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Research on Innovative Applications of AI Technology in the Field of Cultural Heritage Conservation

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Abstract: *Artificial Intelligence (AI) is developing rapidly, and many countries are actively using AI to protect, inherit, and innovate cultural heritage. This study aims to explore the application of AI in the field of cultural heritage. Keeping up with AI's development trends can enhance the utilization of this new tool and model for the sustainable development of cultural heritage. This research employs qualitative research methods including case studies and content analysis. The cases are drawn from news reports by world-renowned news websites such as BBC, CNN, The New York Times, and The Guardian, as well as from the world's largest video website, YouTube. Content analysis is based on the textual interpretation of the collected cases. The combination of these methods allows the study to comprehensively understand the innovative development of AI in the field of cultural heritage from both macro and micro perspectives. AI can enhance cultural interaction and visual effects, deepen research and analysis processes, expand the depth of artistic creation, and protect and restore cultural heritage. Although there are still some challenges in the application of AI in this field, its unique advantages have already become apparent.*

Keywords: *Artificial Intelligence; Cultural Heritage; Cultural Innovation*

1. Introduction

Artificial Intelligence (AI) has already made profound impacts across various industries and fields globally, such as financial services [1], business management [2], marketing [3], healthcare [4], academic research [5], ecological and environmental protection [6], and cultural heritage preservation [7]. A vast amount of research has confirmed [8][9][10] that these impacts are significant, lasting, and inevitable. ChatGPT, by highlighting its multidimensional influences and potential, has injected transformative power into shaping future AI trends[11]. Under the guidance of ChatGPT, a plethora of innovative AI applications have emerged, presenting a thriving scene in the AI industry. In the field of innovative development in cultural heritage, many developed countries have already started actively using AI technology. This not only showcases the powerful technical capabilities of AI but also reflects its profound influence as an innovative way of thinking. Facing the unstoppable surge of AI, this undoubtedly brings significant opportunities for the innovative development of cultural heritage. Therefore, this study holds the following significance: (1) The application of AI promotes the popularization of innovative ways of thinking, fostering the integration and co-development of technology and cultural fields. (2) Utilizing AI technology to strengthen the transmission of cultural diversity, enhancing the accessibility and popularity of global cultures. (3) The innovative applications of AI compel policymakers to redesign cultural heritage protection policies to adapt to technological advancements. (4) The combination of AI and cultural heritage protection offers new perspectives for interdisciplinary research, promoting the deep integration of science and humanities.

2. Review of the Literature

Current research findings are primarily concentrated in the field of computer science. Some studies have noted that "pattern recognition" in cultural heritage is growing rapidly, especially in image analysis, classification, and restoration [12]. Researchers have developed an AI collaborative assessment system named CollabLearn, designed to accurately evaluate the damage to cultural heritage in natural or man-

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made disasters [13]. Additionally, a system called CrowdHeritage has been built by researchers, which utilizes crowdsourcing and AI technology to encourage participation from various groups in the preservation and transmission of cultural heritage, aiming to improve the quality of cultural heritage metadata [14].

In terms of specific applications, research has developed the AISAS model based on attention, interest, search, action, and share. It has been found that cultural creative products generated by AI technology effectively promote the sustainability of intangible cultural heritage [15]. Researchers have also explored the connection between sports cultural heritage and three-dimensional reconstruction technologies [16], which help enhance understanding of history. Additionally, researchers have proposed that smart positioning and radio frequency technology can be used for real-time monitoring of tangible cultural heritage, considering factors like weather and lifespan.

Additionally, there are discussions involving ethics. One study examined the characteristics of "digital ontology" [18], suggesting that the social groups' perception of AI is a crucial factor influencing the digitalization, dissemination, and popularization of cultural heritage. It emphasizes that the digitalization of cultural heritage should be people-centered. Another study argues that cultural heritage created by AI should be integrated into the existing cultural heritage management systems [19].

Generally, most research findings suggest that AI technology is beneficial for the innovative development of cultural heritage. For instance, constructing an accessible cultural heritage experience using AI represents a new direction [20]870; it can enhance the semantic content of cultural heritage images [21] and deepen the understanding of scenes within cultural heritage [22]. One study also proposed a method to revitalize intangible cultural heritage by integrating cutting-edge technologies such as 5G, 8K, AI, and VR [23]. However, there are controversies surrounding this technology. For example, cultural heritage museums that introduce AI are inevitably faced with issues of openness and privacy [24]; AI restoration of cultural heritage paintings might trigger copyright issues [25].

Based on existing research findings, it is evident that the literature specifically focusing on the application of AI in the field of cultural heritage is relatively weak, involves a narrow range of disciplines, includes few practical examples, and lacks sufficient ethical discussion. This indicates that there is still considerable room for research in this area. Consequently, this study focuses on case analyses of AI applications in innovative practices of cultural heritage, combining these with theoretical research to provide a more solid theoretical foundation.

3. Research Case and Methodology

3.1 Research Design

This study employs qualitative research methods, specifically case analysis and content analysis. Case analysis aids in understanding the complex concepts of AI interactions with cultural heritage, grasping the applications, effects, and limitations of AI in this field, and revealing innovative practices of AI in showcasing cultural heritage abroad. The cases for this study are sourced from prominent global news websites such as BBC, CNN, The New York Times, and The Guardian, as well as from the world's largest video site, YouTube. These news websites are chosen as sources because their international reach and professionalism make them ideal for obtaining accurate, comprehensive, and authoritative information, reflecting the trends in AI and cultural heritage development. YouTube is selected for its visual representations of AI interacting with cultural heritage in real-world applications. Content analysis helps systematically describe the characteristics of the collected textual materials, categorizing and summarizing them to identify current trends, patterns, and expert opinions in AI applications. The content analysis in this study is derived from textual interpretation of the collected cases. The combination of these methods allows the research to comprehensively understand the innovative developments of AI in cultural heritage from both macro and micro perspectives internationally.

Credibility Verification. First, saturation sampling. Researchers continue their searches until no new or significant information is obtained, enhancing the completeness of the results. Second, reliability testing. Different researchers within the research team conduct the same search method twice, comparing the results of both searches to verify the consistency and stability of the data. Third, providing data sources to increase credibility.

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3.2 Data Collecting

First, researchers search on Google News. The exact phrase used is "AI cultural heritage". Websites inputted are "BBC.com" (BBC), "CNN.com" (CNN), "nytimes.com" (The New York Times), and "theguardian.com" (The Guardian). The date range selected is "Past year," spanning from January 12, 2013, to January 12, 2014. In this step, a total of 110 news reports were initially retrieved. Second, researchers manually eliminate erroneous news reports, reports completely unrelated to the study topic, and those with low relevance to the research theme, ultimately retaining 9 cases suitable for the study. Third, researchers conduct searches on YouTube, entering "AI cultural heritage" in the search bar. The upload date is set to "this year," covering the same period from January 12, 2013, to January 12, 2014. The duration filter is set to either "More than 20 minutes" or "4-20 minutes," and sorting is based on the "Degree of relevance." Fourth, a total of 16 videos are retrieved, from which researchers manually remove any erroneous videos, resulting in 12 videos suitable for the study. Fifth, a total of 21 study cases are gathered. Researchers then proceed to summarize and abstract the content of both the news reports and the videos.

3.3 Statistical Results (see Table 1)

Table 1: Statistical Results

Case Source: Renowned Global News Websites	News Websites	News Headlines	News Content
	BBC	Case 1: The World's Next-Generation Digital Playground	"teamLab Borderless," Japan's first digital art museum, showcases a rich array of intangible cultural heritage. Among its exhibits, "Bubble Universe" consists of 3D lights in various colors and shapes, demonstrating the allure of digital art. Researchers at the museum are dedicated to exploring how digital art can shape the world, delving deeply into the concept of a "borderless world" and themes such as art, space, nature, and identity. These works not only display the limitless possibilities of art but also offer new insights into the self and the world.
		Case 2: How a 1574 Portrait was Made 'Insta-fabulous'	Although one might assume that changes in modern beauty standards are driven by technology, especially the latest AI techniques, the practice of beautifying and modifying human images has a long history. For instance, when British heritage conservators recently cleaned a portrait of a great-granddaughter of Lord William Cecil Burghley, one of Queen Elizabeth I's closest confidants, they used an AI "beauty filter" to enhance it. As a result, the authentic lines on the portrait were completely erased. This indicates that, both historically and currently, people have been altering and beautifying images in various ways.
		Case 3: The Spectacular World of 'Data Sculpture'	Digital artist Refik Anadol innovatively integrates AI technology into the creation of data sculptures, a unique art form that visualizes data, allowing us to understand and interpret complex datasets more profoundly. This approach offers a novel way to comprehend data.
		Case 4: Bosnia and Herzegovina's Mysterious 'Stećci' Stones	The mysterious "stećci" stones of Bosnia and Herzegovina are a distinctive type of tombstone, numbering over 60,000, scattered across the countryside. They provide a unique perspective on medieval life in the region. Currently, cultural heritage researchers are utilizing AI technology to analyze data in order to uncover the collective meanings of these enigmatic stones.
		Case 5: The Apps Making Indian Monuments More Accessible	"Wnder," developed by Immersive Trails, is an audio application that allows users to explore ancient sites and regions in West Bengal, enhancing their understanding of the country's history. Another app, "Augtraveler," offers virtual multimedia tours of India's World Heritage sites, including audio narrations, 360-degree images, augmented reality models, and on-screen text. The "HopOn India" app provides 116 tours covering 14 cities. This app is designed for on-the-ground walking tours, allowing users to move through a map on their screen, guided by GPS tracking that prompts them to pause or continue at specific points. Additionally, the app offers virtual tours where audio narratives are accompanied by pop-up images of the locations, providing a rich, immersive user experience.
	CNN	Case 6: The Future of Travel: 10 Concepts That Will Change the Way We Experience the World	Specterras Productions is leveraging technology to make the world's natural and cultural wonders more accessible. They utilize AR technology in museums to create dynamic busts, giving people the opportunity to interact up close with sculptures of figures like Alexander the Great or Herodotus through their smartphones. This interaction is akin to a real-life version of "Night at the Museum." Additionally, experimental artist KAWS has been showcasing his "Expanded Holiday" project since 2020, featuring massive AR sculptures in 12 cities worldwide, offering the public a novel way to experience art.
		Case 7: 'Westernization is not the answer': Artist Àsìkò Explores Yoruba Culture Through Mythology	Artist Àsìkò has created a connection between regional Yoruba mythology and global myths by combining Yoruba mythological portraits and images with AI and digital editing technologies. This fusion of traditional photography with AI opens up new realms of imagination, showcasing the limitless possibilities of art and technology.
	The New York Times	Case 8：Will A.I. Replace Pop Stars?	A song generated by AI that mimicked the voices of Drake and The Weeknd garnered widespread attention on social media. However, it was quickly removed from major streaming services by Universal Music Group (UMG) due to "copyright

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			infringement." Experts note that with the rapid development and improvement of generative AI in fields such as text, images, sound, and video, this technology has the potential to reshape cultural heritage projects on various levels. As a result, artists must adapt to new norms to address these changes.
	The Guardian	Case 9：The most exciting US art exhibitions of 2024	Harold Cohen is a pioneer in computer art, algorithmic art, and generative art, and his masterpiece, AARON, is an AI software specifically designed for artistic creation. The Whitney Museum held an exhibition titled "AARON," which focused on this theme, showcasing artworks created with the assistance of AARON and deeply analyzing the software's mechanisms of operation in cultural heritage.
Case Source: YouTube	Publisher Name	Video Title	Video Content
	Ethics at Work	Case 10：AI for Cultural Heritage	In the field of digital paleography, AI plays a crucial role in quickly and efficiently transcribing manuscripts. A prime example is the research work conducted at the AI Lab of the University of Notre Dame, where they have developed an algorithm that advances the preservation of cultural heritage. This project is an interdisciplinary collaboration that combines visual psychophysics from psychology with artificial neural networks from computer science to enhance the accuracy of AI transcription. The process involves cooperation with medieval Latin manuscripts from Switzerland and Geez manuscripts from Ethiopia, requiring collaboration with language experts. The AI-driven approach significantly accelerates the availability of extensive manuscript collections to scholars and also allows the public access to historical texts they might not be familiar with, thereby fostering a broader understanding and appreciation of our past. Furthermore, the project plans to expand its research scope to other cultural artifacts and writing styles, including Hebrew amulets, Arabic inscriptions on pottery, and classical Chinese calligraphy, undoubtedly broadening the possibilities for historical and cultural exploration using AI.
	Balboa Park Online Collaborative	Case 11：Dreaming of AI: Perspectives on AI Use in Cultural Heritage	AI plays a significant role in the digital processing of collections in museums, libraries, and archives, performing image recognition and content description. By analyzing big data through AI, researchers can gain new insights and deeper understanding of the historical and cultural contexts of the collections. In museums and exhibitions, the use of AI technologies like virtual reality (VR) and augmented reality (AR) can enhance visitor experiences. AI is also employed in monitoring and protecting cultural heritage, for example, by analyzing environmental data to predict and prevent potential damage. Additionally, AI can create content related to cultural heritage, such as automatically generating descriptions for exhibitions or educational materials.
	European Parliamentary Research Service	Case 12：Artificial intelligence in the context of cultural heritage and museums [Policy podcast]	AI technology has demonstrated its potential in completing unfinished works, such as successfully completing Beethoven's unfinished Tenth Symphony. In the realm of reconstruction and restoration, AI has assisted in reconstructing missing parts of Rembrandt's famous painting "The Night Watch" and performed detailed 3D digital modeling of Notre Dame Cathedral after it was damaged by fire. AI's application in museum exhibitions and visitor experiences, such as enhancing the digitization and interactivity of collections, has significantly improved both the exhibits and the experience. Additionally, AI has played a role in combating the illegal trade of cultural artifacts, for example, in customs screening processes. Finally, AI technology has made cultural heritage more accessible to people with disabilities, further promoting accessible visits.
	PyData	Case 13：Robert Erdmann - Keynote - Python for Imaging and Artificial Intelligence in Cultural Heritage	AI technology plays a crucial role in high-precision image capture and stitching, exemplified by the automated robots and high-resolution cameras used to precisely capture Rembrandt's "The Night Watch," with AI performing accurate image stitching. AI is also used in canvas texture analysis to determine whether different paintings originate from the same roll of canvas, thus aiding in the authentication and categorization of artworks. In 3D modeling and reconstruction, AI can recreate 3D models of objects from photos taken from multiple angles, such as artifacts excavated from Dutch shipwrecks. AI also performs color correction and lighting simulation to provide a visual experience closer to the original artwork. Additionally, AI tools like CLIP are used to explore semantic associations between images and text, providing richer contextual information for artworks.
	Ahmed Bouzid	Case 14：Season 3, Episode 17: On Generative AI & Intangible Cultural Heritage - A Conversation with Sun Park	AI technology plays a significant role in collecting and analyzing specific cultural heritage data, including historical records, images, and community interviews. Utilizing generative AI, we can transform text data into visual data, for example, converting text descriptions of traditional ceremonies into visual images or videos. By creating virtual reality games or experiences, users can immersively experience different cultures' traditional ceremonies or activities, such as tug-of-war games and rituals. Furthermore, AI-generated tools and content, such as games or interactive experiences, increase the interest of younger generations in traditional cultural heritage, thereby promoting the sustainability of cultural heritage.
	LatinX in AI	Case 15：AI for the Preservation of Cultural Heritage: Classifier-Guided Diffusion for Art Restoration	AI technology plays a crucial role in the restoration and reconstruction of damaged artworks, such as its use in the restoration of the murals in the Spanish town of Ecija. This technology can generate multiple possible reconstruction scenarios and help in selecting the best option. Once trained, AI models can act as art critics, assessing whether the reconstructed artwork aligns with the original style and era. Additionally, AI is used to restore unfinished artworks, like those by Paul Cézanne. Diffusion models are employed to generate content that harmonizes with the artist's style, era, and the artwork itself. These models, known for their expressiveness and diversity, are particularly suitable for reconstructing artworks.
	Computer Arts Society	Case 16：P12: The Dance of the Doppelgängers - AI and	ChatGPT can simulate specific individuals' writing styles to generate content, but this may produce inaccurate or false information. AI tools like Mid-Journey can create artworks, such as a series of animal paintings in the style of Rembrandt, but

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		the Cultural Heritage Community	this also raises issues regarding copyright, originality, and artists' rights. AI technology can be used to reconstruct or repair damaged artworks, but this also introduces concerns about the authenticity and accuracy of the AI-generated results. This video primarily discusses the applications of AI in the field of cultural heritage and the issues it raises, including copyright, authenticity, ownership, biases, and the illusions created by AI-generated content.
	Diriyah Biennale Foundation	Case 17：Digital Technology, AI and our Islamic Cultural Heritage	AI is applied in the field of Arabic calligraphy to understand and generate complex calligraphic styles and explore new artistic forms and expressions. This technology allows for the analysis of traditional scripts and the creation of innovative designs that maintain the essence of Arabic calligraphic art while incorporating modern artistic influences.
	Unfold Artifitial Intelligence	Case 18：AI: The Guardian of Cultural Heritage	AI plays a crucial role in the preservation and revitalization of endangered languages by recording and analyzing these languages to support their conservation efforts. In the field of cultural heritage, AI acts as a guardian, using technologies like drones to monitor and protect historical sites. Additionally, in the preservation of art and music, AI is used to restore damaged audio recordings and can mimic the styles of famous artists, offering new possibilities for the protection and transmission of artistic works. These applications not only demonstrate the versatility and flexibility of AI technology but also highlight its significant value in maintaining and enriching human cultural heritage.
	Tech Orbit	Case 19：How Technology Advancement is Protecting Art: Preserving Our Cultural Heritage	Digital preservation leverages high-resolution digital scanning and photography to create precise digital images of artworks. These images not only facilitate digital storage and access but also enable the production of exact replicas or facsimiles. 3D printing technology plays a crucial role in replicating fragile or endangered artworks, allowing experts to conduct detailed studies and analyses without risking damage to the original pieces. Additionally, Internet of Things (IoT) technology is vital for monitoring museum environments and the storage conditions of artworks. It provides real-time data on critical environmental conditions such as temperature, humidity, and lighting, which are essential for ensuring the long-term preservation of artworks.
	The Thinking Circuit	Case 20：AI: Cultural Savior or Homogenizer?	In the preservation of endangered languages, AI effectively records and analyzes languages like the Ainu language of Japan through advanced speech recognition and machine learning algorithms. This technology allows for the accurate documentation of languages that may have limited numbers of speakers and are at risk of disappearing, providing a crucial tool for linguistic preservation and revitalization.
	Save Cultural Heritage Group	Case 21：Iranian Cultural Heritage and AI | Niloofar Yazdkhasti | Session 01 | Ancient Paths & Modern Tracks	AI technology plays a significant role in bridging history and the modern world. It identifies connections between artworks and cultural heritage by recognizing colors, patterns, and expressions of emotion, thus creating a link between ancient art and contemporary people.

3.4 Data Analysis

3.4.1 The Primary Application Areas of AI in the Field of Cultural Heritage

Digital Presentation and Interaction. The following cases demonstrate the diverse applications of AI in the field of digital presentation and interaction. Through innovative technologies, they enhance the interactivity and visual effects of cultural experiences, deepening the public's understanding and interest in cultural heritage.

The Boundless Exploration of Digital Art (Case 1): Japan's "teamLab Borderless" digital art museum showcases how AI can create captivating exhibitions of intangible cultural heritage with its "Universe of Water Particles" exhibit, combining 3D lighting and digital technology.

Visual Art Transformation of Data (Case 3): Digital artist Refik Anadol transforms complex datasets into visual art pieces, demonstrating AI's innovative application in data visualization. This method not only offers audiences a new perspective on understanding data but also enhances its appeal.

Enhancing Heritage Experience with Digital Technology (Case 5): Applications developed by Immersive Trails, such as "Wnder," "Augtraveler," and "HopOn India," combine AI and augmented reality (AR) to provide interactive and immersive cultural heritage exploration experiences, including audio guides, 360-degree images, AR models, and on-screen text.

Digital Interactive Experiences (Case 6): Specterras Productions utilizes AR technology to create dynamic busts in museums, such as those of Alexander the Great or Herodotus, offering audiences novel and educational interactions with historical figures.

Digital Fusion of Tradition and Modernity (Case 7): Artist Àsìkò combines Yoruba mythology with AI technology, illustrating the connections between regional and global myths. This work explores the similarities between myths and demonstrates the fusion of traditional culture with modern digital technology.

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Artistic Integration of Digital Technology (Case 9): The Whitney Museum's "AARON" exhibition showcases art created with the assistance of the AARON software, providing an in-depth analysis of the software's operational mechanism in cultural heritage.

3.4.2 Historical and Cultural Research and Analysis

The following cases illustrate AI's role in historical and cultural heritage research, demonstrating how its efficient data processing and analysis capabilities allow the public to gain a deeper understanding of the historical context of cultural heritage. These AI applications not only provide new tools and methods but also greatly enrich the public's appreciation and knowledge of historical heritage.

Unveiling the Mysteries of Historical Sites (Case 4): AI has played a crucial role in analyzing the "stećci" tombstones in Bosnia and Herzegovina. By helping researchers decode the meanings of these ancient gravestones, AI provides a unique perspective on medieval life in the region.

Transcription and Interpretation of Ancient Texts (Case 10): In the field of digital paleography, AI has become a powerful tool. Projects from the University of Notre Dame's AI lab showcase how AI efficiently and accurately transcribes and interprets ancient manuscripts, such as medieval Latin texts and Ethiopian Ge'ez manuscripts. This not only accelerates the accessibility of these documents but also offers new ways for the public to understand and appreciate these historical texts.

Connecting History and Modernity (Case 21): AI technology establishes connections between cultural works and heritage by analyzing elements such as color, patterns, and emotional expression. This builds a bridge between ancient art and modern audiences, allowing for a deeper appreciation of historical artifacts.

3.4.3 Art Creation and Expression

The following cases demonstrate how AI drives innovation across various art fields, including music, visual arts, traditional crafts, and modern digital technology. AI not only provides artists with new tools and sources of inspiration but also challenges traditional understandings of art and creativity.

Modern Reshaping of Historical Portraits (Case 2): While cleaning a portrait of one of Queen Elizabeth I's closest friends, William Cecil, the British heritage conservationists used an AI "beauty filter" to enhance the image. This resulted in the portrait's authentic lines being completely erased.

AI Music Creation (Case 8): AI has been used to mimic the music of famous artists like Drake and The Weeknd, sparking discussions about copyright and originality. This case highlights AI's application in music creation and the new copyright challenges it introduces.

Generative AI and Intangible Cultural Heritage Display (Cases 14 and 11): Generative AI can transform textual descriptions of traditional rituals into visual images or videos, and create exhibition descriptions or educational materials related to cultural heritage. This application offers new forms of expression for traditional cultural heritage, fostering interest and understanding among younger generations.

AI Exploring New Art Forms (Case 17): AI's application in Arabic calligraphy involves understanding and generating complex calligraphic styles, showcasing AI's potential in exploring and creating new art forms.

3.4.4 Cultural Heritage Preservation and Restoration

AI technology finds extensive applications in the preservation and restoration of cultural heritage. From completing historic works to restoring damaged artifacts, protecting endangered languages, and utilizing 3D printing to replicate artworks, AI not only improves the efficiency of restoration and preservation but also offers new ways to pass on and popularize cultural heritage.

Generation and Preservation of Artistic Content (Case 16): AI showcases its capabilities in mimicking specific artistic styles, such as creating animal paintings in the style of Rembrandt, and reconstructing or restoring damaged artworks. This application has sparked discussions on the authenticity and accuracy of AI-generated results.

Protection of Endangered Languages and Cultural Heritage (Cases 18 and 20): AI plays a crucial role in recording and analyzing endangered languages, such as Japan's Inu language. This supports the preservation of these cultural heritages and enhances their understanding and accessibility. Additionally, IoT technology is essential in monitoring critical conditions in museums and art storage environments, such as temperature, humidity, and light, ensuring the long-term preservation of artworks.

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Digital Preservation and 3D Printing Technology (Case 19): Using high-resolution digital scanning and photography, AI creates precise digital images of artworks for preservation and access. These images can also be used to produce accurate replicas or facsimiles. 3D printing technology is vital in replicating fragile or endangered artworks, enabling research and analysis without harming the originals.

Digital Reconstruction of Cultural Heritage (Case 12): AI plays a significant role in completing Beethoven's unfinished 10th Symphony, reconstructing the missing parts of "The Night Watch," and digitally restoring Notre Dame Cathedral after the fire. AI is also used to combat illegal trading of cultural artifacts and enhance accessibility for people with disabilities to cultural heritage.

Restoration of Artworks (Case 15): AI technology has shown its value in efficiently and innovatively restoring damaged artworks, such as the Ecce Homo fresco in Spain. AI diffusion models can generate content consistent with the artist's style, creation period, and the artwork itself, making them ideal for reconstructing artworks due to their expressiveness and diversity.

Precise Analysis and Authentication of Artworks (Case 13): AI plays a critical role in the precise analysis and authentication of artworks. For example, automated robots and high-resolution cameras were used to capture and analyze Rembrandt's "The Night Watch," with AI performing precise image stitching. AI can also correct colors and simulate lighting to provide a visual experience closer to the original. Additionally, AI analyzes canvas textures to determine if different paintings came from the same roll of canvas, aiding in the authentication and classification of artworks. AI tools like CLIP explore semantic relationships between images and texts, providing richer background information for artworks.

4. Discussion

Advantages of AI in the field of cultural heritage. Enhancing Cultural Interaction and Visual Effects. In the field of digital presentation and interaction, AI has significantly enhanced the interactivity and visual effects of cultural experiences[26]. This not only deepens the public's understanding and interest in cultural heritage but also drives the development of a series of innovative applications. These applications include boundless exploration of digital art, which breaks the boundaries of traditional art, allowing viewers to freely explore and experience art in a virtual space. The visual art transformation of data converts abstract data into intuitive visual images, enabling people to understand and perceive data more directly. The enhanced heritage experience through digital technology uses virtual reality (VR) and augmented reality (AR) to allow people to immerse themselves in historical sites and cultural attractions. Digital interactive experiences enable viewers to directly participate in and influence the creation and display of art through interactive devices and applications. Additionally, the combination of traditional cultural elements and modern digital technology creates entirely new forms of art and experience. In summary, AI not only enhances the presentation of traditional cultural content but also opens new possibilities for the innovative development of cultural heritage through the effective integration of new technologies. This innovative combination not only stimulates public interest but also provides broader perspectives and platforms for the preservation and dissemination of cultural heritage.

Deepening research and analysis processes.AI's application in historical and cultural research and analysis has demonstrated its unique advantages[27]. Firstly, through its efficient data processing and in-depth analysis capabilities, AI can reveal the deeper meanings of historical sites, providing new dimensions to our understanding of past cultures. This deep analysis not only uncovers the mysteries of historical sites but also enriches our ways of understanding and appreciating them. Secondly, in the field of digital paleography, AI has become an essential tool for researchers and offers innovative ways for the public to understand and appreciate ancient manuscripts. Additionally, AI has established new bridges between cultural artworks and heritage, providing platforms for the exchange between modern and ancient art, further enriching our multi-dimensional understanding of art. In summary, these applications of AI not only introduce innovative tools and methods but also greatly expand the public's understanding and appreciation of historical cultural heritage. These significant advantages make AI a crucial tool in the field of historical and cultural research and analysis, highlighting its special contributions to the domain.

Expanding the depth of artistic creation。The advantages of AI in artistic creation and expression are primarily manifested in several key areas. Firstly, AI has driven innovation across various artistic fields, including music, visual arts, traditional crafts, and modern digital technologies[28]. This innovation is evident not only in the diversity of artistic forms but also in the depth and breadth of the artistic creation process. Secondly, AI provides artists with new creative tools and sources of inspiration, challenging and redefining the concepts of traditional art and creativity. This not only changes the ways in which art is

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created but also expands the boundaries and possibilities of art. Furthermore, AI uses generative technologies to convert traditional ritual text descriptions into visual images or videos, giving traditional cultural heritage new forms of expression and sparking interest and understanding among the younger generations. This transformation not only enhances the means of presenting cultural heritage but also ensures the transmission of traditional culture in a more intuitive and vivid manner. Lastly, in the exploration and creation of new artistic forms, AI demonstrates its significant potential in understanding and generating complex artistic styles. This not only proves AI's powerful learning and mimicking capabilities but also showcases its substantial potential in artistic innovation and development.

New tools for cultural heritage conservation and restoration. The application of AI in the field of cultural heritage conservation and restoration has not only significantly enhanced work efficiency but also opened new pathways for the inheritance and protection of cultural heritage. The advantages of AI are particularly prominent in the following areas: First, AI can learn and mimic specific artistic styles, providing diversity in artistic creation and aiding in the modern revival of traditional art forms. Second, by recording and analyzing endangered languages, AI offers strong data support for the protection and revival of these precious languages. Third, AI utilizes high-resolution digital scanning and photography technologies to create precise digital images of artworks, which not only facilitates the preservation and dissemination of these artworks but also provides valuable resources for academic research. Fourth, through 3D printing technology, AI can accurately replicate fragile or endangered artworks, protecting them from the ravages of time and environmental factors. Lastly, AI plays a key role in the precise analysis and identification of artworks, significantly improving the accuracy and efficiency of these processes. Overall, the extensive application of AI in the field of cultural heritage conservation and restoration not only highlights its vast potential but also indicates that AI will play an increasingly important role in future cultural heritage conservation efforts[29].

The limitations of AI in the field of cultural heritage. Originality and Copyright Disputes. The application of AI in the field of artistic creation has sparked in-depth discussions about originality and copyright. For example, AI-generated songs imitating the styles of famous artists like Drake and The Weeknd not only initiate debates about the originality of music composition but also highlight the challenges of balancing AI-created content with existing copyright laws. Additionally, AI-generated artworks with specific artistic styles, such as animal paintings created in the style of Rembrandt, have also led to disputes over the originality of artworks and the rights of artists. These cases illustrate the complexity of determining originality and ownership in AI-assisted or fully generated artistic works. Such disputes reflect the challenges of AI applications in the arts, emphasizing the importance of finding a balance between AI innovation and intellectual property frameworks, and prompting a reevaluation of the essence and ownership of artistic creation.

Technical accuracy and reliability.While AI's application in cultural heritage and artistic creation brings innovation, it also reveals some limitations. For example, AI's role in the digital reconstruction of cultural heritage and image capturing of artworks may fail to fully capture or reproduce subtle historical and artistic details, which could affect the authenticity and historical accuracy of the results. In art restoration projects, AI may lack a deep understanding of the original materials and techniques, leading to restorations that do not fully return artworks to their original states or reflect the artists' creative intentions. Moreover, although AI can mimic certain artistic styles or techniques, it may lack the creativity and emotional depth of human artists, which somewhat limits the expressiveness and impact of AI-generated works. Therefore, despite providing valuable tools and methods in these areas, AI still faces challenges in maintaining the authenticity, accuracy, and deep expressiveness of art and cultural heritage.

5. Implications and Conclusion

By analyzing AI applications in the field of cultural heritage, this study has identified the main scopes, advantages, and disadvantages of AI usage, revealing several key implications for the integration of cultural heritage with AI. The research suggests utilizing AI to enhance interactivity and visual effects, thereby improving the experience of traditional culture and creating a platform for its innovative development and modern integration. AI serves as a crucial tool in cultural heritage research, enabling the creation of databases for historical interpretation, revealing the deeper meanings of historical sites, and expanding public understanding. Furthermore, AI can broaden the depth and breadth of artistic creation, bridge the gap between modern and ancient art, redefine traditional art and creativity, and introduce new forms of expression for traditional culture. Leveraging AI's efficient data processing capabilities can achieve the protection, restoration, and reproduction of cultural heritage, injecting new

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vitality into its innovative development.

Despite these advantages, AI still faces challenges in maintaining the authenticity, accuracy, and deep expressiveness of cultural heritage and artworks, particularly in capturing subtle details, restoring original appearances, and expressing emotional depth. Addressing these issues requires interdisciplinary collaboration, including contributions from experts in art history, computer science, and machine learning.

The need for a balanced approach between AI application and cultural heritage innovation is evident, prompting a reevaluation of the essence of cultural creation and related legal and regulatory issues. Although AI as an emerging technology has found applications in cultural heritage, as evidenced by globally renowned news and video websites, relevant cases remain rare, indicating that further development, promotion, and application are necessary. The inevitability of AI's role in the conservation, inheritance, and innovative development of cultural heritage is recognized, suggesting that its benefits should be fully utilized to promote further development.

This study also acknowledges limitations due to the limited number of AI application cases collected in cultural heritage, restricting the analysis's breadth and depth. Moreover, the absence of field visits and interviews with practitioners makes it challenging to deeply understand the specific application models and impacts of AI in cultural heritage and the perspectives of related institutions and individuals. Future research should increase sample sizes and include field visits and interviews to mitigate these shortcomings, enhancing the understanding and application of AI in cultural heritage.

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Institutional Review Board Statement

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Author Contributions

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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