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The Investigation of Artificial Intelligence in Cultural Relics Protection

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Abstract:

It is well-known that the importance of cultural heritage in history, culture, art and other aspects is self-evident. However, due to various force majeure damage, the situation of cultural heritage protection is becoming more and more severe. This article will review and look forward to the application of Artificial Intelligence (AI) in cultural relics protection. The method section of this paper demonstrates various AI technologies such as Generative Adversarial Networks (GAN), deep learning, and reinforcement learning, and applies them to cultural relic digitization, damage detection, virtual restoration, and cultural heritage management and display. The next section outlines the specific tasks for which these AI techniques are applicable, demonstrating the potential of these innovations to improve accuracy and efficiency in work. In the subsequent discussion section, the current limitations and challenges of AI in this field are analyzed, such as data dependency and "black box" characteristics. At the same time, the future direction of AI is discussed, such as interpretable AI (XAI) and adaptive learning. Finally, this paper concludes that although AI has challenges, it will play an increasingly important role in the field of cultural heritage protection in the future.

Keywords: Artificial Intelligence, deep learning, cultural relics protection

1. Introduction

Cultural relics refer to objects of historical, cultural or artistic value handed down from ancient times, including ceramic, calligraphy, painting, sculpture and architecture. These cultural relics are not only important carriers for people to understand the past, but also represent the technical level, lifestyle and aesthetic concepts of ancient society. However, after hundreds or even thousands of years of baptism, cultural relics are often affected by natural factors (temperature, microbial corrosion) and man-made destruction (war, theft), causing irreversible damage to cultural relics. Therefore, how to effectively restore and protect precious historical heritage has become an extremely challenging subject. Although the traditional restoration methods have accumulated rich experience and technology, they are often powerless in the face of complex restoration tasks, for example, manual repair has limited accuracy and requires a considerable time and manpower. However, the intervention of modern science and technology, especially the development of artificial intelligence technology, provides new possibilities for the restoration of cultural relics. For example, generative models such as Generative Adversarial Networks (GAN), which have been widely used in various fields. This technology has already played a major role in chemical molecule design, medical image generation, virtual facial expression synthesis and other fields. And in terms of cultural relic protection, the application of artificial intelligence technology has gradually attracted attention. The reason for this phenomenon is that through deep learning algorithms, artificial intelligence can automatically identify damaged parts of cultural relics, and simulate the missing parts based on existing historical data and existing sample repair cases to significantly improve the efficiency and accuracy of repair work.

In recent years, the academic community has conducted extensive and effective research on the application of Artificial Intelligence (AI) in cultural relic restoration. Pan et al. explored the wide application of GAN in cultural relic image generation and virtual restoration and demonstrated the great potential of GAN in learning unlabeled image data and generating high-quality images [1]. In addition, Pavlidis and others combined AI algorithms and high-precision 3D scanning technology to optimize the 3D modeling process of cultural relics and effectively improve the accuracy and efficiency of data collection [2]. Jin et al. [3] and Li et al. [4] proposed a GAN-based cultural relics classification method by classifying cultural relics. This method proves the conclusion that GAN can generate highly consistent replacement images through the application of GAN technology in the virtual restoration of cultural relics, fill in the damaged areas of cultural relics, and significantly improve the repair efficiency [3]. The above

three studies have shown that AI technology can be used in virtual restoration of cultural relics. Cultural relics protection has a wide range of application scenarios and huge potential.

The rest of this article is structured as follows: The method section discusses the application of AI technologies, including generative models like GANs, in digitization, virtual restoration, and damage detection of cultural relics. The discussion section analyzes the limitations of these methods, such as data dependency and the "black box" problem, while exploring potential solutions like interpretable AI. Finally, the conclusion summarizes the current applications and future prospects of AI in cultural heritage preservation.

2. Method

2.1 Introduction of Generative Model

A generative model is a machine learning model that can generate similar new dataset instances based on a given dataset. The principle is to learn the underlying distribution of the data and then generate new samples from it. Due to this feature, generative models are widely used in many tasks, such as image generation, audio synthesis, text generation, etc. In this model, the generative adversarial network (GAN) model is a typical representative: GAN consists of two neural networks: a generator and a discriminator. The generator can generate new data samples while the discriminator evaluates the authenticity of these samples. In order to make the sample quality higher and higher, the generator attempts to generate realistic data to deceive the discriminator, while the discriminator strives to distinguish between real data and generated data. Through the continuous confrontation between the two networks, the generator will eventually generate samples of higher and higher quality. Pan et al. carefully reviewed the various applications of GANs, especially emphasizing their importance in scenarios such as image generation and restoration [1]. Specifically, they summarized how GANs can learn from a large amount of unlabeled image data and generate high-quality images for virtual reconstruction and restoration of cultural relics [1]. This study undoubtedly demonstrated the great potential of GANs in a wide range of scenarios such as image restoration.

2.2 AI Technology in Digitization

The digitization of cultural relics refers to the process of digitally recording, preserving and displaying cultural relics using modern scientific and technological means. This process includes but is not limited to 3D modeling, virtual restoration and digital archive creation. The purpose of digitizing cultural relics is to fully and accurately preserve the form and details of cultural relics through digital technology without changing their physical form, thereby achieving long-term preservation and wide dissemination of cultural relics.

2.2.1 3D modeling

Through 3D modeling and high-definition scanning technology, the detailed shape and state of cultural relics can be permanently preserved, even if the cultural relics themselves are damaged or lost due to time, natural disasters or human factors, digital archives can still provide a complete record of information. Pavlidis et al. [2] proposed a method to optimize the accuracy and efficiency of 3D scanning through AI technology. The principle is to use high-precision 3D scanning equipment combined with AI algorithms to achieve the purpose of accurately capturing the details of cultural relics.

2.2.2 Virtual Restoration

With the support of existing 3D modeling technology, cultural relics can be digitally restored virtually. This means that there is no need to worry about possible secondary damage caused by direct physical repair of the real object. By simulating and restoring the original appearance of the cultural relics through digital space and exploring different repair schemes, it will provide an important reference for actual repair. In Jins et al. Study [3], how to use GAN to generate high-quality replacement images without physical intervention and use them to fill and replace damaged cultural relic areas. Through designed experiments, Jin et al. proved that the GAN model can accurately simulate the original form of the cultural relics and generate images that are highly consistent with the undamaged parts to replace the damaged parts. This technology not only improves work efficiency but also reduces secondary damage during the physical repair process [3].

2.3 Application of AI Technology in Damage Detection

During the long-term preservation of cultural relics, they are often affected by various factors, resulting in damage such as cracks, corrosion, and fading. Fading mainly occurs in paintings, murals, and textiles, mainly due to factors such as ultraviolet radiation and air pollution. Corrosion is more common in metal cultural relics such as bronzes. This is mainly caused by various chemical reactions. The most common one is that moisture, oxygen, and pollutants in the air accelerate chemical reactions and lead to the loss of metal cultural relics. In recent years, the research of Li et al. and Masiero et al. has shown that deep learning algorithms (such as CNN) have obvious advantages in detecting damage to cultural relics [4, 5]. Among them, Li et al. [4] proposed an AI-based image recognition

method to automatically detect cracks, corrosion, fading, and other problems on cultural relics through a model that has been trained with a data set. This technology can not only reduce manual inspection time, but also improve the accuracy of damage identification.

2.4 Application of AI in Cultural Heritage Management and Display

The application of artificial intelligence in digital museums and virtual displays will significantly enhance the public's interactive experience of cultural heritage. Through high-precision 3D modeling and virtual restoration of cultural relics, viewers can watch realistic cultural relics online without leaving home and can even observe details that cannot be seen offline by zooming in and rotating. At the same time, the combination of virtual reality (VR) and augmented reality (AR) technologies provides audiences with an immersive visiting experience. These technologies not only make cultural heritage dissemination broader and more convenient, but also provide a new communication platform for education and research.

2.4.1 Digital museum and virtual display

Roussou & Drettakis explores the use of AI in the creation of virtual museums and digital exhibitions that leverage AR and VR technologies to provide an immersive experience for the public [6]. These AI technologies can automatically generate digital exhibition content and optimize virtual tour paths to improve audience participation and interactivity

2.4.2 Object data management

Mendoza et al. studied the application of AI in the management of cultural relics database [7]. AI optimizes the management and search efficiency of cultural relics information through intelligent classification and retrieval system. AI can automatically label and classify cultural relic images, reduce manual input errors, and improve the availability of data.

3. Discussion

3.1 Disadvantages of Current Methods

The methods provided by the above references have produced great results for the protection of cultural relics, but each method still has many defects. For example, GANs have great potential for generating high-quality images, especially in virtual reconstructions and restorations of cultural relics. However, Pan et al. also mentioned that the training process of the GAN model is very complicated, because the samples generated by the generator lack diversity, and the phenomenon of mode collapse is easy to occur. In addition, due to the strong correlation between the production quality of GAN and the training data, if the data is not diverse or accurate, the generated results will also be affected. In the application of AI in the management and display of cultural heritage, since AI can automatically generate exhibition content and optimize the virtual tour path, it greatly improves the audience's participation and interaction. Roussou and Drettakis also argue that such technologies rely on high-quality digital content and the maturity of AI algorithms [6]. And for some small museums or cultural institutions with limited resources, the cost and technical requirements of creating and maintaining these systems can pose challenges. In addition, virtual displays cannot completely replace physical exhibitions, which may affect the audience's real perception and experience of cultural relics.

3.2 Limitations and Challegnes

From the macro level of artificial intelligence technology, there are still significant limitations in the field of cultural relics protection. For example, it is obvious that artificial intelligence models rely heavily on high-quality, well-labeled training data, but such complete and perfectly expressed data is often very scarce in this field. Because each cultural relic has a unique form of expression, different materials and different causes of damage, the collection of relevant data becomes complicated and non-universal. In addition, the lack of specialized data sets for specific cultures seriously hinders the effectiveness of artificial intelligence models in different cultural contexts. It is also because of this data scarcity and variability that artificial intelligence is difficult to effectively apply in tasks such as damage detection and virtual restoration of different cultural relics. Another obvious limitation is that many current artificial intelligence technologies, especially deep learning models, due to their complex internal structure and multi-level calculations, only show the final results without indicating the interpretable generation process. This phenomenon is often regarded as a „black box". Therefore, this means that when the model produces output, even if these models perform well in tasks such as image recognition, the decision-making process is not transparent to users, and the uninterpretability of the generated output may bring challenges in areas that require a high degree of trust.

3.3 Future Prospects

Although there are some drawbacks of AI in heritage conservation that cannot be ignored, the advantages brought by its innovative application undoubtedly far outweigh these challenges. With the continuous progress and improvement of technology, the application of AI in the field

of cultural relics protection will not only become more extensive and in-depth, but also its importance and influence will be significantly increased, bringing new possibilities and higher efficiency for the restoration, protection and management of cultural relics, interpretable AI (XAI) is a key technology in the future, which increases the transparency of the decision-making process of AI models [8, 9]. It can make it easier for heritage conservation experts to understand and trust AI's recommendations, so that the output of AI can be evaluated and adjusted more effectively, reducing the risk of wrong decisions. At the same time, adaptive learning and transfer learning techniques can help AI models achieve better generalization when data is scarce or heterogeneous [10, 11]. This is particularly important for conservation, where transfer learning allows AI models to apply knowledge learned from one domain to another, for example from weathering detection of ancient buildings to corrosion detection of other types of artifacts. In addition, Deep Reinforcement Learning (DRL) shows great promise in the development of automated repair strategies [12]. Through continuous testing and feedback, the DRL model can optimize the restoration strategy, simulate multiple methods in the virtual environment, and finally select the solution with the least damage and the best effect to be applied to the actual cultural relic restoration. Taken together, these technologies will further enhance the application effect of AI in cultural heritage protection. The innovation and development of these technologies can meet the expectations of AI in cultural relic protection

4. Conclusion

This review comprehensively discusses the application of artificial intelligence (AI) in cultural relics protection, lists the application scenarios of AI, as well as its advantages and disadvantages, and looks forward to the future of AI. In the method section, this review focuses on the application of AI technology in multiple scenarios such as digitization, damage detection, virtual restoration, and cultural relics management and display, and discusses how to use different AI methods (such as GAN, deep learning) to solve specific challenges. At the same time, it points out some major challenges that AI still faces today, including the dependence on high-quality training data, the lack of specialized data sets suitable for different cultural backgrounds, and the „black box" nature of AI models. Despite this, the potential of AI in protecting culture cannot be ignored. With the development of interpretable AI (XAI), adaptive learning, and deep reinforcement learning, these technologies will be able to provide more concise, efficient, transparent and universal solutions. As long as the current limitations and obstacles are overcome, artificial intelligence will become more and more important in cultural heritage protection, laying a solid foundation for the cultural heritage of current and future generations.

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