

Research on Management of Color Information of Mongolian Oil Paintings from Perspective of Cultural Heritage Protection

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Abstract: Mongolian oil paintings, as an important cultural heritage, demonstrate high artistic value through their unique color application and themes related to the nomadic culture. However, due to material aging, environmental factors, and limitations in protection technology, these oil paintings are currently facing severe challenges such as color distortion and deterioration of pigments. This article systematically reviews the research on the application of color information management technology in the conservation of Mongolian oil paintings, and discusses the implementation paths of key technologies such as digital acquisition, multispectral imaging, and color standardization in their conservation practices. The study shows that establishing a color information management framework specific to the characteristics of Mongolian oil painting materials, combined with dynamic monitoring and virtual restoration technologies, can effectively achieve the scientific conservation and inheritance of oil paintings. This article further proposes that specific technical standards should be formulated, interdisciplinary cooperation should be strengthened, and intelligent protection solutions should be explored to address the insufficient targeting issues in current research, providing theoretical support and technical references for the long-term preservation of Mongolian oil paintings.

Keywords: Mongolian oil paintings; Color information management; Multispectral imaging; Cultural relic protection; Digital archiving.

1. Introduction

Mongolian oil paintings, as an important manifestation of Mongolian national art, carry unique historical memories and cultural identities, and possess irreplaceable artistic and heritage value. Their works are often characterized by vivid colors and rich themes related to the nomadic culture, reflecting strong ethnic aesthetic features (Gantumur Amartsetseg, 2016)[1]. However, due to material aging, environmental changes, and limitations in protection technology, many oil paintings are facing serious problems such as color distortion and paint peeling, and urgently need scientific protection measures. In the practice of cultural heritage protection, the accurate recording, management, and reproduction of color information are the core links to ensure the long-term preservation and effective inheritance of the original appearance of oil paintings. In recent years, digital color management technologies, such as multispectral imaging and color standardization systems, have gradually been applied in the field of cultural relics, providing new possibilities for the protection of oil paintings (Zhao Liang, 2008; Piao Shi, 2012)[4][7]. However, existing research mostly focuses on general conservation protection or practical cases in China, lacking systematic studies on the material characteristics, environmental conditions, and cultural background of Mongolian oil paintings. Therefore, this paper aims to review the current application status and challenges of color information management technology in the protection of Mongolian oil paintings, combined with their artistic characteristics and material properties, and explore the color management paths applicable to this field, in order to provide theoretical references for subsequent conservation practices.

2. Literature Review

2.1. Research on Artistic Characteristics and Materials of Mongolian Oil Painting

Mongolian oil paintings gradually developed their unique style in the early 20th century, integrating the visual elements of traditional nomadic culture with European painting techniques. Particularly, their color application demonstrated distinct regional and ethnic characteristics (Daurismugi, 2021)[2]. Artists often employed high-saturation and strong contrast color combinations to depict the natural scenery of the grasslands, scenes of ethnic life, and historical themes. This color preference originated from aesthetic traditions and was also related to the plateau natural environment and light conditions in Mongolia (Gantumur Amartsetseg, 2016)[1]. In terms of material usage, early Mongolian oil paintings were influenced by Soviet art, commonly using oil canvas and mineral pigments. Some painters also attempted to combine local natural pigments to enhance the cultural expression of the works. However, these materials were prone to degradation due to environmental factors such as ultraviolet radiation, temperature and humidity fluctuations during long-term preservation, resulting in color fading, coating cracking or yellowing (Han Hongbin, 2015)[3].

From the current research, the aging mechanism of oil painting materials has become an important issue in the field of cultural heritage protection. Han Hongbin (2015) pointed out that light, especially ultraviolet radiation[3], is the main factor causing the degradation of organic pigment molecular structures, while changes in humidity can cause the expansion and contraction of supporting materials (such as canvas), intensifying the peeling of the pigment layer. Additionally, chemical interactions between different pigments may

accelerate color deterioration. Although these studies provide a foundation for understanding oil painting aging, there is still a lack of systematic analysis of Mongolian oil painting materials. Daurismugi (2021)[2], in the research of representative painters such as Qipeng Bukzabuz, briefly discussed the relationship between pigment selection and the durability of the picture, but did not deeply explore environmental adaptability or color stability issues. Therefore, in the future, it is necessary to further combine material science and environmental analysis to study the chemical composition, optical properties of commonly used pigments in Mongolian oil paintings and their degradation paths under specific climatic conditions, providing a basis for subsequent color information management.

2.2. Application of Color Information Management Technology in Cultural Relics Protection

Color information management refers to the process of systematically controlling the collection, processing, storage, and reproduction of the colors of cultural relics through standardized and digital methods. Its core objective is to achieve a high degree of color restoration and long-term consistency. In the field of cultural heritage conservation, this technology has become an important tool for digital recording and preventive conservation (Piao Shi, 2012; Zhao Liang, 2008)[4][7]. The commonly used color management processes include equipment calibration, color space conversion, characteristic file construction, and output correction, among others. These steps jointly ensure the color authenticity throughout the process from image acquisition to output.

In the protection of oil paintings, multispectral imaging and high-precision spectrophotometers are two key technologies. Multispectral imaging can capture colors that are invisible to the human eye, revealing the underlying painting structure and pigment changes, thereby assisting in identification and condition assessment (Zhao Liang, 2008) [7]. Spectrophotometers can be used to establish a color database for pigments and quantitatively describe them using standard color spaces such as CIE Lab, providing a scientific basis for color restoration. Piao Shi (2012) in the digital reproduction project of flat cultural relics at the Capital Museum detailed how the color management process was used to achieve a high degree of consistency between replicas and the originals[4], including methods such as using a standard light source environment, professional color calibration software, and output equipment control. Similar technologies can also be applied to oil painting conservation, especially for Mongolian oil paintings that are sensitive to color changes, establishing reliable digital color archives is crucial.

Furthermore, with the development of digital technology, color information management is no longer limited to traditional replication and recording, but has expanded to virtual display, restoration simulation, and public education. For example, Zhang Shuping (2009) explored the application of color management in art design laboratories, emphasizing the value of cross-media color consistency in cultural dissemination[6]. Sun Qin (2025) studied the color language transformation mechanism in the integration of oil paintings and digital media, pointing out that digital technology can provide new presentation methods for traditional art. These studies provide a broader application perspective for oil painting conservation, indicating that color management is

not only a technical means but also a bridge connecting traditional art and contemporary audiences.

However, existing applications are based on a general conservation framework and lack adaptive adjustments to specific cultural contexts and material types. For example, certain natural pigments commonly used in Mongolian oil paintings may have special spectral reflection characteristics, requiring customized color collection and processing plans. Therefore, when promoting color management technology, cultural context and material specificity must be considered, and general models should not be directly applied.

2.3. Summary of Literature Review

Although color information management technology has been widely applied in cultural heritage protection, there are still significant deficiencies in the related research on Mongolian oil paintings. Firstly, most existing literature focuses on cases from China or Europe, such as Dunhuang murals (Zhao Liang, 2008) or museum-held paintings (Piao Shi, 2012)[4], while Mongolian oil paintings, due to their unique historical development and cultural environment, have their own particularities in material usage, creative themes, and preservation conditions. Therefore, targeted research is urgently needed. Secondly, current color management research mainly focuses on the general description of technical processes, failing to fully combine the aging mechanism of oil painting materials and environmental influencing factors. In particular, the color stability issues under typical Mongolian environmental conditions such as high ultraviolet radiation and dry continental climate have not been systematically explored. Additionally, there is a lack of unified standards and protocols for the long-term preservation and utilization of digital color information. The cultural heritage institutions in Mongolia may have limitations in technology application and resources. How to develop low-cost and efficient color management solutions is also a problem that future research needs to address. Finally, existing art research literature (such as Daurismugi, 2021; Gantumur Amartsetseg, 2016) provides good descriptions of oil painting styles and color application[1][2], but mostly from the perspectives of art history or aesthetics, without a deep intersection with conservation science. Therefore, future research should focus on interdisciplinary cooperation, integrating fields such as material chemistry, environmental engineering, and digital technology, to establish a color information management framework applicable to Mongolian oil paintings, in order to achieve their long-term preservation and sustainable utilization.

3. Technical Framework for Color Information Management of Oil Paintings in Mongolia

Based on the literature review, this chapter aims to construct a color information management technology framework for the protection needs of Mongolian oil paintings. This framework intends to achieve precise collection, reliable storage, dynamic monitoring and scientific restoration of the color information through a systematic technical process, providing technical support for the long-term preservation and research of Mongolian oil paintings.

3.1. Digital Acquisition and Standardization of Oil Painting Colors

The precise collection of color information forms the foundation of the entire management process. For Mongolian oil paintings, their characteristic of bright and contrasting colors requires that the collection technology must have high fidelity. Currently, high-precision scanning and multispectral imaging (Multispectral Imaging, MSI) are the two most core collection technologies. High-precision scanning usually uses professional-level scanners or digital cameras combined with precise supports, and is captured under strictly controlled lighting conditions (such as using the D50 standard light source) to obtain high-resolution RGB images of the oil painting surface (Piao Shi, 2012)[4]. However, RGB images can only record the spectral information visible to the human eye and have limitations.

Multispectral imaging technology can go beyond the limitations of the human eye. This technology captures a series of images in different narrow wavelength bands (from ultraviolet, visible light to infrared) to obtain the spectral reflectance data of each pixel point of the oil painting. This is particularly important for the conservation of Mongolian oil paintings because: Firstly, MSI can reveal hidden underlayers, modification traces, and early restoration histories of the paintings, providing new materials for art history research (such as studying the creative processes of painters like Chubukzhabu) (Daurismugi, 2021)[2]. Secondly, different pigments have unique spectral "fingerprints", and MSI can non-invasively identify the types of pigments, providing scientific basis for subsequent degradation monitoring and restoration. For example, certain specific blue or red pigments used in Mongolian oil paintings, their spectral characteristics can be compared with the database for accurate identification.

The original data collected must undergo standardized processing to ensure its scientific value and application consistency. The core of color standardization is to establish device-independent color spaces (such as CIE Lab) and use ICC characteristic files (ICC Profile). The specific process is as follows: During collection, a standard color card (such as X-Rite ColorChecker) is placed next to the painting for simultaneous shooting. Then, using color management software, the collection equipment (camera or scanner) is calibrated based on the known standard values of the color card to generate the ICC characteristic file of that device. This file is used to convert the RGB data related to the device to the standard color space (Zhao Liang, 2008). Through this process, it can effectively solve the problem of color distortion caused by factors such as device model and light source changes, ensuring that the color data of Mongolian oil paintings collected by different institutions and at different time points have comparability and interchangeability, laying the foundation for establishing a national color database.

3.2. Color Data Storage and Dynamic Monitoring

A vast amount of color data, especially multi-spectral image data, needs to be securely and orderly stored and managed. Building a structured color database is an essential step. This database should not only store the final image files but also include rich metadata (such as basic information of the oil painting (name, author, date), collection conditions (device model, light source, aperture shutter parameters), color space information, ICC configuration files, and the

pigment recognition results extracted from multi-spectral data, etc.). The design of the database should follow international common cultural heritage data standards (such as CIDOC CRM) to ensure the long-term readability and shareability of the data. This is of great significance for the cultural heritage institutions in Mongolia, as it enables the digital preservation and efficient retrieval of oil painting color assets, providing data support for protection decisions.

The goal of color information management is not only to make static records, but also to dynamically track the changes of oil paintings over time, that is, the aging process of the materials. Digital technology provides efficient monitoring methods for this. The method is to regularly (such as every year or every two years) re-collect standardized images of the oil painting under exactly the same collection conditions, and then precisely register and compare the new images with the baseline images in the database. Using image processing algorithms, the color values of specific areas (such as ΔE values in CIE Lab) can be quantitatively calculated, thereby objectively evaluating the degree and speed of color deviation (Han Hongbin, 2015)[3].

This dynamic monitoring is of great significance for evaluating the effectiveness of protection measures, predicting future degradation trends, and formulating priority protection strategies. For example, through long-term monitoring, it can be discovered whether a certain specific red pigment in a certain painter's works shows an abnormal fading rate under the climate conditions of Ulaanbaatar, and thereby prompting the protectors to investigate the cause and take targeted preventive protection measures, such as adjusting the lighting and humidity of the exhibition environment.

3.3. Color Restoration and Virtual Repair

When oil paintings suffer from color fading or damage due to physical or chemical changes, digital color restoration technology can recreate their original visual appearance without touching the physical object. A common method is color migration. This technology is based on reference images, which can be an earlier, better-conditioned copy or photograph of the oil painting, or another intact painting by the same artist from the same period using similar pigments. Through algorithms, the color style and statistical information from the reference image are transferred to the current faded image, thereby generating a speculative original color version (Sun Jin, 2025)[5]. This is highly valuable for researching and displaying the original artistic intentions of Mongolian oil paintings.

In recent years, artificial intelligence technology, especially deep learning, has shown great potential in color prediction and restoration. Convolutional Neural Networks (CNN) can be trained to learn the complex mapping relationships between a large number of intact oil paintings and their faded versions or images from different bands (such as infrared and ultraviolet). Once the model is trained, simply inputting the current state image or multispectral image of the Mongolian oil painting into the algorithm enables it to predict and restore its possible original color. The advantage of this method lies in its ability to handle more complex nonlinear degradation patterns.

4. Implementation Suggestions and Future Outlook

4.1. Formulate Targeted Technical Standards

Establishing a color management standard system specifically applicable to Mongolian oil painting materials is the fundamental work for implementing color information management. Although the currently internationally accepted digitalization standards for cultural heritage provide a basic framework, they lack sufficient consideration of the particularities of Mongolian oil paintings. It is suggested that the Mongolian cultural heritage institutions take the lead, in collaboration with technical experts, to formulate a complete set of standard specifications covering the entire process of data collection, processing, and storage. In the data collection stage, it is necessary to clearly define the technical parameters of professional-level scanning equipment, the band range of multi-spectral imaging, and the lighting requirements of the D50 standard light source, to ensure the accurate capture of common high-saturation colors and special pigment features in Mongolian oil paintings. In the data processing stage, an ICC configuration file-based color correction process should be established, and a spectral data analysis method specific to Mongolian traditional pigments should be formulated. In the data storage stage, metadata specifications including basic information of the works, material data, environmental history, and color indicators should be designed, and international common cultural heritage data standards should be adopted to ensure the long-term readability and shareability of the data. The establishment of these standards will provide important guarantees for the scientific management and effective utilization of Mongolian oil painting color information.

Promoting the implementation of these standards requires supporting policies and technical training. It is suggested that the Mongolian cultural authorities incorporate the color management standards into the guidelines for cultural heritage digitalization work and promote their application in major museums and conservation institutions. At the same time, systematic technical training should be conducted to enhance the awareness of the importance of color management and the specific operational capabilities of conservation personnel. A quality assessment mechanism for standard implementation can also be established to regularly test and certify the digitalization results, ensuring that all standard requirements are implemented. Through standardization work, not only can the current protection work be elevated to a more scientific level, but also interfaces for future technological development can be reserved, enabling the sustainable development of the conservation work.

4.2. Promote Interdisciplinary Cooperation and International Exchanges

The conservation of oil paintings in Mongolia is a complex and systematic project that requires the joint participation and close collaboration of professionals from multiple disciplines. It is recommended to establish a multidisciplinary research team consisting of conservation experts, material scientists, art historians, digital technology experts, and traditional painters. Conservation experts can analyze the aging mechanism and protection requirements of oil painting materials; material scientists can identify the pigment

components and degradation products through modern analytical techniques; art historians can provide the historical background and artistic value interpretation of the works; digital technology experts are responsible for the technical implementation of the color information management system; and traditional painters contribute their practical experience in materials and techniques. This interdisciplinary cooperation helps to form a comprehensive and systematic conservation plan, ensuring that the application of technologies conforms to the principles of cultural heritage conservation and artistic laws.

Strengthening international exchanges and cooperation is an important way to enhance the protection level of oil paintings in Mongolia. It is recommended to actively establish cooperative relationships with international cultural heritage protection institutions such as ICCROM and UNESCO, and participate in international protection projects and technical exchange activities. One can learn and draw on advanced experiences from China in the protection of Dunhuang murals and from Europe in the restoration of oil paintings, especially the technical methods in color information management. At the same time, bilateral cooperation with protection institutions in neighboring countries should be carried out, establishing a mechanism for technology sharing and personnel exchange. For example, one can collaborate with Chinese conservation institutions to build a database of Mongolian oil painting pigments, and jointly study oil painting protection technologies under cold climate conditions with Russian experts. Through international cooperation, not only can technical support and professional training be obtained, but also the international influence of Mongolia in the field of cultural heritage protection can be enhanced.

4.3. Exploring Intelligent and Preventive Protection Paths

With the development of artificial intelligence and big data technologies, the protection of oil paintings is shifting towards an intelligent and preventive direction. It is suggested that the protection agencies in Mongolia actively introduce these advanced technologies and establish an intelligent color monitoring and protection system. By using machine learning algorithms, large amounts of color monitoring data can be analyzed to establish a pigment aging prediction model, enabling early warning of color changes. Through Internet of Things technology, the parameters of the display and storage environment can be monitored in real time, and temperature, humidity, and lighting conditions can be automatically adjusted to prevent color deterioration. The application of these intelligent technologies will change the traditional passive protection mode and achieve a transformation to active preventive protection.

Big data technology provides new research methods and decision support for the protection of oil paintings. It is suggested to establish a Mongolian oil painting color database, systematically collecting color information of works from different periods, painters, and materials. Through the mining and analysis of these data, the regular characteristics of color changes can be discovered, and the actual effects of various protection measures can be evaluated, providing scientific basis for protection decisions. At the same time, digital twin technology can be utilized to build a virtual model of the oil painting, simulating the color change process under different environmental conditions, and optimizing the protection plan.

A public participation platform can also be developed, through digital display and interactive experience, to enhance public awareness and support for oil painting protection. These innovative applications not only can improve the technical level of protection work, but also can expand the ways and means of disseminating the value of cultural heritage.

5. Conclusion

This paper systematically studies the theoretical methods and technical paths for managing color information of Mongolian oil paintings within the context of cultural heritage protection. The research shows that color information management serves as a bridge connecting traditional conservation science and modern digital technology, playing a significant role in the scientific protection and sustainable inheritance of Mongolian oil paintings. By establishing a systematic color information management system, it not only effectively records and preserves the current state of oil paintings but also monitors the color change process and assesses the effectiveness of protection measures, providing decision support for preventive protection. This study emphasizes that the application of technology must be based on a profound understanding of the artistic characteristics and material properties of Mongolian oil paintings. It should adopt advanced science and technology while respecting the authenticity and integrity of cultural heritage.

Looking to the future, the research on color protection of Mongolian oil paintings needs to continue to deepen in multiple directions. On one hand, it is necessary to strengthen basic research and deeply analyze the aging mechanism of traditional oil painting materials, especially the durability issues of unique pigments and techniques in the Mongolian region. On the other hand, it is necessary to expand the application scenarios of technologies, such as multi-spectral imaging and three-dimensional scanning, to be more widely

used in protection practices. At the same time, it is necessary to strengthen international cooperation, draw on advanced protection experience, cultivate professional talent teams, and enhance the overall protection level. The most important thing is to establish a long-term mechanism, incorporate color information management into the daily protection work system, and achieve the standardization and normalization of protection. Through the efforts of all parties, the precious cultural heritage of Mongolian oil paintings will surely be better protected, and their artistic value and cultural connotations will be more fully displayed and inherited.

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