliary," including numismatics, anthropology, archeometry, and remote sensing.[1]

The area of digital archaeology has become independent due to the rapid growth of technology and its extensive integration with humanities and scientific disciplines, including archaeology. It is the focus of this subject to use contemporary IT methodologies and techniques to represent and analyze archaeological knowledge in an organized manner. Through the gathering, analyzing, and sharing of data, digital archaeology is revolutionizing the practice and communication of archaeological study. The use of digital tools to enhance field research, laboratory data analysis (processing and interpreting collected artefacts and samples using sophisticated software), and project management (streamlining administrative and logistical tasks with the help of IT systems) are a few examples. This thing contributes significantly to the preservation and protection of archaeological heritage. [2]

Millions of hectares in the Mediterranean alone had been surveyed by the start of the twenty-first century, according to Alcock and Cherry, and survey activity has increased significantly since then. It is true that many archaeological sites have been found by looking for clues in old documents or maps, and that other sites have practically happened by chance while working on other building projects. However, through field surveys, archaeologists attempt to identify the kind and quantity of discernible remains, which improves the range of possible interpretations.[3]

IV. AI in Exhibition Design and Visitor Interaction

Museums that employ new technology to create new experiences are also encouraging the development of new experience genres. These experiences must be built with superior design, effective marketing campaigns, and appropriate functioning all essential qualities that customers look for in experiences as

[1] A Dictionary of Archaeology. Germany: Wiley, 2008. P 251

[2] "Informatica Archeologica - Enciclopedia - Treccani," accessed July 4, 2024, https://www.treccani.it/enciclopedia/informatica-archeologica_(Enciclopedia-Italiana)/.

[3] P. A. J. Attema et al., "Side-by-Side Survey. Comparative Regional Studies in the Mediterranean World," 2004, https://zoboko.com/text/4e2ene0l/side-by-side-survey-comparative-regional-studies-in-the-mediterranean-world/18.

well as in goods and services[4]. Describe qualities based on a wealth of literature that draws inspiration from the idea of flow[5], a state of mind attained when one is fully engaged in an activity, resulting in a spontaneous and fruitful experience[6]. Nevertheless, what makes an experience unforgettable is inferring meaning and encouraging contemplation on certain viewpoints or difficulties through the dialogue-based experience that museum exhibits foster is another approach to add enjoyment to an encounter. In museums, dialogue has historically fostered an environment for learning as visitors interact with the displays and have conversations about the information they see. Because it encourages discussions and thoughts sparked by exhibitions, content is essential to the informal learning process. Numerous scientific and cultural organizations have embraced technology to establish connections that go beyond the labels that are placed beside the artworks. These consist of augmented reality, RFID tags[7], chatbots[8], robots[9], and QR codes[10].

The state-of-the-art in museum experiences indicates that several research has been conducted on the use of technology to engage visitors[11]. Wright asks, "What is the advantage of museums resisting them when technology is inevitable in a museum?" Wright does stress, though, that technology should not be the focus of trials since it is changing so rapidly that museums are losing money and effort on gear that can quickly become outdated. The tales museums wish to communicate about their collections, the location, and their stories are the content that they must invest in while creating digital experiences[12]. Falco & Vassos showcase many technology relics that enhance the visitor's experience. For instance, there are

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[4] Pine Joseph and James H. Gilmore, "The Experience Economy," Boston: Harvard Business School 7 (1999): 46–51.

[5] Maria Meiha Wong and Mihaly Csikszentmihalyi, "Motivation and Academic Achievement: The Effects of Personality Traits and the Duality of Experience," Journal of Personality 59, no. 3 (September 1991): 539–74, https://doi.org/10.1111/j.1467-6494.1991.tb00259.x.

[6] Albert Boswijk, Thomas Thijssen, and Ed Peelen, "A New Perspective on the Experience Economy," Bilthovenm The Netherlands: The European Centre for the Experience Economy, 2006, https://www.researchgate.net/profile/Thomas-Thijssen/publication/237420015_A_New_Perspective_on_the_Experience_Economy_Meaningful_Experiences/links/55f16f5808aef559dc471672/A-New-Perspective-on-the-Experience-Economy-Meaningful-Experiences.pdf.

[7] Roy Want, "RFID," Scientific American 290, no. 1 (2004): 56–65.

[8] Stefania Boiano et al., "Chatbots and New Audience Opportunities for Museums and Heritage Organisations," in Electronic Visualisation and the Arts (BCS Learning & Development, 2018), https://www.scienceopen.com/hosted-document?doi=10.14236/ewic/EVA2018.33.

[9] Masahiro Shiomi et al., "Interactive Humanoid Robots for a Science Museum," in Proceedings of the 1st ACM SIGCHI/SIGART Conference on Human-Robot Interaction (HRI06: International Conference on Human Robot Interaction, Salt Lake City Utah USA: ACM, 2006), 305–12, https://doi.org/10.1145/1121241.1121293.

[10] Michelle Kelly Schultz, "A Case Study on the Appropriateness of Using Quick Response (QR) Codes in Libraries and Museums," Library & Information Science Research 35, no. 3 (2013): 207–15.

[11] Federica Dal Falco and Stavros Vassos, "Museum Experience Design: A Modern Storytelling Methodology," The Design Journal 20, no. sup1 (July 28, 2017): S3975–83, https://doi.org/10.1080/14606925.2017.1352900.

[12] Evan A. Wright, "Cultural Heritage Destruction in Middle Eastern Museums: Problems and Causes," 2018, https://digitalcommons.buffalostate.edu/museumstudies_theses/18/.

smartphone applications that combine wearable technology, sensor technologies, virtual reality (VR) or augmented reality (AR), and audio or video tutorials. These could use natural language processing, or NLP, technology in conjunction with speech or movement to initiate certain orders. Machine learning technologies have enhanced the museum visitation experience, surpassing the mere technical role of obtaining data for a subsequent examination of the establishment. According to the same authors, computer vision and machine learning have made it possible to access information at museums in a more organic and non-intrusive way[13]. In research, Vassos demonstrates how machine learning is used at the Mario Praz Museum in Rome, Italy, to foster conversations between visitors and artwork. The Messenger app was also utilized throughout the presentation. The goal of the conversational display was to get "digital natives" to pay attention. The analysis indicates that there aren't many conversational AI-based applications at museums that encourage visitors to participate in society[14].

Museums in industrialized nations are increasingly focusing on managing digitalized Cultural Heritage information[15], but many artefacts are off-limits due to exhibition space constraints, ongoing restoration projects, or the fragility of the artefact itself. As a result, there is increasing interest in using digital technologies to overcome the limits of traditional displays at museums, such as Web3D, Virtual Reality (VR), and Augmented Reality (AR). Google Art & Culture allows consumers to explore over a thousand museums in 70 countries with ease[16]. Previous digital exhibition apps have attempted to replicate an actual museum visit online, but they often involve unique experiences for each visitor, making them difficult to share. The "Mobile Digital Museum" project for the Inner Mongolia Museum aims to increase the shareability of these technologies[17]. The touchless paradigm has several benefits, including being non-intrusive, resilient, affordable, easy to use, and safe. The development of cultural guides to provide interactive help to visitors during their museum visit was the first attempt to incorporate technology into an exhibition at a museum[18]. Scientists worked hard to give cultural advisors context-aware tools, such as RFID tags[19] or IrDA beacons[20], to place next to each point of interest along the cultural route in the

[13] Federica Dal Falco and Stavros Vassos, "Museum Experience Design: A Modern Storytelling Methodology," The Design Journal 20, no. sup1 (July 28, 2017): S3975–83, https://doi.org/10.1080/14606925.2017.1352900.

[14] Valentina Vassallo, "Broken Collections: A 3D Approach to the Digital Reunification and Holistic Study of Dispersed Terracotta Figurines Assemblages," Breaking Images: Damage and Mutilation of Ancient Figurines, 2023, 290.

[15] Alexey Semenov, Information and Communication Technologies in Schools: A Handbook for Teachers (Unesco, 2005), https://www.academia.edu/download/34533864/ICT_in_schools-a_handbook_for_teachers.pdf.

[16] Sylaiou Styliani et al., "Virtual Museums, a Survey and Some Issues for Consideration," Journal of Cultural Heritage 10, no. 4 (2009): 520–28.

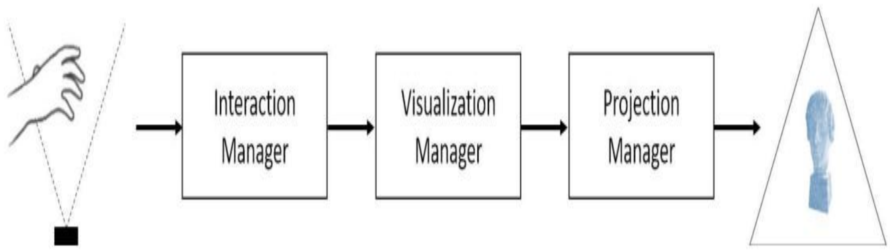
[17] Styliani et al.

[18] Angelo Chianese et al., "SmARTweet: A Location-Based Smart Application for Exhibits and Museums," in 2013 International Conference on Signal-Image Technology & Internet-Based Systems (IEEE, 2013), 408–15, https://ieeexplore.ieee.org/abstract/document/6727222/.

[19] Sherry Hsi and Holly Fait, "RFID Enhances Visitors' Museum Experience at the Exploratorium," Communications of the ACM 48, no. 9 (September 2005): 60–65, https://doi.org/10.1145/1081992.1082021.

[20] Margaret Fleck et al., "From Informing to Remembering: Ubiquitous Systems in Interactive Museums,"

exhibition. Volumetric displays, such as the Virtual Showcase[21], gained traction after 3D display technologies. However, visualization alone is insufficient to comprehend, acquire, and engage with cultural knowledge.



3D Hologram Pyramid for Museum Exhibition[22]

Researchers have started designing natural interfaces to dispel the notion that users are interacting with computers[23]. A touchless interface for manipulating a virtual heritage item is provided, along with a description of a novel natural interaction interface for VR settings based on body motions[24]. The proposed system is a multi-screen projection prototype in the shape of a pyramid, enabling simultaneous viewing of several projections from various angles, similar to a hologram. The proposed system is a non-invasive, non-invasive showcase designed to mimic a genuine cultural exposition. It features projection components in the shape of a three-sided pyramid, with the display area placed at the visitor's eye level to enhance the quality of the perceived visuals. A tracking sensor is positioned in front of the pyramid installation to allow users to interact with the virtual item[25].

IEEE Pervasive Computing 1, no. 2 (2002): 13–21.

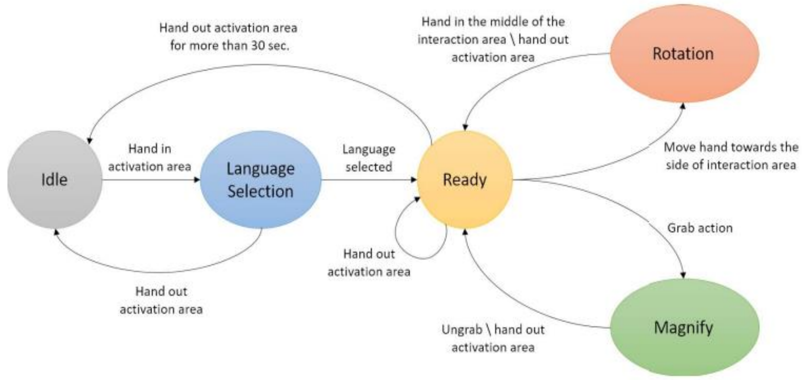
[21] Oliver Bimber et al., "The Virtual Showcase," in ACM SIGGRAPH 2006 Courses on - SIGGRAPH '06 (ACM SIGGRAPH 2006 Courses, Boston, Massachusetts: ACM Press, 2006), 9, https://doi.org/10.1145/1185657.1185804.

[22] Giuseppe Caggianese, Luigi Gallo, and Pietro Neroni, "Evaluation of Spatial Interaction Techniques for Virtual Heritage Applications: A Case Study of an Interactive Holographic Projection," Future Generation Computer Systems 81 (April 1, 2018): 516–27, https://doi.org/10.1016/j.future.2017.07.047.

[23] Thomas M. Alisi, Alberto Del Bimbo, and Alessandro Valli, "Natural Interfaces to Enhance Visitors' Experiences," IEEE MultiMedia 12, no. 3 (2005): 80–85.

[24] Giuseppe Caggianese, Luigi Gallo, and Giuseppe De Pietro, "Design and Preliminary Evaluation of a Touchless Interface for Manipulating Virtual Heritage Artefacts," in 2014 Tenth International Conference on Signal-Image Technology and Internet-Based Systems (IEEE, 2014), 493–500, https://ieeexplore.ieee.org/abstract/document/7081589/.

[25] Sebastian Boring, Marko Jurmu, and Andreas Butz, "Scroll, Tilt or Move It: Using Mobile Phones to Continuously Control Pointers on Large Public Displays," in Proceedings of the 21st Annual Conference of the Australian Computer-Human Interaction Special Interest Group: Design: Open 24/7 (OZCHI '09: Proceedings of the 21st conference of the computer-human interaction special interest group of Australia on Computer-human interaction: design, Melbourne Australia: ACM, 2009), 161–68, https://doi.org/10.1145/1738826.1738853.



The Finite State Machine Describing the State Transitions of the Interface[26]

The prototype sculpture displayed within the pyramid can be controlled by the visitor using a natural gesture-based user interface, thanks to the suggested technology. The system consists of many components that are arranged into a standalone application. The Interaction Manager, responsible for depth image processing, processes the final user's motions, while the Visualization Manager applies the impact of the user's action on the virtual representation of the artefact. The Projection Manager controls the virtual artefact's final projection, arranging it in various viewpoints and considering the reflecting qualities of the materials used to construct the pyramid sides to provide the intended holographic effect. The visualization pyramid is an integral component of the system's implementation, designed with a typical 40-inch high-contrast monitor as the picture source and the reflecting material positioned 45 degrees from the base of the pyramid.

Visitors are encouraged to interact with the cultural item using the touchless interface of the system, which allows them to rest their hand horizontally on top of the tracking sensor in the defined engagement area at a distance of 15 to 25 cm. The interaction area is crucial in the design of the touchless interface, as it records all hand motions needed to properly utilize the proposed interface and allows users to designate how they would want to interact with the object. The artwork's hologram is continually displayed to visitors, giving the impression that it is a typical exhibit holding an actual artefact. The technology detects a visitor's desire to engage and displays a virtual hand in the virtual artefact's identical virtual surroundings when the visitor raises their hand. The Language State is responsible for choosing the language that will be used to reproduce audio content associated with the projected artefact in the visitor's preferred language. When the object hologram is in this condition, the system displays an option menu made up of several language icons[27].

In the "ready state," the audio explanation is playing and the system is ready to take visitor input gestures. In a functioning part with a finite lifespan, the system records the language selected by the visitor. The

[26] Caggianese, Gallo, and Neroni, "Evaluation of Spatial Interaction Techniques for Virtual Heritage Applications."

[27] Nadia Brancati et al., "Touchless Target Selection Techniques for Wearable Augmented Reality Systems," in Intelligent Interactive Multimedia Systems and Services, ed. Ernesto Damiani et al., vol. 40, Smart Innovation, Systems and Technologies (Cham: Springer International Publishing, 2015), 1–9, https://doi.org/10.1007/978-3-319-19830-9_1.

system does not return to the idle state but keeps the session open if the visitor takes their hand out of the interaction area for a little amount of time. Two primary touchless motions are included to enable the user to interact with the virtual artefact: one allows the user to rotate the artefact by adjusting its orientation, and the other allows the user to operate a magnifying glass that enables them to zoom in on certain elements of the artefact. The proposed approach offers a fresh perspective on and means of engaging with a cultural artefact, enhancing visitors' enjoyment of cultural heritage materials.

The development of communication robots is rapidly emerging, intending to provide mental, communicational, and physical support to people in their daily environments. Robots have been applied to various fields, including closed and open environments, where they interact with a wide range of people[28]. A science museum guide robot is a promising application in this field, as it allows visitors to interact with the robots and experience advanced technologies. The implementation of humanoid robots in museums is an innovative approach that combines cutting-edge technology with cultural heritage preservation. Humanoid robots can enhance the visitor experience by providing personalized tours, interactive exhibits, and real-time information. Their ability to engage with visitors in multiple languages and adapt to individual preferences makes them an invaluable asset in making museums more accessible and enjoyable for a diverse audience[29].

One of the primary advantages of humanoid robots in museums is their capability to offer customized tours, offer detailed explanations and answer questions in real time. By leveraging artificial intelligence, they can tailor their presentations based on the visitor's interests and knowledge level, creating a more engaging and educational experience[30]. This personalized interaction can significantly enhance the visitor's understanding and appreciation of the exhibits, making the museum visit more memorable. Humanoid robots can also serve as interactive exhibit components themselves, incorporating sensors and advanced programming to interact with visitors dynamically, responding to touch, voice commands, and facial expressions[31]. This interactivity not only captivates visitors but also provides a hands-on learning experience that is both educational and entertaining. For example, a humanoid robot could demonstrate historical events or scientific principles, offering a tangible connection to the subject matter that static displays cannot achieve.
In addition to enhancing the visitor experience, humanoid robots can assist museum staff in various tasks, such as managing visitor flow, ensuring efficient visitor direction, ticketing, providing directions, and even cleaning. This information can be used to optimize exhibit layouts, enhance educational programs, and tailor marketing strategies to attract more visitors.

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[28] Norihiro Hagita, "Communication Robots in the Network Robot Framework," in 2006 9th International Conference on Control, Automation, Robotics and Vision (IEEE, 2006), 1–6, https://ieeexplore.ieee.org/abstract/document/4150293/.
[29] Shiomi et al., "Interactive Humanoid Robots for a Science Museum."
[30] Takayuki Kanda et al., "Analysis of People Trajectories with Ubiquitous Sensors in a Science Museum," in Proceedings 2007 IEEE International Conference on Robotics and Automation (IEEE, 2007), 4846–53, https://ieeexplore.ieee.org/abstract/document/4209844/.
[31] Eiichi Yoshida, "Robots That Look like Humans: A Brief Look into Humanoid Robotics," Metode Science Studies Journal 9 (2019): 143–51.

The implementation of humanoid robots aligns with the growing trend of digital transformation in cultural institutions, as museums seek to stay relevant in an increasingly digital world. This technological integration can attract tech-savvy visitors, particularly younger generations, who might otherwise be less inclined to visit museums. Humanoid robots can play a crucial role in accessibility, providing assistance for visitors with disabilities, offering sign language interpretation for deaf individuals[32], and providing mobility assistance. This personalized support can make museums more accessible and enjoyable for all visitors, fulfilling an important aspect of social responsibility.

Furthermore, the presence of humanoid robots in museums can stimulate interest in robotics and technology among visitors, particularly students. Museums can use these robots as educational tools to demonstrate principles of engineering, computer science, and artificial intelligence, inspiring the next generation of scientists and engineers and fostering a deeper interest in STEM fields. However, the success of humanoid robots in museums ultimately depends on their acceptance by visitors and staff. Effective communication and education about the benefits and capabilities of these robots are essential to ensure a positive reception. By addressing concerns and highlighting the enhancements that robots bring to the museum experience, administrators can foster a welcoming environment for this technological innovation. Through thoughtful implementation and ongoing evaluation, humanoid robots have the potential to revolutionize the way museums operate, offering enriched experiences that resonate with visitors of all ages and backgrounds.

V. AI in Excavation and Artefact Analysis

Archaeologists face a significant challenge in categorizing excavation fragments due to their historical and cultural relevance. Traditional methods often rely on manual sorting and expert analysis, but new technologies have made it possible to categorize these pieces more efficiently and precisely. Machine learning algorithms, such as convolutional neural networks (CNNs)[33], are used to recognize patterns and traits not immediately visible to the human eye, improving the accuracy of the results while expediting the categorization process. 3D modelling and scanning are another notable advancement, allowing researchers to conduct a more thorough analysis of fragments' morphology by building intricate three-dimensional models. This method sheds light on the methods used during fabrication and the intended use of the artefacts. The integration of 3D models with machine learning further improves categorization accuracy[34].

Spectroscopic methods have significantly improved fragment categorization, allowing for non-destructive analysis of fragments' chemical composition using techniques like Raman spectroscopy[35] and X-ray

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[32] Jennifer J. Gago, Juan G. Victores, and Carlos Balaguer, "Sign Language Representation by Teo Humanoid Robot: End-User Interest, Comprehension and Satisfaction," Electronics 8, no. 1 (2019): 57.

[33] Keiron O'Shea and Ryan Nash, "An Introduction to Convolutional Neural Networks" (arXiv, December 2, 2015), http://arxiv.org/abs/1511.08458.

[34] Maher AR Sadiq Al-Baghdadi, "3D Printing and 3D Scanning of Our Ancient History: Preservation and Protection of Our Cultural Heritage and Identity," International Journal of Energy and Environment 8, no. 5 (2017): 441–56.

[35] Bryan T. Bowie et al., "Anomalies and Artefacts in Raman Spectroscopy," Handbook of Vibrational Spectroscopy 3 (2002), https://www.s-a-s.org/assets/docs/0470027320_Anomalies_and_Artefacts_in_Raman_Spectroscopy.pdf.

fluorescence (XRF)[36]. Combining spectroscopic data with machine learning techniques allows for more sophisticated classifications based on chemical fingerprints. Geographic Information Systems (GIS) have transformed the spatial study of excavation sites, providing insight into the layout and utilization of ancient communities. Collaborative platforms and digital databases have also been introduced, allowing academics worldwide to compare and cross-reference pieces by combining data from several excavation locations.

Advanced search algorithms and metadata tagging have improved the categorization process, with deep learning and multidisciplinary cooperation enabling more reliable techniques. This collaboration between computer science, materials science, archaeology, and other disciplines can lead to comprehensive analyses of archaeological discoveries. Ethical issues are crucial in implementing these systems, and open dialogue with stakeholders and transparent processes foster confidence. Educational programs teaching future archaeologists how to use advanced techniques are essential for continuous progress.

Ceramic art has evolved significantly with the rapid development of digital technology, providing artists with new creative tools and forms of expression[37]. This has changed the ceramic manufacturing process and the way of displaying ceramic works. However, digital technology also brings challenges, such as the need for ceramic artists to balance traditional craftsmanship with digital technology. The integration of digital technology in the ceramic industry has led to the optimal use of ceramic materials, improved product performance, and improved production management. Artificial intelligence technology has contributed to the revitalization of China's ceramic industry economy and improved productivity levels[38]. Despite these challenges, artificial intelligence has made significant contributions to the ceramic industry, improving market competitiveness, enterprise efficiency, and the transition from traditional to modern transformation.

Researchers have developed various applications of AI technology in various industries, such as product optimization, production intelligence monitoring, and marketing. Experimental studies have shown that using digital image technology can improve the shear performance of ceramic composite z-pins[39], develop Si3N4-SiO2 composite ceramics[40], and enhance the safety factor of zirconia (ZrO2) ceramic dental

[36] Michael Mantler and Manfred Schreiner, "X-Ray Fluorescence Spectrometry in Art and Archaeology," X-Ray Spectrometry 29, no. 1 (January 2000): 3–17, https://doi.org/10.1002/(SICI)1097-4539(200001/02)29:1<3::AID-XRS398>3.0.CO;2-O.

[37] Kai Liu et al., "Influence of Particle Size on 3D-printed Piezoelectric Ceramics via Digital Light Processing with Furnace Sintering," International Journal of Applied Ceramic Technology, April 21, 2022, ijac.14074, https://doi.org/10.1111/ijac.14074.

[38] Ye Tian and Xiaobing Hu, "SWOT Analysis of China's Ceramic Industry and the Use of Computers for Scientific and Technological Innovation Research," ed. Punit Gupta, Scientific Programming 2021 (August 13, 2021): 1–9, https://doi.org/10.1155/2021/5395988.

[39] Guoqiang Yu et al., "Shear Failure Evolution and Its Dispersion of Plain Woven Ceramic Matrix Composites Z-pin Structure," International Journal of Applied Ceramic Technology 19, no. 6 (November 2022): 3288–99, https://doi.org/10.1111/ijac.14161.

[40] Rufei Chen et al., "Preparation of Broadband Transparent Si3N4-SiO2 Ceramics by Digital Light Processing (DLP) 3D Printing Technology," Journal of the European Ceramic Society 41, no. 11 (2021): 5495–5504.

implants. Additionally, AI technology has been used in ceramic additive manufacturing strategies to overcome shape-structure defects in ilmenite and strengthen printing properties. The intersection of digital technology and ceramic art is expected to continue to promote the development and upgrading of the ceramic industry. Cultural relics are cultural remains of a specific period with high historical heritage value and scientific value. Museums should protect, repair, and conduct scientific research on these relics to ensure their preservation and safety. The collection information database, primarily using digital technology, collects relevant data and information for all-around collection, storage, and management systems.

Various studies have been conducted to protect and restore cultural relics, such as designing intelligent detection systems for fabric artefacts, using customized cameras for stable and flexible monitoring, preserving genetic artefacts, and analyzing bronze paintings. Restoration of historical monuments has also been studied, with solutions proposed for surface coatings and preserving structural elements. Portable X-ray diffraction (XRD) and X-ray fluorescence (XRF) instruments have been used to analyze and make programmatic decisions about restoration programs[41].

VI. AI in Human Remains Analysis

Compared to other skeletal tissues, teeth and bones are more resilient than human remains, which are readily destroyed. Given that acid can destroy metals, DNA, and the entire body, it is frequently employed to thwart bodily identity. When it comes to identifying people, forensic dentistry has long been a dependable field. It does this by utilizing dental features like wear patterns, malocclusions, pathologies, hypodontia, morphology, size and shape variations, numbers of cusp, colour, and other unique dental anomalies. Modern post-mortem forensic exams frequently employ post-mortem-computed tomography (CBCT), and a CT scanner is an invaluable instrument. 2D dental forensic comparisons and identification are now possible because of protocols that have been devised to consistently and reproducibly reformat the CBCT volumes.

Unidentified compounds discovered at a crime scene are identified using forensic toxicology, a subset of forensic chemistry. Modern artificial intelligence algorithms have shown to be effective tools for handling digital data, giving forensic professionals access to never-before-seen analytical capabilities. Anatomical location, time of origin, and kind of diagnostic equipment are among the many digital data of varying quality that may be compared to post-mortem dental patterns. Artificial intelligence's (AI) capacity to mimic ageing through large-scale data-trained networks can aid in the timely adaptation of these records and their valuable integration into the final mosaic of the rebuilt tooth pattern. Deeper insights into social and historical settings that would be difficult or impossible to get through traditional approaches alone are now feasible because of AI tools, which have transformed the examination of human remains[42].

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[41] Auxiliadora Gómez-Morón et al., "Multi-Approach Study Applied to Restoration Monitoring of a 16th Century Wooden Paste Sculpture," Crystals 10, no. 8 (2020): 708.
[42] Andrej Thurzo et al., "Human Remains Identification Using Micro-CT, Chemometric and AI Methods in Forensic Experimental Reconstruction of Dental Patterns after Concentrated Sulphuric Acid Significant Impact," Molecules 27, no. 13 (2022): 4035.

In bioarchaeology, machine learning algorithms are applied to evaluate skeletal remains, which is one of the key uses of AI in the study of human remains. Artificial Intelligence (AI) enables more thorough population research by automating the study of massive information, exposing social structures and demographic patterns within prehistoric civilizations. Because AI-driven isotope analysis may disclose details about nutrition, geographic origins, and mobility, it is a great tool for studying historical diets and migration. Advances in AI have also improved facial reconstruction techniques, enabling researchers to accurately rebuild faces from skeletal remains of humans. Utilizing AI for the examination of human remains requires interdisciplinary cooperation, integrating knowledge from computer science, genetics, anthropology, archaeology, and other disciplines. When employing AI tools to examine human remains, ethical issues are crucial. Research must be performed honestly and ethically, while also preserving the cultural legacy and sensitivities of descendant populations.

- **Some case examples that highlight the accuracy and effectiveness of AI in anthropological studies;**

Foundation Ethnographic Research: The need for ethnography as a research methodology for artificial intelligence (AI) has grown in recent years. Academics with a variety of backgrounds have been urged to adopt qualitative approaches, especially ethnography, in place of quantitative approaches. However, for good study outputs on AI, ethnography must be grounded in certain methods of interacting with one's field site. The results of the study might be skewed in the absence of this foundation. Devoted fieldwork, trustworthy participant-researcher connections, and attention to nuanced, unclear, or absent-present data are important components.

Integrative Research Using Ethnography: The results generated by automated systems frequently include power imbalances and underlying reasons that quantitative approaches are unable to identify. The qualitative approach of ethnography provides insights into technology as a sociotechnical phenomenon. Ethnography may illuminate issues and offer a critical comprehension of AI's effects by examining AI holistically[43].

Multi-Case Research Methodology: Multi-case studies have been employed by researchers to examine the ethics of AI. They investigate real-world ethical concerns surrounding AI by classifying the available literature and carrying out focused case studies. The results from these case studies spanning a variety of disciplines must be analyzed using qualitative methods[44].

[43] Roanne van Voorst and Tanja Ahlin, "Key Points for an Ethnography of AI: An Approach towards Crucial Data," Humanities and Social Sciences Communications 11, no. 1 (2024): 1–5.
[44] Mark Ryan et al., "Research and Practice of AI Ethics: A Case Study Approach Juxtaposing Academic Discourse with Organisational Reality," Science and Engineering Ethics 27, no. 2 (April 2021): 16, https://doi.org/10.1007/s11948-021-00293-x.

VII. AI in Site Detection and Exploration

AI techniques are transforming difficult-to-find terrestrial archaeological sites and their study. The accuracy, effectiveness, and breadth of archaeological research are improved by these methods, which include artefact detection and classification, drone-based surveys, LIDAR, ground-penetrating radar (GPR), satellite imagery analysis, remote sensing, predictive modelling, multispectral and hyper-spectral imaging, and image enhancement and reconstruction. Artificial intelligence (AI) systems are capable of analyzing high-resolution satellite photos to detect minute details, such as soil imprints, plant patterns, and topographical irregularities; that are suggestive of historic sites. By using laser pulses to build precise 3D scans of the ground, LIDAR technology makes it possible to find man-made structures concealed behind overgrowth. The geophysical method known as GPR creates pictures below the surface by using radar waves, making it possible to identify buried structures.

AI techniques also make it possible to analyze time series data, which aids in the understanding of degradation processes like as erosion and looting by archaeologists.

In several disciplines, including archaeology, remote sensing—the use of sensors such as temperature, humidity, hyper-spectral, and satellite imagery to locate or monitor places of interest without direct observation—has been used. Drones or other aerial equipment are needed for LIDAR, a popular technology because of its high-resolution photographs. It's easy to find RGB photographs that are open-source using web resources like Bing or Google Maps. Deep learning has been applied in archaeology to categorize items and text, identify commonalities, create three-dimensional models, and locate sites. Throughout the 20th century, remote sensing technologies have been employed by archaeologists, including radar, aerial photography, multi-spectral imaging systems, and landscape-level analysis. The study of Near Eastern landscapes has been transformed by the CORONA satellite program, and Synthetic Aperture Radar (SAR) data with resolutions higher than 30 meters is readily accessible. Although there are still significant conceptual and methodological problems, geospatial technologies have shown promise in identifying and predicting the geographical distribution of archaeological sites[45].

Sensor technology has been used by the UK water sector to monitor drinking water distribution networks for operational management and network calibration. Accurate measurements of water temperature, turbidity, conductivity, color, pH, dissolved oxygen, and redox parameters are now possible because of advancements in water quality sensor technology[46]. One aspect of the field that receives little attention is computer-based online leakage identification and localization from sensor data. While effectively used in many different issue areas, artificial neural networks (ANNs) demand extensive prior understanding and proficiency with the ANN technique. Because of their habitat and depth, underwater archaeological sites—such as submerged villages, historic ports, and shipwrecks—are sometimes inaccessible to the

[45] Douglas C. Comer and Michael J. Harrower, Mapping Archaeological Landscapes from Space, vol. 5, SpringerBriefs in Archaeology (New York, NY: Springer New York, 2013), https://doi.org/10.1007/978-1-4614-6074-9.
[46] Stephen R. Mounce and John Machell, "Burst Detection Using Hydraulic Data from Water Distribution Systems with Artificial Neural Networks," Urban Water Journal 3, no. 1 (March 2006): 21–31, https://doi.org/10.1080/15730620600578538.

general public and specialists[47]. New developments in virtual reality (VR) provide a special chance for digital accessibility for academics and the general public.

IX. Discussion of Merits and Demerits

AI technology has significantly improved data processing in archaeology, allowing for more detailed analysis of large-scale datasets. However, it also raises concerns about over-reliance on technology, which can lead to a lack of critical thinking and value for complex interpretations. Additionally, AI algorithms may be influenced by the data they are trained on, leading to potential biases or errors in the analysis. Additionally, AI system maintenance and upgrades may require significant resources, making it challenging for projects with limited budgets. To balance AI integration with traditional archaeological knowledge, a multifaceted strategy is needed. AI should be used as an adjunct to human knowledge, allowing archaeologists to focus on data analysis and drawing well-informed conclusions. Regular training and seminars can keep professionals updated on AI developments, fostering a collaborative environment where technology complements traditional methods.

X. Conclusion

Artificial intelligence (AI) has been incorporated into archaeology, with the result that investigations of archaeological sites are now more thorough and efficient due to the major improvements in data processing speed, accuracy, and analysis of massive datasets. The necessity for a balance between technology and conventional knowledge is highlighted by issues like possible over-reliance, misunderstanding hazards, and the requirement for ongoing maintenance. Archaeologists should use stringent validation procedures, work with interdisciplinary teams that are cooperative, and employ AI as a supplemental tool to address these issues. To guarantee AI improves conventional approaches, future integration should include continuous training, strong cross-verification mechanisms, and continued tool enhancement.

[47] Fotis Liarokapis et al., "3D Modelling and Mapping for Virtual Exploration of Underwater Archaeology Assets," The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 42 (2017): 425–31.