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Digital Protection and Recovery Method of Traditional Paper Horse Art Based on Image Processing Technology

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ABSTRACT

The argument of the article comes from the rapid development of digital technology and the urgent need for the digital protection and restoration of traditional paper horse art. For this reason, this paper proposes a method of digital protection and restoration of traditional paper horse art based on graphics processing technology. The traditional paper horse art image is collected, the image is denoised using mean filtering, the paper horse image is decomposed in gray scale through spatial conversion, and then its double histogram equalization is processed to obtain the color-enhanced image. Combined with the convolutional image restoration strategy, the paper horse art is digitally displayed. The method of this paper can enhance the color of the paper horse art image and retain the original details, and at the same time, in terms of the clarity effect, the method of this paper improves the comparison method by 25.27%~339.39%. In addition, the method in this paper has better image restoration quality with subjective evaluation rating $\geqslant$ 4 and higher PSNR and SSIM. What's more, the scores on the evaluation dimension of digital preservation and restoration effect ranged from 4.02 to 4.48, and the overall effect performance was relatively good.

Keywords: Image Processing Techniques, Mean Filtering, Gray Scale Decomposition, Convolutional Method Recovery, Digital Preservation and Restoration

1. Introduction

There are many kinds of traditional Chinese folk art, and paper horse is one of them. Paper horse refers to the paper art used in folk rituals, and the scenes used are mostly for welcoming and sending off gods, witchcraft practices, etc. [1-2]. Paper horses appeared after the invention of papermaking and engraving in China [3]. The materials needed for printing are paper, ink and various colors of pigments, because the paper horse is usually burned after use, so the requirements for the paper are not high, most of the use of cotton paper, jute paper, grass paper and other low-cost, easy-to-burn paper to print.

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As a branch of woodblock prints, paper horses carry aesthetic and practical values, providing theoretical references and image bases for the study of woodblock print art. However, with the passage of time, traditional cultural heritage similar to paper horse art is fading out of traditional ritual applications. In order to protect, repair and inherit these valuable cultural heritages, digitization technology has been introduced as an important means of cultural heritage preservation and restoration [4-7]. Digital technology provides new methods and means for the preservation and inheritance of cultural heritage. Through digitization technology, we can perform operations such as three-dimensional scanning, image shooting and video recording of cultural heritage, which can be transformed into digitized form [8-10]. This kind of digital preservation can effectively avoid the risk of destruction and disappearance of cultural heritage due to various reasons. At the same time, digitization technology also helps us to transmit these precious cultural heritages to more people, so that anyone can appreciate and learn the essence of cultural heritages through digital media, regardless of time and space constraints [11-12]. The restoration of cultural heritage often requires a great deal of research and analysis to understand its history, material construction, and causes of damage. Digital technology provides new means for these tasks. Through three-dimensional scanning and digital modeling technology, we can analyze and restore the cultural heritage in an all-round way, which provides precise reference and guidance for the restoration work, and makes the restoration work more efficient and accurate [13-15]. In addition, digital technology can also simulate the morphology of cultural heritage in different environments and ages to realize the reproduction of cultural heritage, which can help us understand its evolution process and provide more clues and ideas for the restoration work [16-17].

In conclusion, digital technology has great potential and important role in the conservation and restoration of cultural heritage. Through digital technology, we can better preserve, restore, study and pass on cultural heritage, and realize the regeneration and re-creation of cultural heritage.

This paper designed a research framework for the digital preservation and restoration of traditional paper horse art, including the purpose of the study, the content of the study, and collected and processed images of traditional paper horse art from various parts of China through field surveys. The study specifically analyzes the digital preservation process of paper horse art based on image processing technology, including denoising, gray scale decomposition and image enhancement of the collected images as well as image edge detection. Meanwhile, an image restoration algorithm based on partial differential equations is used to realize the digital restoration of paper horse art.

2. Research design for digital preservation and restoration of traditional paper horse art

2.1. Purpose of the study

The purpose of digital protection and restoration of traditional paper horse art is to realize the sustainable development of paper horse art, to lead the art of paper horse out of the museum and into people's daily life, and to let people understand the uniqueness of paper horse art and the necessity of protection. As a representative of China's non-heritage art, the artistry and folklore of paper horses are extremely high, and its materials, carvings, modeling, and decorations show the historical style of an era and the local customs of a region.

Effective measures are taken and modern scientific means are utilized to turn these precious paper horse arts into sustainable wealth. Through the use of advanced digital technology, in-depth excavation and integration of paper horse data and information, the formation of a perfect digital protection mechanism, and the adoption of effective digital inheritance measures to enhance the vitality of the paper horse, which is the core of this study.

2.2. Content of the study

This study takes the paper horse as the research object, summarizes and summarizes its artistic characteristics and cultural connotation, grasps the law of digital protection and inheritance, and tries to construct a feasible digital protection and restoration method for it, so as to provide a new idea and a new direction for the digital protection and restoration of regional and even Chinese intangible cultural heritage.

2.2.1. Paper Horse Art and Digital Conservation. Paper horse is a folk art form, it is a kind of folk prints handed down from ancient times, the ancient Chinese working people themselves created the image of the god of the stove, the mountain god, the land, the god of the city and the image of the ancestor, the people use the image of these gods into woodblock prints, and then in folk festivals or on various occasions to paste or burn the way to sacrifice or pray for blessings. The size of the paper horse has a variety of versions, the paper horse works of different styles and styles, the content of the gods of the paper horse involves Taoism, Buddhism, witch gods, myths, legends, customs, etc. In addition, the paper horse contains the gods can also be divided from the category of the gods. The content of the paper horse art involves all aspects of folk life and culture, it has a broad popular base, and its use in the folk can be said to have a long history.

Digital protection, after digitizing the data and information of the objects to be protected, digital technology is applied to store them on computers or digital devices in order to realize the protection of their data and information. Whether it is paper horse art, or most other folk arts are presented mostly as material or inheritor carriers, but this traditional form of carrier can cause many problems, such as inheritor generation break, difficulty in protection of works, lack of innovation and other problems, which makes the non-heritage farther and farther away from the public's field of vision. This kind of traditional folk art is collected through text, pictures, video, audio, etc. and then collected and analyzed, and then innovatively displayed, which reduces the actual cost of protection and increases the path of protection and recovery.

2.2.2. Analysis of the current situation. After understanding the relevant concepts of paper horse and digital protection, it is also necessary to further summarize the status of artists and works in the current situation of protection and inheritance of traditional means of paper horse, as well as the efforts made and results achieved in the digital protection and inheritance of paper horse using digital technology at present, after the results of field research. It also draws on the successful experience of digital protection and inheritance of other non-heritage, analyzes the dilemmas and shortcomings encountered in the process of protection and inheritance, and points out the direction for the construction of the later methods.

2.2.3. Method construction. Based on the research data, we construct the method of digital conservation and restoration of paper horses according to the characteristics of paper horses, select the digital technology suitable for digital conservation and restoration of paper horses, determine the main content and path of digital conservation and restoration, analyze the new problems in the new era, and provide theoretical and methodological support for the practical research of digital conservation and restoration of paper horses.

2.2.4. Design practices. Based on the method construction of digital protection and inheritance of paper horse, combining theory and practice, firstly, on the basis of the theoretical method construction, we try to redesign the paper horse resource database to provide a platform for its digital protection. Secondly, relying on the paper horse resource database, the method of digital protection and restoration of paper horse art based on image processing technology [18] is proposed. Finally, experiments are carried out to verify the feasibility of the method proposed in this paper, such as the effect of digitized protection of paper horse art and the evaluation of the quality of image restoration.

2.3. Traditional Paper Horse Art Image Acquisition and Preprocessing

Image acquisition, using a video camera to ingest the optical image of the image intensifier is converted into a video signal and transmitted to an image capture card for digitization, forming an array of image data for computer processing and storage. In this paper, the traditional paper horse art production process as well as images of finished products were captured in several places in China (Hunan, Jiangxi, Hebei, etc.) through the fieldwork method to provide a data source for the following validation experiments.

In the process of acquisition, the missing edges and corners in the images make the images incomplete, and the images have different degrees of distortion, which require pre-processing of the acquired images.

1) Image Correction. Firstly, a mathematical model for geometric correction is established, secondly, the parameters of the model are determined using known conditions, and finally the image is geometrically corrected according to the determined model.

2) Image Filling. The image pixel points are counted to find out the pixel points where the pixel values of an image appear the most. The maximum boundary is found out by utilizing Hough straight line detection. Again find out the edges of Tibetan literature using edge detection operator. Finally the maximum boundary of the image is subtracted from the edge of the document and the resulting gap region is filled with the pixel value that occurs the most times.

3. Digital preservation and restoration of the art of the paper horse under image-processing techniques

3.1. Digital protection design

3.1.1. Protection framework. The specific process of using image processing technology to protect the art of paper horses is shown in Figure 1. The principle followed is that the whole is first followed by the local, the structure is first followed by the texture, and then combined with the characteristics of the traditional paper horse, the damaged paper horse is repaired using the restoration method based on image decomposition. The process of restoration is as follows: first judge whether it belongs to the structural or textural map, then determine the area to be restored by edge detection and manual labeling, and then use different image restoration techniques to repair it. For the structural map, first judge the main lines of the original map, and then connect the main lines in the area to be restored to complete the restoration of the structural information. For texture map according to the known information of the original image to add the necessary details, that is, texture, to get the final repair results.

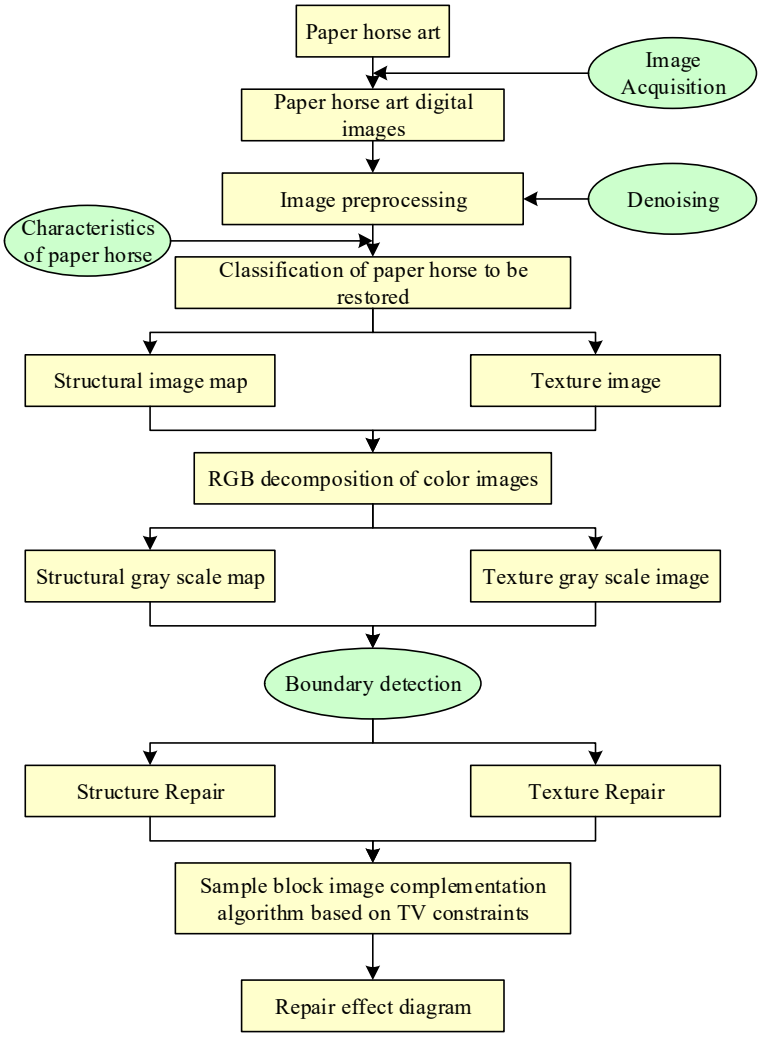

Fig. 1. Traditional paper horse art digital protection flowchart

3.1.2. Mean filter image denoising. Mean value filtering [19] is also known as linear filtering, and the main method it uses is neighborhood averaging. The basic principle is to replace each pixel value in the original image with the mean value, i.e., the current pixel point (x,y) to be processed selects a template which consists of a number of pixels in its immediate neighborhood, finds the mean value of all the pixels in the template, and then assigns the mean value to the current pixel point (x,y) as the grayscale of the processed image at the point $g(x,y)$, i.e., $g(x,y)=\frac{1}{M}\sum f \in sf(x,y)$, where s is the template, and M is the total number of pixels in that template including the current pixel.

3.1.3. Image Gray Scale Decomposition and Color Enhancement. Paper horses are generally colored, color images and grayscale image is different from the color image is composed of each other there is a certain correlation between the red, green and blue band data. In order to achieve better restoration results, choose $La\beta$ color space for channel decomposition, and then repair separately.

$La\beta$ Color space is based on data-driven research on human perception, which assumes that the human visual system is ideally adapted to the processing of natural scenery, where L is a non-color component denoting luminance values, α denotes yellow-a-blue related color values, and β denotes red-a-green related color values. The $La\beta$-color space basically eliminates the correlation between the components and is the most compatible with human visual perception, therefore, the $La\beta$-color space was chosen to be used for channel decomposition to achieve the restoration of color

images. For the broken paper horse work, the image is first transformed from RGB color space to LMS space, and then the LMS space is transformed to $La\beta$ color space. Using the transformation algorithm of $La\beta$ color space, the image of the paper horse is decomposed into three grayscale images L, ^{a}, and β according to the three channels of $La\beta$ color space.Then for each grayscale image, double histogram equalization is carried out [20] to obtain the enhanced image of double histogram equalization, and then, according to the following formula, the color restoration coefficient is computed $w_k(k = L, a, \beta)$. Taking the parameter ∂=120, the sub-images are subjected to the fusion operation to obtain the enhanced Image:

$$w_k(i,j) = \log[1 + \frac{\partial I_k(i,j)}{\sum_{n=1}^{N} I_k(i,j)}] \tag{1}$$

3.1.4. Edge detection. Cracks are mainly caused by aging, drying, thermal expansion and contraction due to temperature change, or mechanical failure, while detachment is mainly caused by natural factors such as diseases, earthquakes, or man-made damages that result in localized pigment detachment of the paper horse artwork or localized coverage of unremovable dirt scores. Detecting and dividing these defective areas is a prerequisite to assist in the diagnosis and virtual restoration of paper horse art. Detection steps [21]:

1) Filtering. Edge detection is mainly based on derivative calculations but is affected by noise. The filter reduces the noise and at the same time leads to a loss of edge strength.

2) Enhancement. Enhancement algorithms highlight points in the domain that have significant changes in gray scale. This is generally done by calculating the gradient magnitude.

3) Detection. However, in some images with large gradient magnitude are not edge points.

4) Localization. Determine the location of the edge precisely.

3.2. Traditional Paper Horse Art Image Recovery Methods

3.2.1. Paper Horse Art Image Restoration Algorithm. Among many broken image restoration algorithms, the common one is the image restoration algorithm based on partial differential equations. Suppose an image is $f(x,y)$, which has been geometrically distorted into $g(u,v)$, where, (u,v) represents the coordinates of the distorted image rather than the coordinates of the original image (x,y). The above change can be expressed as:

$$u = r(x,y) \tag{2}$$

$$v = s(x,y) \tag{3}$$

Here, $r(x,y)$ and $s(x,y)$ are spatial transformations that produce the geometrically distorted image $g(u,v)$.

Assuming that the functions are known to be $r(x,y)$ and $s(x,y)$, then the corresponding pixel coordinates can be calculated from the known conditions. In the case where $r(x,y)$ and $s(x,y)$ are known, this can be expressed as an approximate polynomial:

$$u = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} a_{ij} x^i y^j \tag{4}$$

$$v = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} b_{ij} x^i y^j \tag{5}$$

where N is the number of polynomials and a_{ij} and b_{ij} are the coefficients of each.

1) Geometric correction with known conditions $r(x,y)$ and $s(x,y)$. The geometric correction is categorized into the following two methods:

Direct method. A corrected image is generated by introducing $\begin{cases} x = r'(u,v) \\ y = s'(u,v) \end{cases}$ from $\begin{cases} u = r(x,y) \\ v = s(x,y) \end{cases}$, then keeping the gray value of each pixel constant, calculating the corrected coordinate value for each pixel with irregular pixel distribution.

Indirect method. Assuming that the pixels of the recovered image are intersections of an equidistant grid within the base coordinate system, from the coordinates (x,y) of the grid intersections, the coordinates (u,v) can be computed on a known geometrically distorted image, i.e:

$$(u,v) = [r(x,y), s(x,y)] \tag{6}$$

2) Geometric distortion under unknown conditions of $r(x,y)$ and $s(x,y)$. Assume that the relationship between the spatial coordinates of the pixels of the reference image (x,y), and the spatial coordinates of the corresponding pixels of the image to be corrected (u,v) is represented by a binary polynomial with the following expression:

$$u = r(x,y) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} a_{ij} x^i y^j \tag{7}$$

$$v = s(x,y) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} b_{ij} x^i y^j \tag{8}$$

In the above equation, the coefficients to be determined for each are a_{ij} and b_{ij}, and the polynomial is of order N

For linear distortion:

$$u = r(x,y) = a_{00} + a_{10}x + a_{01}y \tag{9}$$

$$v = s(x,y) = b_{00} + b_{10}x + b_{01}y \tag{10}$$

For general (nonlinear) quadratic distortion:

$$u = r(x,y) = a_{00} + a_{10}x + a_{01}y + a_{11}xy \tag{11}$$

$$v = s(x,y) = b_{00} + b_{10}x + b_{01}y + b_{11}xy \tag{12}$$

The distortion image is created based on the spatial position of the corrected image in relation to the other pixels and the position of the "connection" in the image, and the corrected image distortion is accurately obtained. It is assumed that the process of geometric distortion in the quadrilateral region can be expressed by the quadratic distortion equation as follows:

$$r(x,y) = a_{00} + a_{10}x + a_{01}y + a_{11}xy \tag{13}$$

$$s(x,y) = b_{00} + b_{10}x + b_{01}y + b_{11}xy \tag{14}$$

Substituting the above two expressions into equations (2) and (3) is shown below:

$$u = a_{00} + a_{10}x + a_{01}y + a_{11}xy \tag{15}$$

$$v = b_{00} + b_{10}x + b_{01}y + b_{11}xy \tag{16}$$

Since there are four pairs of "connection points", substituting Eq. (15) and Eq. (16) yields eight simultaneous equations, which can be solved for eight coefficients, and as long as the coefficients are available, recovering the image becomes very simple. If one knows where $f(x_0, y_0)$ is mapped in the distorted image, one can find the value of (x_0, y_0) at any point of the nonlinear distorted image. Thus, (x_0, y_0) can be substituted into Eqs. (15) and (16) to obtain the geometric distortion coordinates (u_0, v_0). The value that is mapped to point (u_0, v_0) in the distortion-free image is $g(u_0, v_0)$. Thus, the

value of the recovered image is $\hat{f}(x_0, y_0) = g(u_0, v_0)$.

3.2.2. Convolution-based recovery strategy. The basic idea and method of convolutional recovery:

The principle is to back-project the data image from each direction to the direction of each position, if multiple projection directions in each direction there is an inverse projection, you can set up a plane of multiple parts. In this case, the more common treatment is to recover the convolutional backprojection. By a variation of the algorithm, the projection theorem is operationalized and solved based on the Fourier transform. Following the standard definition of the two-dimensional Fourier inverse transform, there are $f(x,y) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} F(u,v)e^{j2\pi(ux+vy)}dudv$, making the substitution: $u = R\cos\theta$, $v = R\sin\theta$.

Write in the form of polar coordinates (R,θ):

$$f(x,y) = \int_0^{2\pi}\int_0^{+\infty} F(R,\theta)e^{j2\pi(x\cos\theta+y\sin\theta)}RdRd\theta \tag{17}$$

Using the Fourier transform conjugate symmetry, there:

$$f(x,y) = \int_0^{\pi+\infty}\int_{-\infty}^{+\infty} F(R,\theta)e^{j2\pi(x\cos\theta+y\sin\theta)}|R|dRd\theta \tag{18}$$

Order:

$$f'(x,y;\theta) = \int_{-\infty}^{+\infty} e^{\rho 2\pi(x\cos\theta+y\sin\theta)}|R|F(R,\theta)dR \tag{19}$$

Then it can be expressed as:

$$f(x,y) = \int_0^{\pi} f'(x,y;\theta)d\theta \tag{20}$$

When the FFT is used to compute the Fourier transform $F(R,\theta)$ of the projected data, the projected data $g(\rho,\theta)$ is always finitely truncated. When the sampling interval of ρ is d, the variation in the transform domain R ranges from $-1/2d$ to $1/2d$, and so the projection inverse transform recovery formula can be written approximately as:

$$f(x,y) \approx \int_0^{\pi}\int_{-\frac{1}{2d}}^{\frac{1}{2d}} |R|F(R,\theta)e^{j2\pi R(x\cos\theta+y\sin\theta)}dRd\theta \tag{21}$$

Markers are used:

$$h(\rho) = \int_{-1/2d}^{1/2d} |R|e^{j2\pi R\rho}dR \tag{22}$$

This can be shown in conjunction with the Fourier projection theorem:

$$\begin{aligned} f'(x,y;\theta) &= \int_{-1/2d}^{1/2d} |R|F(R,\theta)e^{j2\pi R(x\cos\theta+y\sin\theta)}dR \\ &= \int_{-1/2d}^{1/2d} |R|\left[\int_{-\infty}^{+\infty} g(\rho,\theta)e^{-j2\pi R\rho}\right]e^{j2\pi R(x\cos\theta+y\sin\theta)}dR \\ &= \int_{-\infty}^{+\infty} g(\rho,\theta)\int_{-1/2d}^{1/2d}|\mathrm{Re}^{j/2\pi R(x\cos\theta+y\sin\theta-\rho)}\,dRd\rho \\ &= \int_{-\infty}^{+\infty} g(\rho,\theta)h(x\cos\theta+y\sin\theta-\rho)d\rho \end{aligned} \tag{23}$$

Convolutional projection is equivalent to first filtering the data and then back-projecting the results back, convolution can be seen as a means of filtering, so that the data image can be corrected.

4. Analysis of the effects of digital preservation and restoration of traditional paper horse art

4.1. Evaluation of image color enhancement performance

In order to verify the effectiveness of the image processing techniques, a comparison is made between the method of this paper and HE color image enhancement algorithm with segmentation based color image algorithm and Retinex theory color preserving color image enhancement algorithm.

Fig. 2 and Fig. 3 show the original image of the traditional paper horse as well as the histogram of the $La\beta$-color spatial decomposition after enhancement, respectively. Combining the two figures, it can be seen that the histogram of the original image is concentrated in the middle and low ranges (<300), which indicates that the image is darker overall and the details are not prominent. After enhancement by the method of this paper, the dynamic range of the histogram remains basically the same, and there are individual pixel changes, the enhanced paper horse art image, the contrast is significantly improved, the details are remarkable, and no pseudo-colors are produced.

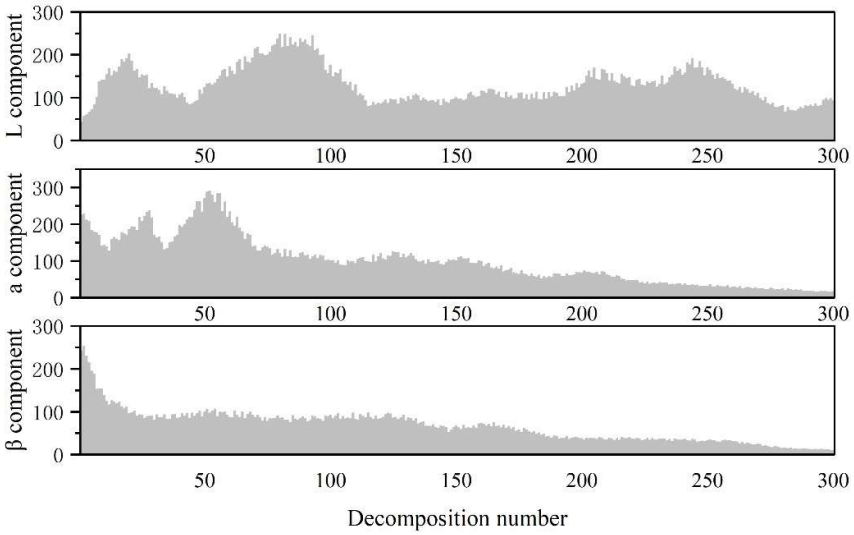

Fig. 2. Original graph component histogram

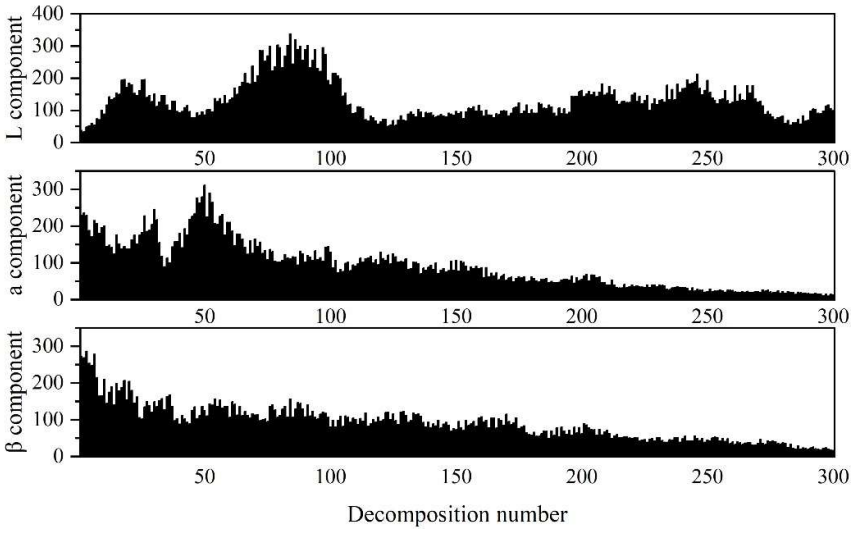

Fig. 3. Enhanced graph component histogram

To evaluate the image enhancement effect from an objective point of view, it mainly relies on the

parameters such as mean value, information entropy and peak signal-to-noise ratio (PSNR) of the image.In this section, the same image is evaluated for the image enhancement effect among different algorithms. After measurement, the mean value of the original image is 114.67 and the information entropy is 6.713 (J/K).

The peak signal-to-noise ratio (PSNR) is calculated as follows:

$$PSNR = 10\log_{10}\left[\frac{\left[Max(f(x,y))\right]^2 \times M \times N}{\sum_{x=1}^{M}\sum_{y=1}^{N}\left[g(x,y)-f(x,y)\right]^2}\right] \tag{24}$$

Table 1 shows the comparison results of parameters of different enhancement algorithms. As can be seen from the figure, the average value of this paper's method for paper horse image enhancement is higher than the comparison algorithm by 9.09~32.05, PSNR is improved by 16.72%~34.63% compared with other algorithms, and the information entropy is 7.961, which is the highest among all the algorithms, which emphasizes that this paper's method is highly efficient and high-quality, and it can obtain a clear and detail-maintaining enhanced image.

Table 1. Comparison results of different enhancement algorithm parameters

Algorithm	Mean	Information entropy	PSNR
He enhancement algorithm	121.56	7.435	31.64
Segmentation enhancement algorithm	101.79	7.446	27.43
The retinex enhancement algorithm	124.75	7.239	28.14
Ours	133.84	7.961	36.93

4.2. Comparative Analysis of Clarification Effects

In order to further verify the reliability of the results of this paper, the experimental results of this paper are compared with other methods for paper horse art restoration clarity, and five stained paper horse art images are randomly selected for the experiment. The comparison methods are MSR algorithm, dark channel a priori algorithm and resolution reconstruction method, including the method of this paper, which are recorded as methods 1-4 in turn.

The comparison results of different algorithms' clarification effects are shown in Fig. 4. As can be seen from the figure, for the five paper horse art images selected for the experiment, this paper's method obtains the highest average gradient value, which is improved by 25.27%~339.39% compared with the comparison method. It shows that after the proposed method of this paper for paper horse art image clarity processing, the image guarantees more details and is better than other methods in terms of clarity, which further verifies the effectiveness of this paper's method for paper horse art image recovery.

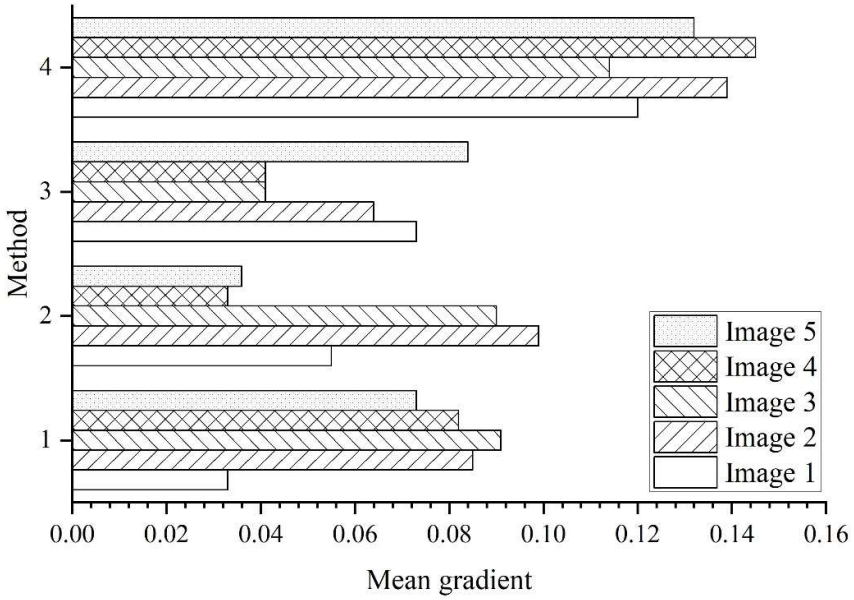

Fig. 4. Comparison results of different algorithms

4.3. Quality Assessment of Paper Horse Art Restoration

The images to be restored used in this section are all the images captured and preprocessed in the above paper, and for the convenience of analyzing and illustrating the experimental process and results, the five traditional paper horse sample images are denoted as Restoration work 1-5.In order to validate the restoration performance of the restoration algorithm proposed in this paper, the restoration results are compared with the image contrasts of the great likelihood estimation algorithm (MLE), the projected on convex set method (POCS), and the MAP estimation based on gradient penalty function (MAP-H) algorithm.

The Dual Stimulus Continuous Quality Grading (DSCQS) method, i.e., the subjective recovery quality evaluation was performed for the to-be-determined images by dividing the recovery grades into 1-5, with an incremental increase from poor to very good. Peak signal-to-noise ratio (PSNR), and structural similarity (SSIM), two objective quality evaluation indexes were constructed at the same time, and the larger the ratio of the evaluation indexes, the better the quality of the recovered image.

Assuming that a and b represent the original image and the restored image, respectively, the SSIM evaluation model is:

$$SSIM(x,y) = l(x,y)^{\alpha} \cdot c(x,y)^{\beta} \cdot s(x,y)^{\gamma} \tag{25}$$

Table 2 shows the subjective quality evaluation ratings of the recovered images. From the table, it can be seen that the five images recovered by this paper's method have achieved a high subjective evaluation, with an evaluation grade $\geqslant$ 4, i.e., this paper's method is basically or even completely capable of removing the stains and noise in the images of the paper horses, and realistically conveying the information of traditional paper horse art.

Table 2. Subjective quality evaluation level of restored image

Image name	Recovery quality grade	Quality description
Restoration work 1	4	Stains and noise are basically filtered out
Restoration work 2	5	The stain and the noise are completely filtered out and the image is exquisite
Restoration work 3	4	Stains and noise are basically filtered out

Restoration work 4	4	Stains and noise are basically filtered out
Restoration work 5	5	The stain and the noise are completely filtered out and the image is exquisite

In this section of the algorithm experimental process, for the selection of the number of iterations, a number of experiments are carried out. 5 sample images of each iteration of the output image for the calculation of the PSNR value, it is necessary to select the best performance and the least number of iterations according to the change in the PSNR value of the output image.

The trend of change in PSNR values of the five recovered images with the number of iterations is shown in Fig. 5. From the folded line in the figure, it can be seen that the beginning of the image quality slowly improve, but with the increase in the number of iterations of the algorithm, the objective evaluation index will be due to the growth of the number of iterations brought about by the system memory overhead to reach the peak, and then followed by a decline in the original image of the early manipulation of the destruction of the quality of the quality of the phenomenon of degradation and distortion. When the algorithm is iterated for the 10th time, the PSNR values of the five images are the highest, and when iterated for the 11th time, the PSNR values of the images begin to decline. To summarize, the proposed algorithm in this paper iterates 10 times will give the most desirable results of restoration.

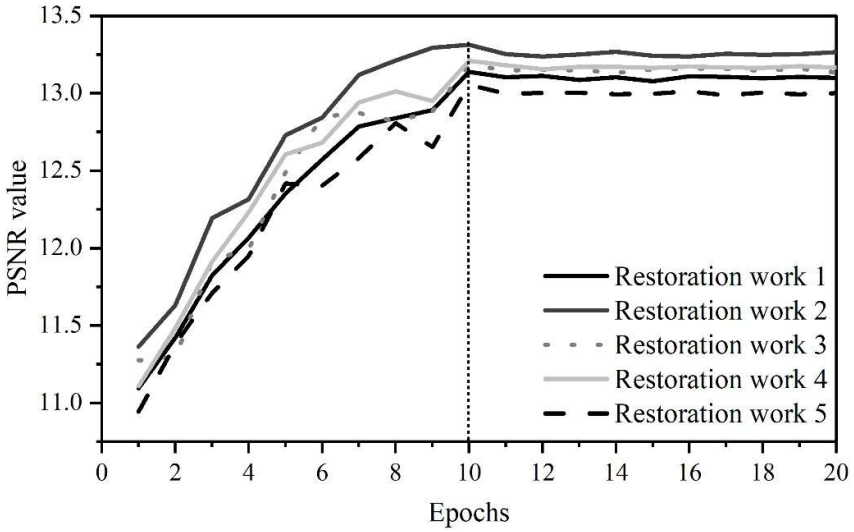

Fig. 5. PSNR value curve of each iteration

Fig. 6 shows the comparison results of objective evaluation indexes of recovered paper horse images by each algorithm. It can be clearly seen from the figure that this paper's method has increased in PSNR and SSIM values compared with the restoration results of other algorithms. Among them, the PSNR value of this paper's method in five restored works is between 13.056 and 13.312, which is increased by 1.23% to 3.92% compared with the comparison algorithms, and the SSIM value is even improved by 0.97% to 5.23%.

In summary, the method in this paper has relatively good performance in both subjective and objective traditional paper horse image recovery quality evaluation, and the performance of recovered images is good.

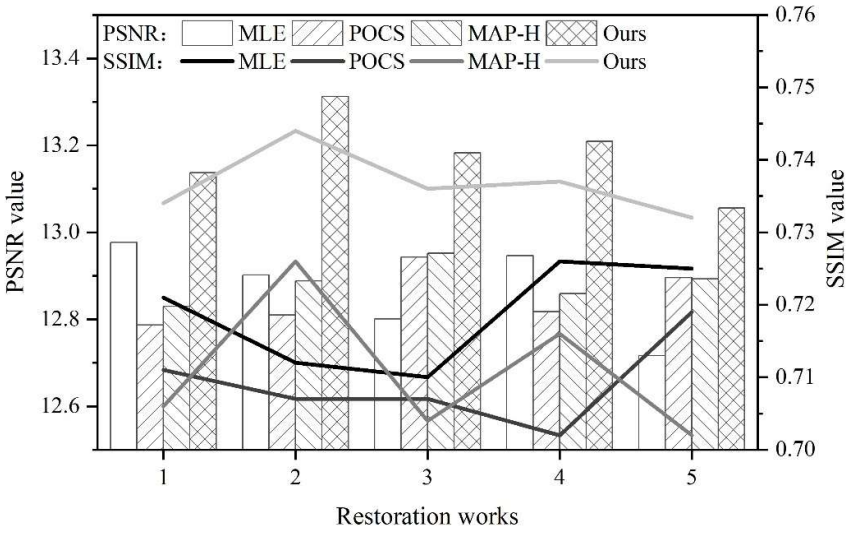

Fig. 6. Objective quality parameters of restored image by each algorithm

4.4. Comprehensive study of protection and restoration effects

This section is designed to include five dimensions of digital recording of art information, digital display, efficiency and reproducibility, storage and transmission, and art restoration, which are recorded as dimensions 1-5 in order, and each dimension is equipped with four related dimensions to evaluate the effect of the method proposed in this paper on the digital preservation and restoration of the traditional paper horse art through a questionnaire survey.

The investigators are mainly community residents, tourists, inheritors, and scholars who understand the current situation of traditional paper horse art. The survey method was a combination of on-site questionnaire and online questionnaire, supplemented by interview method. The five evaluation dimensions of the digital protection of traditional paper horse art were designed as Likert five-level scale questions to explore the respondents' evaluation of the digital protection effect of traditional paper horse art, among which the five-level scale corresponded to the numbers "1", "2", "3", "4" and "5" in the questionnaire, representing the attitudes towards the questionnaire questions were "very disagree", "disagree", "general", "agree" and "very agree". That is, the protection and recovery effects of the variables corresponding to this question are "very bad", "bad", "fair", "good", and "very good" respectively.

A total of 100 valid questionnaires were recovered in this study, and through subsequent data processing, the average score of each dimension was obtained as shown in Figure 7. As can be seen from the data in the figure, the comprehensive score of the effect of digital conservation and restoration of traditional paper horse art is 4.23, indicating that the effect of digital conservation of traditional paper horse art is better. Specifically, the average scores of digital recording, digital display, efficiency and reproducibility, storage and transmission, and artistic restoration are 4.13, 4.33, 4.02, 4.48, and 4.18 in turn, with different degrees of differences between different evaluation dimensions, and combined with the data in the figure, the investigators have the same differences in the recognition on the same dimensions, i.e., a higher degree of dispersion, such as dimension 3 (digital display), the difference between the maximum value and the minimum value is 1.89 points, indicating that there is still some room for improvement using the method of this paper.

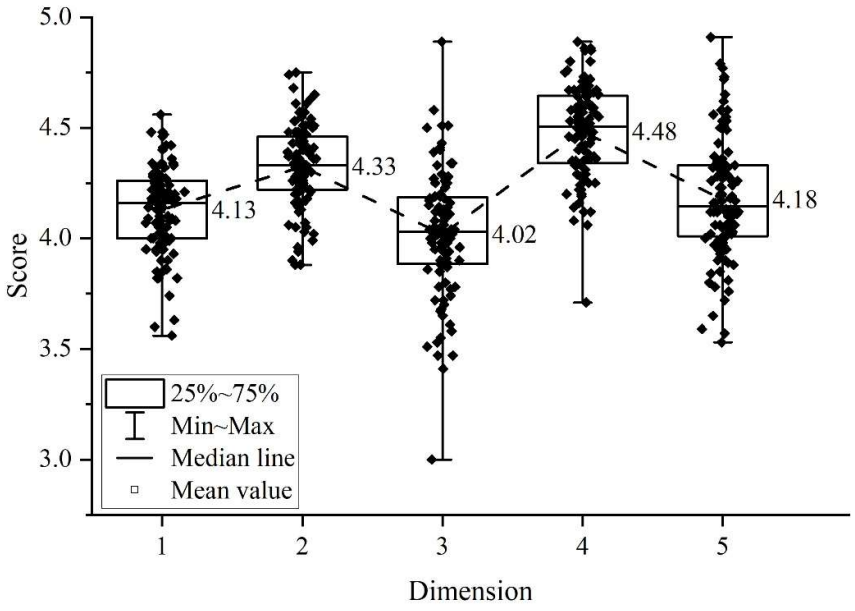

Fig. 7. Average scores per dimension

5. Conclusion

The article designs the method of digital conservation and restoration of traditional paper horse art from the level of research purpose and content, and collects images of paper horse art from many places to provide data basis for the later image conservation and restoration. The research adopts image processing technology to carry out experiments, using mean value filtering, image gray scale decomposition and color enhancement as well as edge detection, and combining with image restoration algorithms to realize the digital protection and restoration of traditional paper horse art. The method of this paper has a significant effect on the image enhancement of the paper horse art, the average value of which is 9.09~32.05 higher than that of the comparison algorithm, and the average gradient value of the clarity effect of this paper's method on the image is 0.114~0.145, which can show the details of the paper horse image more clearly. For the quality of paper horse image restoration, the method in this paper achieves better results from both subjective and objective perspectives. In terms of digital protection and restoration effect, the comprehensive score of this paper's method is 4.23, which is a better performance.

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