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From Photochemistry to AI: The Evolution and Multiple Values of Film Cultural Heritage Restoration Technology

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Abstract: As an art form rising in the 20th century, film has not only made important achievements in history and art but also become an important object of global cultural heritage protection. With the advent of the digital age, especially the rapid development of artificial intelligence (AI) technology, the restoration of film cultural heritage has emerged. This paper traces the historical evolution of film restoration techniques, analyzing the technological advancements from photochemical restoration to digital restoration and then to AI restoration. It discusses how film restoration has undergone revolutionary changes driven by digital technology and artificial intelligence. Through the discussion of specific restoration cases, this paper further reveals the multi-value of film cultural heritage protection and looks forward to the potential of AI in promoting film cultural heritage protection in the future.

Keywords: Film cultural heritage; Restoration technology; Digitization; Artificial intelligence; Cultural values

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1. The historical evolution of film restoration techniques

1.1. Development of early film restoration and photochemical technology

Since the birth of film, the fragility and wastage of its material carrier have been a difficult problem in the preservation and restoration of film heritage. Early film storage mainly relied on nitric acid negatives, which were not only flammable but also easily damaged over time. Film studios had a weak sense of preservation in the early 20th century, and as a result, a large number of silent films were lost in circulation, and the film heritage faced serious losses. With the introduction of photochemical reproduction technology, film restoration began to become standardized in the 1950s, forming relatively standard preservation and restoration procedures [4].

Although photochemical restoration provided a new means for film preservation, the technique relied on

the existence of physical negatives, making restoration extremely difficult once the original film was severely damaged or lost. Due to the high cost of photochemical restoration and the relatively limited technical means, a large number of films could not be effectively protected in time. The practice of film restoration in this period was more oriented toward commercial needs, and the academic and cultural value of films as cultural heritage was not widely recognized [5].

1.2. The awakening of restoration consciousness and the rise of the global film restoration movement

In 1969, the British Film Institute (BFI) collaborated with the French Film Library to restore Abel Gans' classic film Napoleon, a project that was a milestone in the history of film restoration. The work, led by Kevin Brownlow, took ten years to complete, culminating in 1979 in the restoration of the great silent film to a near-original condition [1]. Since then, film restoration has not only been for commercial interests but also given cultural and academic significance [2].

During this period, the awareness of film restoration was further awakened, and after the 1970s, film studios, archivists, and scholars gradually realized the importance of film as a cultural heritage. The fading of color in film, in particular, attracted widespread attention, and directors such as Martin Scorsese and the film industry pressured Kodak to improve its film technology to meet the challenge. At the same time, efforts to restore classic films in Europe and the United States led to the early development of film heritage preservation [3].

1.3. The rise and application of digital restoration technology (1990–present)

Entering the 1990s, digital technology gradually changed the practice of film restoration. The Cineon Digital cinema system, introduced by Kodak, marked the birth of digital film restoration. The classic silent comedy Sherlock Holmes II, for example, underwent a 4K digital restoration in 2023. The film, starring acclaimed director and actor Buster Keaton, is widely regarded as one of the most innovative and influential silent films in cinema history. The restoration project, led by the Academy of Motion Picture Arts and Sciences (AMPAS), aims to digitally restore the sharpness and color layers of the original images while removing scratches, smudges, and blurred parts of the negatives that have been created over time [6]. In the process, the team used modern artificial intelligence image enhancement techniques to maintain the texture and detail of the film's original images. The case not only shows how technological advances can breathe new life into classic films but also highlights the importance of digital restoration in silent film conservation [7].

2. Application of digitalization and artificial intelligence in film restoration

2.1. Advantages of digital restoration technology

Digital restoration technology has shifted film restoration from traditional photochemical methods to digital processes, significantly improving both the efficiency and accuracy of restoration. Compared with photochemical restoration, digital restoration can analyze and process the image in more detail, especially in the aspects of color correction, defect repair, and detail reconstruction of the picture [12]. Digital tools make it easy for restorers to detect scratches, blemishes, and deterioration in the negatives, greatly increasing productivity. Simultaneously, the application of digital restoration technology is not only limited to restoring old films but also can give these works new historical and artistic value. By digitally archiving restored films, they can be disseminated more widely, accessed globally, and further enhanced through modern media.

2.2. Intelligent restoration facilitated by artificial intelligence

In recent years, the rapid development of artificial intelligence technology has brought breakthroughs to film restoration. The application of AI technology has made the restoration process gradually intelligent, especially in image recognition and automatic restoration. Through deep learning algorithms, AI can automatically identify damage in film footage and carry out accurate repairs, greatly reducing the time and cost of manual intervention.

For example, AI technology can automatically remove scratches, and blemishes, and even repair severely damaged pictures by analyzing details such as color and texture of film negatives. This intelligent restoration technology greatly improves the efficiency of restoration and can ensure the high precision of restoration work while retaining the original artistic characteristics. Additionally, AI can also automatically classify materials and retrieve content during the digitization of historical images, providing a new means for film restoration work.

2.3. Case application of AI in film restoration

AI not only improves the visual effects of films but also enhances the audience's ability to empathize through modern audio-visual means, giving these historical images a new lease of life. Another important example is the full digital restoration of Blue Planet (1990). The project used the latest high Dynamic Range (HDR) technology to improve the color contrast and brightness of the images, especially in space images of the Earth, making the details sharper. Moreover, the team used machine learning technology to remove noise from the old film, maximizing the original visual impact of the film. The restoration project represents a historic advance for Image MAXimum (IMAX) films and reinforces the role of technology in the preservation of cultural heritage, taking the film's visual impact to new heights.

3. The multifaceted value of film cultural heritage

3.1. Application of film cultural heritage in modern media

Digital restoration technology is not only about preserving historical heritage, it also expands the application of film in modern culture. The restored films can not only be redistributed but also provide material for modern cultural content such as short videos and immersive exhibitions. AI-assisted creative processing can provide new cultural products for restored films and further promote the dissemination and re-creation of film cultural heritage. The restored classic film materials can provide audiences with an immersive cultural experience through virtual reality (VR) and augmented reality (AR) technologies so that historical images and cultural memories can be integrated with modern science and technology to radiate new vitality [10].

3.2. The value of digital humanities and cultural inheritance

The application of digitalization and artificial intelligence in film restoration is not only the progress of technology but also reflects the arrival of the era of digital humanities. Through digital storage and restoration, film cultural heritage can be permanently preserved and become a global cultural asset. Digital technology enables these cultural heritages to be shared and disseminated across regions through the Internet, breaking the limitations of time and space and enabling them to serve more academic research and cultural inheritance work [8].

The cultural inheritance value of film restoration is not only reflected in the preservation of images of the past but also in the fact that a new generation of audiences can draw nutrients from history and art. Many restored classic films have been re-released around the world, enabling new audiences to feel the cultural influence of

these films firsthand [9]. Furthermore, these restored films provide inspiration and material for future filmmakers, laying the foundation for innovation in the art of filmmaking [11].

4. Challenges and prospects of film restoration

4.1. Technical and ethical challenges

Although digitalization and artificial intelligence have brought significant advances to film restoration, the work still faces many challenges. At the technical level, the complexity of film restoration is far beyond imagination, especially when dealing with badly stored and damaged negatives, which still require a lot of manual intervention and the artistic judgment of restorers. In addition, although the application of artificial intelligence has improved efficiency, its "intelligence" still has limitations. AI sometimes ignores the style and artistic intention of the original film when it is automatically repaired, which leads to certain technical and ethical disputes [13].

4.2. The potential of AI technology in the future of film restoration

With the continuous development of AI technology, its application in film restoration will be more extensive and in-depth. AI's deep learning algorithms will play a greater role in the restoration process in the future, especially when dealing with complex image restoration tasks, and AI can further enhance the level of automation. For example, AI is expected to automatically recognize various details in the film in the future, including faces of people, edges of objects, and background of scenes, to achieve more accurate restoration. Concurrently, AI can also infer missing parts of original images through predictive algorithms, helping restorers to better restore historical films [14].

5. Conclusion

With the continuous evolution of film restoration technology, especially the rapid development of digitalization and artificial intelligence technology, the protection of film cultural heritage has entered a new stage. From early photochemical restoration to modern digital restoration, and then to AI-assisted intelligent restoration, film restoration technology has not only greatly improved the efficiency and accuracy of restoration, but also endowed the restored films with new historical and artistic value [15]. The application of digital technology and AI makes the multi-value of film cultural heritage more prominent and plays an important role in cultural inheritance, education, creative industry, and other fields.

In short, the restoration of film cultural heritage is not only a technical work but also a great cause related to cultural inheritance and global sharing. With the continuous advancement of technology, film restoration will play an important role in a broader cultural context, bringing more restored classic film works to global audiences, and at the same time promoting the continuous innovation and development of film art.

Disclosure statement

The author declares no conflict of interest.

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