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Extraction method of Yuan blue and white porcelain pattern based on multi-scale Retinex and histogram multi-peak threshold segmentation

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Abstract

Aiming at the problem of "crystallization" on the surface of Yuan blue and white ceramics, which causes reflections and loss of image texture, an image processing method is proposed to repair the image texture information. A multi-scale Retinex pre-processing method is proposed to enhance the contrast between the pattern and the background. A color factor is introduced to prevent color distortion. A weighted average function is constructed to enhance image details and improve texture information. The Yuan blue and white pattern can be effectively segmented from the background using a combination of multi-peak thresholding for segmentation and other techniques. The experimental results demonstrate that, in comparison to other algorithms, the multi-scale Retinex and histogram multi-peak threshold coupled segmentation method proposed in this paper exhibits the highest F1-score of 0.03067 and an accuracy of 92.67% in cross-evaluation with other algorithms. This indicates that the overall performance of the algorithm is the best. The proposed method has the potential to inform the protection of cultural relics.

Keywords Yuan blue and white patterns, Multi-scale Retinex, Histogram multi-peak threshold segmentation, Pattern extraction, Cultural relics protection

Introduction

The Yuan blue and white porcelain is a pivotal work in the history of Chinese ceramics. It marks the transition from plain porcelain to colored porcelain and represents the crystallization of direct cultural exchanges between Central Asia. Jingdezhen, previously a kiln town, became renowned as a porcelain capital due to this development [1, 2]. The unique combination of technology and artistry in the ceramic industry represented by Yuan blue and white porcelain has established a leading position on the global stage, with high archaeological value [3, 4]. The immaturity of the protection technology has resulted in the damage and pollution of some ancient Yuan blue and white porcelain [5, 6]. To facilitate the advancement of ceramic archaeology, the value of Yuan blue and white porcelain is examined, and the digital collection and application of ancient ceramics are promoted. This is achieved through the use of machine vision technology, which is employed to extract patterns characteristic of Yuan blue and white porcelain [7, 8]. The images that are restored through the use of image processing can be considered to be powerful historical material evidence. Furthermore, they assist the development of the

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cultural tourism industry and can be regarded as digital supplements to Jingdezhen's ancient ceramic gene bank. The advent of artificial intelligence and the concomitant development of machine vision technology has led to an increasing prevalence of image processing applications, particularly in the domain of image texture detail processing [9–11]. Different algorithms have different extraction effects and image processing capabilities. To ensure that the Yuan blue and white porcelain pattern and color are not affected by the reflected light intensity, and to extract the Yuan blue and white porcelain pattern completely, a multi-scale Retinex algorithm is proposed and color factors are introduced to repair the defects of local color distortion in the image.

A multi-scale Retinex algorithm is proposed based on the optical three-color theory and color constancy theory [12–14]. The algorithm is capable of compressing the dynamic range of the image while maintaining its fidelity, and it can also enhance colors, achieve color constancy, and apply global and local dynamic range compression. Wang et al. [15, 16] proposed a low-light image enhancement algorithm based on frame accumulation and multi-scale Retinex to jointly process low-light images, aiming at problems such as image information loss, low signal-to-noise ratio and edge blurring caused by low visible light and noise. The results show that the peak signal-to-noise ratio of the image processed by the combined enhancement algorithm is increased by 1.799 dB. Muniraj et al. [17] proposed underwater image enhancement based on adaptive color correction and improved the Retinex algorithm to carry out an adaptive color correction on underwater distorted images to effectively solve the color bias problem. The improved Retinex algorithm was used to enhance the edge part and obtain the edge-enhanced image. Zhuang et al. [12] proposed a Bayesian Retinex algorithm for underwater single image enhancement based on multi-order reflection and gradient, which transforms the complex underwater image enhancement problem into two simple denoising problems. This model achieves high speed in pixel computation, eliminates color bias, and restores the naturalness of the image. Liu et al. [18] proposed a rapid, low-light image enhancement algorithm based on Retinex. This algorithm restores information obscured by low illumination, estimates illumination images through adaptive gamma correction, and employs the Retinex model to realize a brightness model. The experimental results demonstrate that the enhanced image exhibits favorable qualitative and quantitative evaluation. The above method fully demonstrates the method of the Retinex algorithm for image enhancement and correction in a low-light environment, ignoring the extraction of image texture segmentation. For those studying the Yuan dynasty blue and white porcelain, the Yuan blue and white surface is an essential starting point in understanding the production process of this type of ceramics. It is also an important vehicle for connecting the craftsmanship, aesthetics, and history of Yuan blue and white production, and even cultural heritage. That fully conveys the artistic and social value of Yuan blue and white. The proposed multi-scale Retinex with histogram multi-peak thresholding segmentation method is to further optimize the Retinex algorithm for image recognition, restoration, and enhancement of images in low-light and complex environment images. The image is segmented into different color regions based on the histogram multi-peak thresholding method, which identifies and separates the Yuan blue and white texture.

To address the issue of missing texture on the surface of Yuan blue and white images, we propose a method for extracting Yuan blue and white patterns. This method is based on multi-scale Retinex and histogram multi-peak threshold segmentation. The Retinex preprocessing method uses a weighted average function to enhance image details and improve texture information. Additionally, a multi-peak threshold segmentation method is employed to improve the poor effect of single-peak grayscale images. This method effectively enhances the details and texture information in the image and significantly improves the accuracy of image segmentation. This is of great significance in the field of cultural relics protection and restoration.

Element Yuan blue and white feature analysis and algorithm flow chart

Analysis of Yuan blue and white characteristics

Yuan blue and white is a treasure of Chinese ceramic art. However, due to immature preservation technology during inheritance, the pattern may be contaminated or the Yuan blue and white may be broken or missing. To create a digital exhibition hall, pictures of the Yuan blue and white ancient ceramics are needed, and texture features will be extracted from these pictures. Due to the clean surface of Yuan blue and white, the photography process may reflect bright spots, causing the pattern to appear missing. A comprehensive analysis of the Yuan blue and white textiles is presented in Fig. 1.

Figure 1a depicts the Yuan blue and white image, which is comprised of four components. The Yuan blue and white image comprises four components: the Yuan blue and white image itself, the Yuan blue and white background, the Yuan blue and white reflective features, and the Yuan blue and white missing features. Figure 1b1–b2 shows detailed features, with b1 representing the reflective features of Yuan blue and white. These features are a result of the molecular movement of the glaze during formation, which leads to the

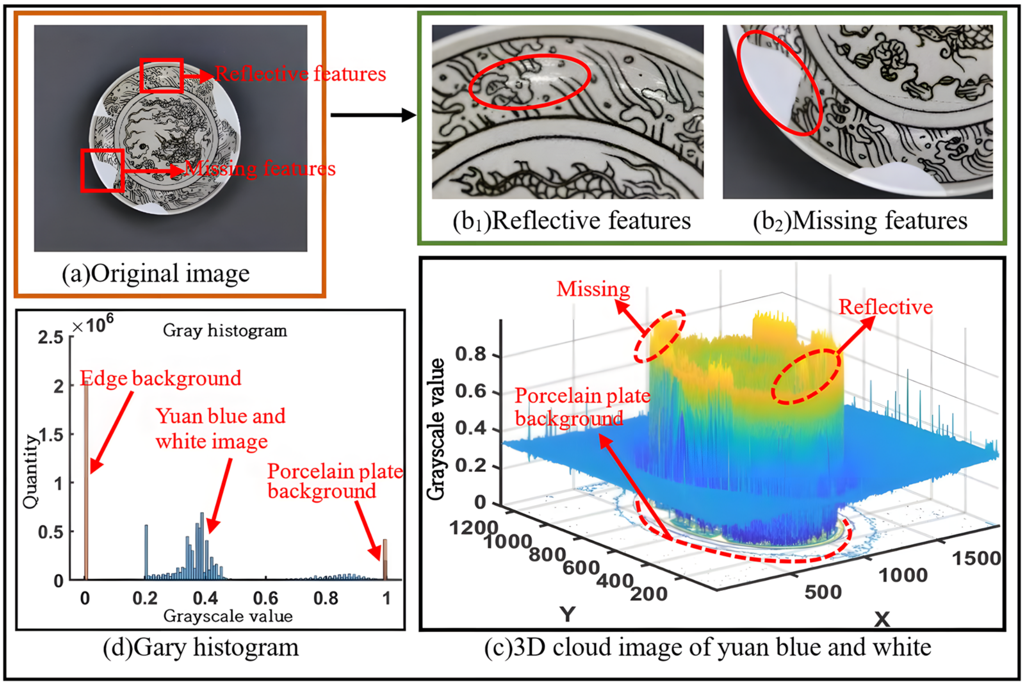

Fig. 1 Analysis of texture features of Yuan blue and white

formation of crust or adsorption of impurities in the pulp. As Yuan blue and white ceramics age, the molecular structure of the glaze becomes more orderly, resulting in a 'crystallization' effect. The Yuan blue and white pattern on b2 is incomplete, likely due to improper preservation or other damage that caused the porcelain to break and the pattern to be lost. Figure 1c shows the three-dimensional cloud image of Yuan blue and white. The reflective and missing features in the Yuan blue and white image are shown in yellow. The dark blue portion of the bottom near the XY side of the axis is shown as the background of the ceramic disk. Figure 1d shows the grayscale histograms. The grayscale value of "0" represents the background of the Yuan blue and white edge, which is entirely black. The grayscale value of "1" corresponds to the background of the Yuan blue and white porcelain plate. Furthermore, the distribution of information in the central portion of the image about the Yuan blue and white porcelain is more concentrated overall.

The Yuan blue and white image features a realistic depiction of the 'Rui beast' totem in the middle, with concentrated and complex information distribution. The surrounding features are nearly symmetrical cycles. To improve the extraction and segmentation of Yuan blue and white, a method based on multi-scale Retinex and histogram multi-peak threshold segmentation is proposed. This method comprehensively extracts the Yuan blue and white pattern features and related information while avoiding the influence of irrelevant information.

Algorithm flow chart

To enhance the digital protection of ancient ceramics and advance archaeological science and technology, a method for extracting complex pattern information from Yuan blue and white ceramics was developed. The method utilizes a multi-scale Retinex and histogram multi-peak threshold segmentation coupling to improve clarity and contrast. See Fig. 2 for the algorithmic flowchart.

The reflective part of the Yuan blue and white pattern undergoes gray stretching and binarization. This separates the ancient ceramics from the background. The morphological 'holes' function is then applied to fill the middle white area of the binarized image. Contour recognition detection is used to extract the outline of the background information, resulting in a large background of Yuan blue and white. The RGB image is converted to LAB and the brightness channel is extracted. A Gaussian surround function is constructed and applied separately to each scale, with the result normalized. A weighted average function is then created and applied to each channel, avoiding interference between them and producing a more accurate result. Determine the maximum and minimum gray values, as well as the initial threshold value, Segment the Yuan blue and white image into pattern and background using a threshold value. Then, determine the

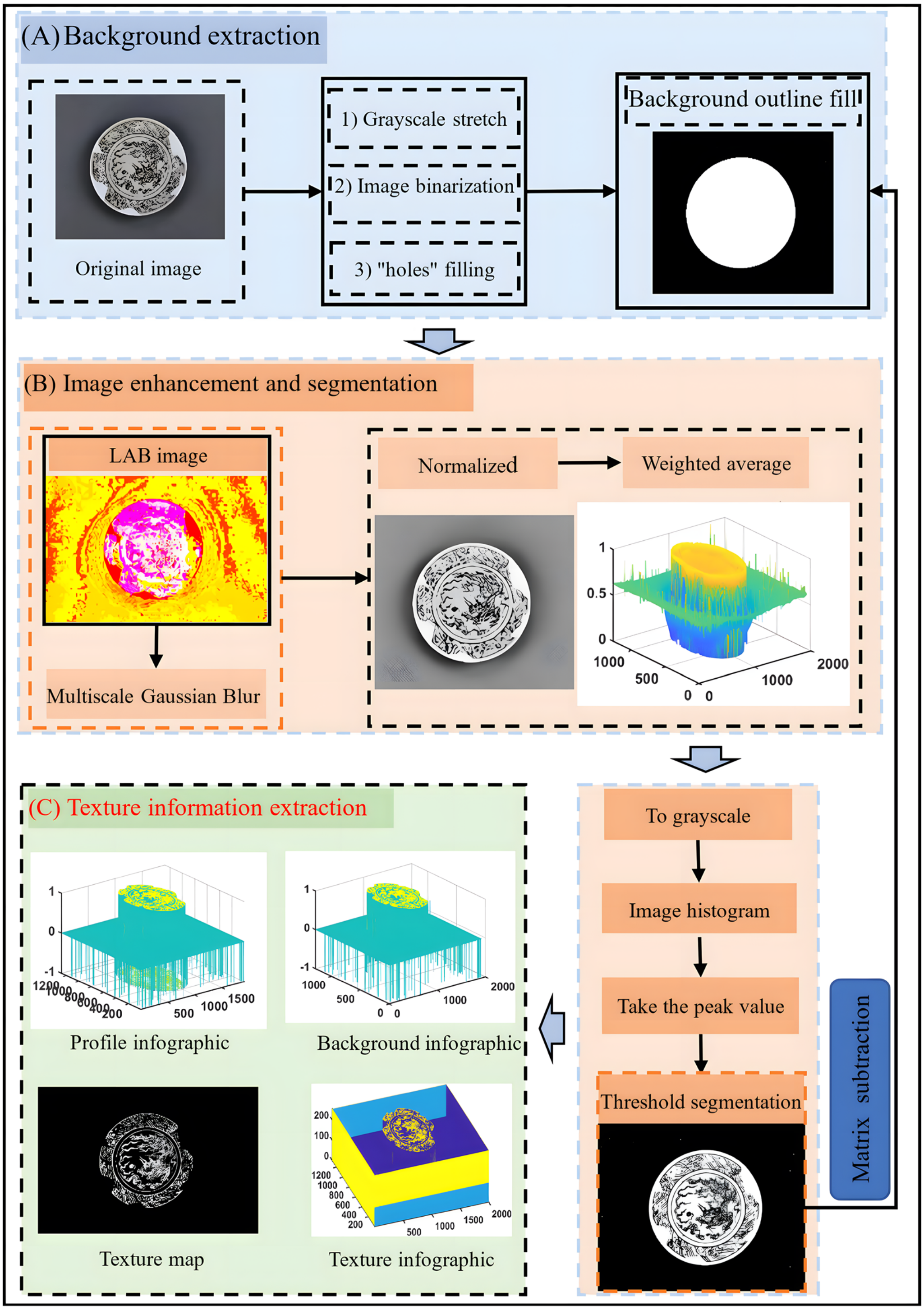

Fig. 2 Flow chart of the blue and white pattern extraction algorithm for multi-scale Retinex and histogram multi-peak threshold segmentation

average gray value and compare it to the initial threshold value to ensure consistency. Histogram multi-peak thresholding is utilized to segment the enhanced image, extract the histogram multi-peak threshold and the multi-peak threshold position, and use the intermediate value between the multi-peak thresholds as the threshold for image segmentation. This improves the clarity and contrast of Yuan's blue and white pattern extraction.

The pattern is extracted by subtracting the pattern background information matrix and the Yuan blue and white background information matrix. This is done after image enhancement and segmentation using a two-dimensional matrix operation method.

Multi-peak threshold segmentation algorithm based on multi-scale Retinex and histogram

Multi-scale Retinex algorithm enhancement

Multi-scale Retinex is an image enhancement technology, based on the Retinex theory, image contrast and clarity are enhanced through multi-scale image fusion [19]. The multi-scale Retinex algorithm employs a process of multiple sampling and fusion of the original image, to gradually restore the inherent properties of the image, including color, brightness, and contrast. The details of the multi-scale Retinex enhancement effect are illustrated in Fig. 3, it depicts the flow chart of the aforementioned process.

The Multi-scale Retinex method allows for the simultaneous maintenance of high fidelity in images while also compressing the dynamic range of images. The RGB image is converted into a LAB image and the luminance channel is extracted. Different scale parameters and stabilization coefficients are set by analyzing the characteristics of the image. The most suitable scale parameter is selected based on the effect of comparing different results. The stabilization coefficient is used to control the stability of Gaussian blur in Retinex algorithm, which is usually taken as a constant value, and in most cases, the stabilization coefficient is set to 1. It constructs Gaussian surround functions, applies Gaussian blur processing to each scale, calculates the Retinex results, and normalizes the obtained results to obtain the average Retinex value of the luminance channel. A weighted averaging function is created to obtain the weighted average of the results obtained for each channel, avoiding mutual interference of weights between different channels and obtaining more accurate results. The process for calculating the Retinex results is as follows:

$$retinex = \log(lChannel + \in) - \log(blur + \in) \tag{1}$$

The following functions are represented: *log()* the natural logarithm function, *lChannel* the luminance channel, *blur* the image after Gaussian blur, and ∈ the stability coefficient, which is typically set to 1. The weighted averaging function is created as follows:

$$weight = scales(i) - scales(i-1) \tag{2}$$

$$result = 255result + weight \times retinex \tag{3}$$

Among them, *weight* are weights, *i* for each scale. The weighted averaging method can avoid mutual interference of weights between different channels and achieve more accurate results.

The multi-scale Retinex algorithm represents an effective technology for enhancing images. It employs a step-by-step analysis and processing of images to achieve this enhancement. In this paper, first apply multi-scale processing to the element blue glaze image, extracting

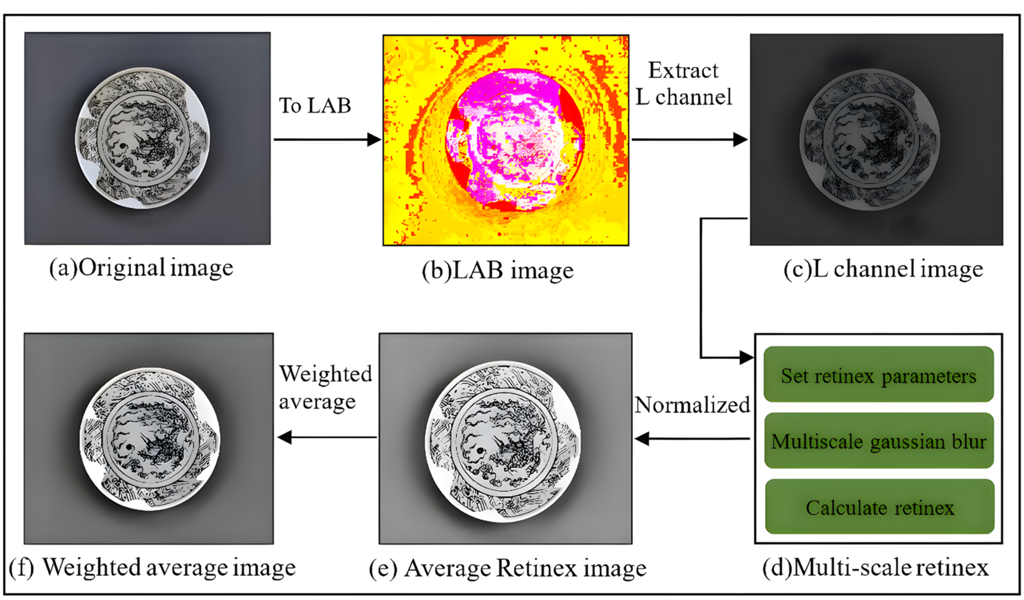

Fig. 3 Multi-scale Retinex enhancement effect flow chart

features at different scales. Construct a weighted averaging function to fuse the feature maps obtained at different scales, generating multi-scale images. The detailed effect is shown in Fig. 4 multi-scale Retinex enhancement effect diagram.

Figure 4a depicts the color value distribution diagram of the original RGB image, which is divided into three channels R, G, and B. The frequency of the R channel is the greatest. The enhanced image is subjected to multi-scale Retinex processing, which involves multi-scale analysis of the Yuan blue and white images. Features are extracted at different scales and a weight average function is constructed to fuse the feature maps of different scales. This generates multi-scale images. The color value distribution diagram of the RGB image is shown in Fig. 4b. The frequencies of the three channels of R, G, and B of the enhanced image are found to be the same. The vertical coordinates of the two graphs indicated that the frequencies of the three channels of R, G, and B of the enhanced image were all reduced and the same.

Histogram multi-peak threshold segmentation

The traditional binarization segmentation method is known to be rigid and inflexible. This paper presents an adaptive segmentation method based on gray-level multi-peak threshold features that overcome these limitations. The method is improved based on the bimodal algorithm to enhance its performance. The segmentation effect is demonstrated in the histogram multi-peak threshold segmentation effect diagram in Fig. 5.

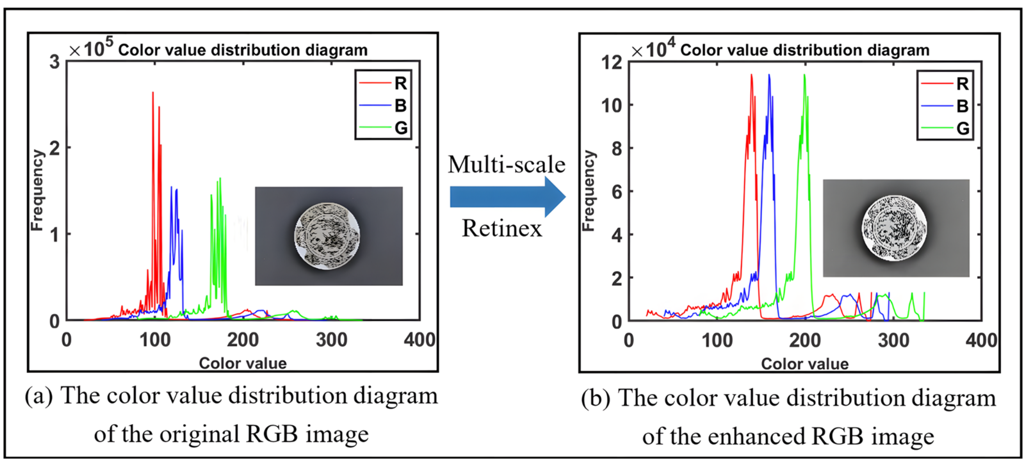

Fig. 4 Comparison of multi-scale Retinex enhancement effects

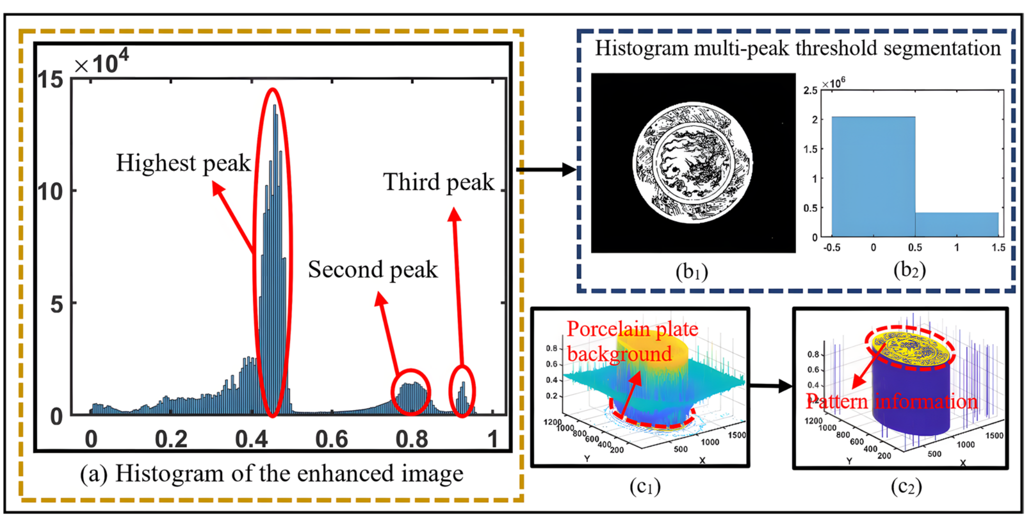

Fig. 5 Histogram multi-peak threshold segmentation effect diagram

Figure 5a is the histogram of the enhanced image, the histogram has three multimodal thresholds, are the highest peak, the second peak, and the third peak, respectively, extract the multipeak threshold and multipeak threshold position of the histogram, compute the distance between multimodal thresholds, find the two multimodal thresholds with the largest distance, if there are only two multi-peak thresholds, the image is segmented directly using the Otsu algorithm, for the case of more than two multimodal thresholds, use the median value between each multimodal threshold as the threshold for segmentation. The graph (b1) is obtained through histogram threshold segmentation. The segmentation of the Yuan blue and white textures is relatively complete. Figure 5b2 is the histogram after segmentation. The improved multi-peak threshold segmentation algorithm in this paper was used to divide the pixels of the image into binary images with a 0 and 1 distribution from 0 to 255. Figure 5c_1 is the three-dimensional cloud image after image enhancement, you can see the outline of Yuan blue and white, after histogram multi-peak threshold segmentation, the image (c_2) is a segmented three-dimensional cloud image, you can see the Yuan blue and white pattern, significantly improved the clarity of Yuan blue and white pattern segmentation. In the operation of extracting the multi-peak threshold and multi-peak threshold position of the histogram, the process is as follows:

$$[pks, locs] = findpeaks(hist\_data) \tag{4}$$

Among them, *pks* is the multi-peak threshold of the histogram, *locs* the multi-peak threshold position of the histogram, *hist_data* is a set of data that generates a histogram. After extracting the multi-peak threshold position, calculate the distance between the multi-peak thresholds, the process is as follows:

$$dists = diff(locs) \tag{5}$$

Among them, *dists* is the distance between multi-peak thresholds, *diff()* find the distance between multimodal thresholds. Find the two multimodal thresholds with the largest distance, and the two multimodal thresholds with the largest distance between the multimodal thresholds, if there are only two multi-peak thresholds, then directly use the Otsu algorithm to segment the image, the process is as follows:

$$threshold = graythresh(gray\_img) \tag{6}$$

$$segmented\_img = imbinarize(gray\_img, threshold) \tag{7}$$

Among them, *threshold* is the threshold, *graythresh()* to find a suitable threshold, *imbinarize()* binarize the image. For the case of more than two multimodal thresholds, use the median value between each multimodal threshold as the threshold for segmentation. The specific process is as follows:

If i is the area between the last multi-peak threshold position, the threshold calculation formula is:

$$threshold = (L(i) + L(i+1)) / 2 \tag{8}$$

$$S(G > threshold) = i \tag{9}$$

If *i* is the area between other multi-peak threshold positions, the threshold calculation formula is:

$$threshold = (L(i) + L(i+1)) / 2 \tag{10}$$

$$S\begin{pmatrix} G > prev\_threshold \,\&\, G \\ <= threshold \end{pmatrix} = i \tag{11}$$

Among them, *G* is the input grayscale image, *H* is the histogram, *L* is the multi-peak threshold position vector, and *S* is the segmented image. *prev_threshold* is the previous threshold.

Improved bimodal algorithm through dynamic threshold selection strategy and adaptive area processing method, ability to more accurately segment images into parts with distinct regional features, compared with traditional segmentation methods, the improved bimodal algorithm has many advantages. Adaptive threshold selection entails the selection of distinct thresholding strategies by the number of multi-peak thresholds present in the image histogram. This approach allows for the adaptation to the characteristics of different images, thereby enhancing the accuracy and adaptability of segmentation. Dynamic-area processing pertains to the area situated between each multi-peak threshold. It employs an adaptive threshold processing method to more effectively discern the characteristics of disparate regions, thereby improving the accuracy and stability of segmentation. Scalability is achieved as the improved bimodal algorithm can be adjusted and expanded according to specific requirements, for example, introducing more threshold processing strategies or improved peak-finding algorithms, to adapt to more complex image segmentation tasks. The improved bimodal algorithm also has some limitations, dependence on the number of multimodal thresholds, the algorithm's judgment on the number of multi-peak thresholds depends on the distribution of the histogram, the image has a low or high number of multimodal thresholds, may affect the accuracy of segmentation; the algorithm is influenced by the choice of the initial threshold and the position of the multimodal threshold, different initial thresholds and multimodal threshold positions may lead to different segmentation results. The algorithm is highly sensitive to image noise, noise can interfere with the distribution of the histogram and the detection of multi-peak thresholds, thus affecting the accuracy of the segmentation results. Consequently, before the implementation of the enhanced bimodal algorithm, it is essential to enhance the image with the improved multi-scale Retinex method, as detailed in this paper, to enhance the precision of the segmentation process.

Results and analysis

Multi-scale Retinex and histogram multi-peak threshold segmentation algorithm enhancement effect diagram

Experimental results demonstrate the efficacy of the extraction method proposed in this paper for Yuan blue and white patterns. The method is based on multi-scale Retinex and histogram multi-peak threshold segmentation. For further details, please refer to Fig. 6, it illustrates the enhanced effect diagram of the multi-scale Retinex and histogram multi-peak threshold segmentation algorithm.

Figure 6A is an image of Yuan blue and white. In the three-dimensional cloud image, the background of the Yuan blue and white disk can be seen, as well as the reflection and lack of texture on the surface of Yuan blue and white. Figure 6B multi-scale Retinex, after multi-scale Retinex image enhancement method, divide the image into multiple scales, extract features at different scales, construct the weighted average function, combine the obtained results, avoid mutual interference of weights between channels, to get more accurate results, effectively enhanced the accuracy of extracting Yuan blue and white patterns. Figure 6C histogram multi-peak threshold segmentation: The histogram of the image is obtained, and multiple multimodal thresholds are calculated. The distance between each peak is used as a threshold for segmentation, resulting in a segmented image with clear texture and enhanced contrast. The segmented three-dimensional cloud image reveals the texture of Yuan blue and white, and the segmented texture is more distinct.

Matrix subtraction of the segmented image and the large background image of the Yuan blue and white porcelain plate, to get the final texture map, the details are handled better, and the reflective part of the surface of Yuan blue and white is enhanced, after the enhancement of multi-scale Retinex and histogram multi-peak threshold segmentation algorithm, the accuracy of Yuan blue and white image segmentation is significantly improved.

Enhanced comparison chart of different algorithms

Four distinct image enhancement segmentation methodologies are employed in this study, including the original method, the method presented in this paper, the Retinex method, and the Otsu method. The Yuan blue and white image of the Yuan Dynasty is enhanced and segmented.

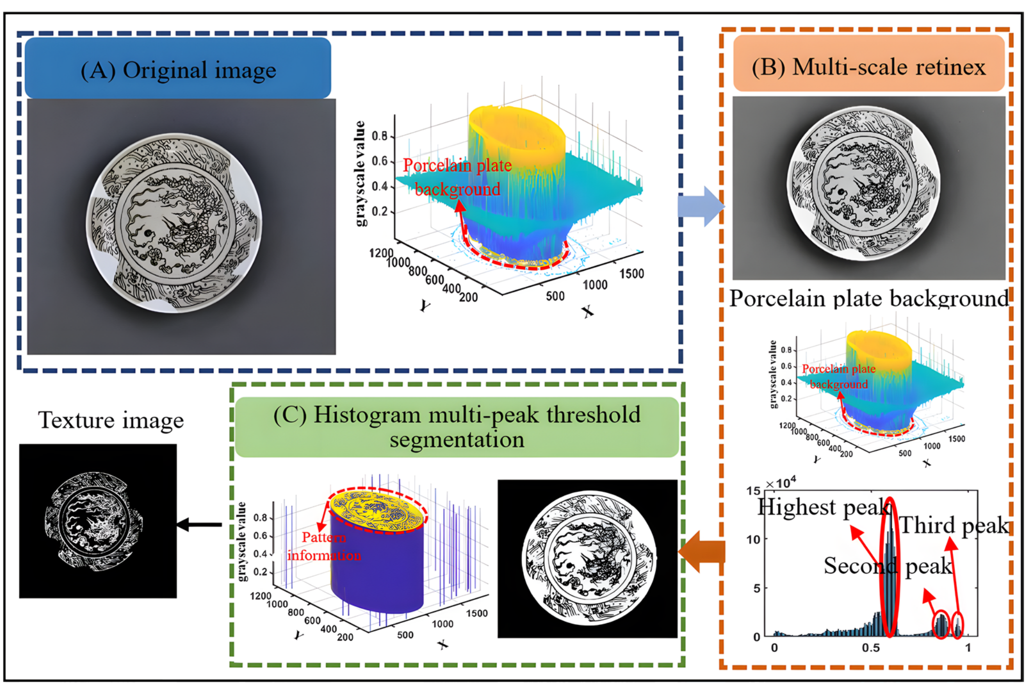

Fig. 6 Enhanced effect diagram of multi-scale Retinex and histogram multi-peak threshold segmentation algorithm

By comparing the experimental results, each algorithm shows different characteristics in different regions of the Yuan blue and white image.

The original method: Gaussian blur to remove noise and detail from Yuan blue and white images. The processed Yuan blue and white image is converted into logarithmic space, and the illumination image is calculated by Gaussian filtering. Then, calculate the difference between the original Yuan blue and white image and the illumination image to get the reflection image. Finally, convert logarithmic space back to linear space, adjust the brightness, and output the image.

Method of this paper: Multi-scale Retinex divides the original Yuan blue and white image into multiple scales. Then Retinex is performed on each layer of scales. Finally, weighted fusion is performed to obtain the final enhanced image.

Single scale Retinex: Creating a Gaussian Surround function, which filters each of the three color channels (R, G, and B) of the image. The filtered image is our estimated light component. Then, the original image and the illumination component are subtracted in the logarithmic domain to obtain the reflection component as the output result image.

Otsu method: The image is divided into two parts, background, and target, according to the grayscale characteristics of the image. The higher the interclass variance between background and texture, the more accurate the target and background segmentation. The interclass variance method is very sensitive to noise and target size, and it produces better segmentation results only for images with a single peak of interclass variance. The interclass variance criterion function may show double or multiple peaks when the size ratio of the target to the background is disparate, it is not good. However, the interclass variance method is the least time-consuming.

All the above four enhancement and segmentation methods can realize the extraction of the Yuan blue and white pattern, distinguish the foreground and background of the image, and segment the texture of the Yuan blue and white image. But there are some differences in the realization. Figure 7A is the original method, the original method is a simple and straightforward segmentation method, easy to implement and understand. However, it is easy to produce noise and blur when processing complex images, and it is difficult to accurately distinguish the foreground and background of the image. Figure 7B is the method of this paper. The method of this paper successfully preserves the rich details of the Yuan blue and white image in the segmented image, and at the same time better distinguishes the background and foreground of the image. The software is capable of producing segmentation results with greater clarity and readability. Figure 7C shows the single-scale Retinex method. The single-scale Retinex method performs well in maintaining image brightness and color balance, and can effectively deal with the global and local contrast of the image, thereby obtaining better segmentation results.

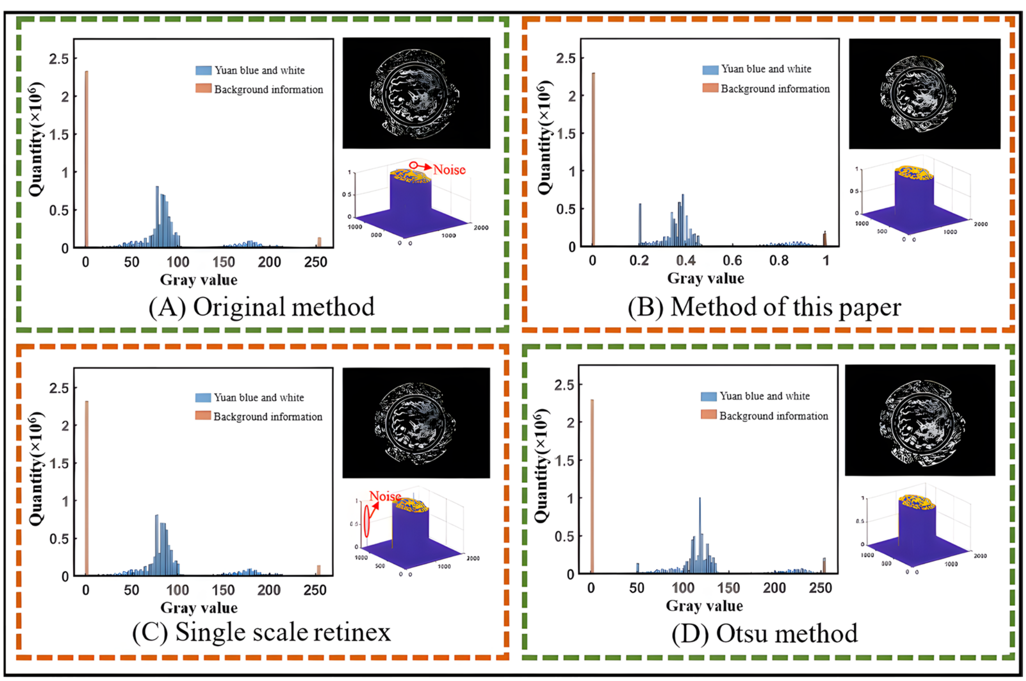

Fig. 7 Comparison of enhancement effects of different algorithms on Yuan blue and white

However, when dealing with reflection problems, the segmentation may not be fine enough in some details, resulting in the loss of image details. Figure 7D shows the maximum between-class method. The maximum between-class variance method is a statistically based segmentation method, the separation of foreground and background is achieved by maximizing the between-class variance and has a better effect on simple images. However, it is easily affected by noise, resulting in obvious noise in the segmentation results, and performs poorly for complex images.

In summary, the method in this paper shows advantages in preserving image details and distinguishing background and foreground, it has high clarity and readability. In contrast, the original method and the maximum between-class variance method are prone to noise and blurring, it is difficult to accurately segment the foreground and background of an image. The Retinex method does an excellent job of maintaining brightness and color balance, but it may lack finesse in dealing with reflections. Therefore, considering the advantages and disadvantages of various methods, the method in this paper achieves the best effect in the segmentation of Yuan blue and white images.

Comparison table of Yuan blue and white segmentation accuracy index

Image processing techniques have a wide range of applications, but the black-box nature of the algorithms makes model interpretability crucial. Cross-evaluation is a useful tool in this field, as it helps to assess the generalization ability, acceptability, and stability of the model, allowing for better selection and tuning of model parameters. The commonly used evaluation metrics for cross-evaluation include Accuracy, Precision, Recall, and F1-score. Accuracy measures the proportion of correct predictions among all samples, while precision measures the proportion of correct positive predictions. The recall statistic measures the proportion of correctly predicted positive samples, while the F1-score provides an overall analysis of precision and recall. It is important to adhere strictly to metrics and units when reporting these values. Table 1 shows a comparison of evaluation indexes for different algorithms used in Yuan blue and white image segmentation. To address the issue of missing texture on the surface of these images, a method for extracting Yuan blue and white patterns is proposed. This method is based on multi-scale Retinex and histogram multi-peak threshold segmentation.

Based on the table analysis, this paper proposes a multi-scale Retinex and histogram multi-peak threshold coupled segmentation method. Compared to the single-scale Retinex method, the maximum inter-class variance method, and the original method, this paper's algorithm achieves the highest evaluation scores for F1-Score, Recall, and Accuracy. Notably, the F1-Score of the model is 0.3067, indicating superior overall performance. However, the multi-scale Retinex algorithm and the histogram multi-peak threshold segmentation method proposed in this paper are processed based on local information. This means that local enhancement or segmentation errors may occur for some image regions. At the same time, there are complex textures and areas subject to illumination changes in this Yuan blue and white image. The illumination changes can cause pixel values to change in localized areas of the image. It affects the effectiveness of the local processing methods and results in lower accuracy values of the image than other methods. The accuracy of 92.67% indicates that Yuan blue and white images can be segmented accurately and efficiently, resulting in significant improvements in clarity and readability.

Table 1 Comparison table of the segmentation effect indicators of Yuan blue and white using different algorithms

Method	Judging indicators			
	Accuracy	Precision	Recall	F1-Score
Original method	88.26	0.79271	0.11436	0.2584
Single-scale Retinex method	87.56	0.7126	0.11365	0.2635
Otsu method	90.12	**0.8027**	0.13598	0.2365
A method in this paper	**92.67**	0.7058	**0.14672**	**0.3067**

Bold values represent the maximum value of judging indicators (Accuracy, Precision, Recall, F1-score) in the four methods

Conclusion

(1) To improve the completeness of Yuan blue and white pattern extraction and texture segmentation accuracy, a coupled algorithm based on multi-scale Retinex and histogram multi-peak threshold segmentation is proposed. This algorithm is capable of recognizing the distinctive blue and white texture information and background characteristics of Yuan while addressing the challenge of uneven shooting illumination and the loss of surface texture. The experimental results indicate that the segmented image has an accuracy of 92.67%. This method can be useful for extracting complex pattern information.

(2) This paper presents a new method for protecting cultural relics. It uses a multi-scale Retinex and histogram multi-peak threshold segmentation coupling algorithm to avoid color distortion in pictures while extracting pattern information. This provides a technical reference for the scientific and technological extraction of colorful and complex patterns in archaeological cultural relics. The multi-scale Retinex and histogram

multi-peak threshold segmentation method proposed in this paper provides a new approach for texture acquisition of Yuan blue and white ancient ceramics. There are still some textures that cannot be accurately captured when segmenting the texture of the Yuan blue and white image, resulting in an accuracy of only 92.67% for the algorithm. Further optimization of the accuracy of the algorithm is taken as the primary goal in the later work. Meanwhile, providing new theories and methods for the scientific and technological archaeology of Yuan blue and white ancient ceramics.

Author contributions
Qi Zheng: Experiment; software; data curation; visualization and writing-original draft. Baoxi Zhu and Qin Cai: Mathematical model building; methodology; writing—review. Jiao Li and Changfu Fang: Build experimental platform. Nanxing Wu: Supervision and formal analysis.

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Data availability
The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Declarations

Competing interests
No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication.

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