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Study on the Colour Structure of Character Costumes in Sun Wen's Illustrated Edition of *Dream of the Red Chamber* Based on Colour Clustering

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Abstract:

Existing research on the colours of clothing in picture books largely relies on manual observation and qualitative descriptions, lacking systematic quantitative analysis of colour structures.To address this issue, this paper proposes a research framework combining digital image processing and colour clustering analysis to conduct a systematic quantitative study of the colour schemes of characters' clothing in Sun Wen's *Dream of the Red Chamber* illustrations. Firstly, human regions were extracted from the picture book images using the YOLOv8 person detection model and Segment Anything Model (SAM) segmentation technology, yielding a total of 3,709 individual ROI images.To eliminate variations in lighting and scanning between different images, a paper colour anchoring strategy was employed in conjunction with the Von Kries colour adaptation model to achieve colour correction without the need for colour charts; Subsequently, the images were converted to the CIE Lab colour space, and K-means clustering was employed to extract the five dominant colours of the characters' costumes and their corresponding weights, thereby constructing a palette dataset for human apparel. Building upon this, the UMAP dimension reduction method was utilised to construct a distribution map of costume colour styles, and hierarchical clustering was applied to identify the structural typology of colour schemes. The results indicate that the colour schemes of the characters' attire in Sun Wen's illustrations exhibit distinct clustering characteristics, which can be categorised into six colour patterns, forming four primary core colour groups.Furthermore, through secondary cluster analysis, the typical colour composition ratios for different colour schemes were obtained. This study establishes a reproducible method for the quantitative analysis of colour structures in picture book costumes, providing a new technical pathway for the digital study of costume colour systems in traditional painting, as well as offering a methodological reference for image colour analysis in the field of digital heritage.

Keywords:

Sun Wen's illustrated edition of *Dream of the Red Chamber,* costume colours, digital

heritage, colour clustering, UMAP

Introduction

As a representative work of classical Chinese novels, *Dream of the Red Chamber* provides important materials for research in literature, art historical, and costume studies through its rich characters and detailed depictions of daily life.The illustrated edition of Dream of the Red Chamber produced by the Qing dynasty painter Sun Wen, characterized by meticulous gongbi character depictions, complex scene compositions and exquisite rendering of costumes, is regarded as a vital visual document for the study of Qing dynasty character imagery and the visual culture of costume. Compared to textual narratives, the illustrations in the book can present the costume shape features, colour relationships and decorative systems of characters' costumes more intuitively, providing key evidence for the analysis of costume visual elements. Sun Wen's illustrated edition features a large number of characters and a rich variety of costume types, with distinct differences in colour selection and matching among the various figures.A systematic analysis of the colours of their costumes is of great significance for understanding the mechanisms of visual construction of character imagery and the expression of costume in painting.

In recent years, research on the illustrated editions of *Dream of the Red Chambe*r has focused on aspects such as artistic style, character imagery and narrative structure. On the one hand, some scholars have examined the position of Sun Wen's illustrated edition within the visual tradition of *Dream of the Red Chamber* from an art-historical perspective, analysing character modeling, compositional techniques and narrative features of the scenes; On the other hand, certain studies have combined the novel's text to explore how the illustrated edition reconstructs plotlines and character relationships through visual means.In the field of costume studies, scholars have largely analysed the relationship between costume shapes and decorative elements and the Qing dynasty's costume regulations, thereby revealing the socio-cultural implications of the characters' portrayals. Although these studies have yielded fruitful results, existing research on costume colours still relies primarily on visual observation and empirical judgement, often remaining at the descriptive or case-based studies, such as analyses of the colour tones or combinations in the attire of specific characters [1-3].Whilst such methods aid in the in-depth interpretation of individual images, they struggle to yield statistically significant, holistic insights when confronted with large-scale illustrated manuscript datasets.Particularly within visual systems featuring a vast number of figures and complex colour schemes, relying solely on manual observation makes it difficult to comprehensively grasp the distribution patterns and underlying structures of costume colours.Consequently, how to conduct quantitative analysis of the costume colours of figures in illustrated manuscripts from a holistic perspective has become an urgent issue requiring resolution.

With the development of digital humanities and cultural heritage research, digital image processing methods have gradually been introduced into art history and visual culture studies. By employing computer vision and image processing technologies to conduct automated analysis of large-scale image datasets, visual patterns and

structural features can be identified at a macro level. For instance, in cultural heritage research, colour analysis techniques are frequently used to study the colouration of murals, paintings and decorative surfaces on artifacts;Meanwhile, image clustering and dimensionality reduction methods can reveal stylistic relationships between different works[4-7].This offers a new research pathway for art history, which has traditionally relied primarily on qualitative analysis. By conducting computational analyses of image colour distributions, pattern structures or visual elements, it is possible to identify structural relationships between images at a holistic level.For instance, colour clustering methods can extract representative colour combinations from images, whilst dimensionality reduction algorithms can map complex high-dimensional colour data onto intuitive two-dimensional structural diagrams, thereby revealing underlying visual patterns [8-10].

Against the backdrop of the aforementioned research, this paper proposes a research framework that integrates image segmentation, colour correction and colour clustering analysis to conduct a systematic analysis of the colour schemes of the characters' costumes in Sun Wen's illustrated edition of *Dream of the Red Chamber*.Specifically, character regions within the illustrated book are first extracted using character detection and image segmentation techniques to construct the costume image dataset for analysis.Subsequently, a color chart–free correction method is employed to eliminate colour bias differences between images through paper colour anchoring and the Von Kries colour adaptation model.On this basis, the images are converted to the CIE Lab colour space, and K-means clustering is utilised to extract the primary colour combinations of the characters' costumes, thereby constructing a character colour palette dataset. Furthermore, using UMAP dimensionality reduction and hierarchical clustering methods, we perform holistic modelling and classification analysis of the colour scheme structures of the characters' clothing, identifying different types of colour scheme patterns and revealing the compositional characteristics of each colour scheme structure through proportional statistics.

Data and Methodology

Data Sources and Pre-processing

The image data used in this paper is derived from digitised illustrations of Sun Wen's illustrated edition of *Dream of the Red Chamber*, available in public digital repositories. Following collation, a total of 203 illustrations were collected; The original image dimensions vary, with the longest side generally ranging from 2,000 to 4,000 pixels. To ensure data consistency, all images underwent the following pre-processing steps: firstly, the images were uniformly converted to the RGB colour space to ensure consistency in colour representation;secondly, the image files were uniformly converted to lossless PNG format to facilitate subsequent processing; Thirdly, the image dimensions were standardised whilst maintaining the aspect ratio, with bilinear interpolation used for resampling to improve computational stability during subsequent image segmentation and colour statistical analysis.

ROI Extraction for Character Clothing

To avoid the background, architecture, rocks and other non-target elements from interfering with the analysis of clothing colours, it is necessary to extract the human regions from the illustrated images.The most ideal approach would be to perform direct clothing segmentation; However, due to the complex boundaries of clothing in traditional paintings and the current lack of high-quality annotated data for ancient painting scenes, direct clothing-level segmentation is highly challenging. Taking the image from Chapter 1 of Volume 004, 'Shi Yin Holding a Child and Encountering Monks and Taoists on the Road; Jia Yucun's Birth at the Gourd Temple'—as an example (Figure 1), the u2net-human-seg model, having been trained on real-world human images, does not perform well in recognising ancient paintings. Therefore, this study employs a combined approach of YOLO and the Segment Anything Model (SAM) to extract the human regions [11-13].



Fig. 1 Comparison of two methods for ROI segmentation in character clothing

During the object detection stage, the YOLO model is used to detect human targets in the input image. Let the input image be $I \in \mathrm{R}^{H \times W \times 3}$, where H and W represent the height and width of the image, respectively. The output of YOLO can be represented as a set of person bounding boxes:

$$B = \{b_1, b_2, \ldots, b_N\} \tag{1}$$

Here, N represents the number of detected objects, and each bounding box is defined as:

$$b_i = \left(x_{\min}^{(i)}, y_{\min}^{(i)}, x_{\max}^{(i)}, y_{\max}^{(i)}\right) \tag{2}$$

In the equation, $\left(x_{\min}^{(i)}, y_{\min}^{(i)}\right)$ and $\left(x_{\max}^{(i)}, y_{\max}^{(i)}\right)$ denote the coordinates of the top-left and bottom-right corners of the i-th detection box, respectively.

During the image segmentation stage, b_i each bounding box detected by YOLO is fed into the SAM model as a prompt to generate the corresponding pixel-level binary mask for the person:

$$M_i = f_{\text{SAM}}(I, b_i) \tag{3}$$

Here, $M_i \in \{0,1\}^{H \times W}$ represents the segmentation mask corresponding to the *i*-th target; it takes the value 1 if the pixel belongs to the human region, and 0 otherwise.

To obtain the complete human region in the image, all individual masks are combined using a logical union operation to produce the overall person region mask:

$$M_{\text{total}} = \sum_{i=1}^{N} M_i \tag{4}$$

By performing a union operation on the segmentation results for all figures to obtain the complete human regions within the image. The overall mask M_{total} is converted into an Alpha channel and composite it with the RGB channels of the original image to generate an RGBA image that retains only the figures in the foreground:

$$I_{\text{out}}(x, y) = \begin{bmatrix} R(x, y) \\ G(x, y) \\ B(x, y) \\ 255 \cdot M_{\text{total}}(x, y) \end{bmatrix} \tag{5}$$

The first three components represent the RGB colour information of the original image, whilst the fourth component is the Alpha channel, which is used to indicate pixel transparency. When a pixel belongs to the human region, the Alpha value is 255; otherwise, it is 0. Following this processing, the resulting RGBA image retains only the human region and can serve as input data for subsequent clothing colour extraction and palette structure analysis.

Colour Correction for Colorless Cards

As the images in Sun Wen's illustrated edition of *Dream of the Red Chamber* originate from different scanning or photography environments, there are overall colour discrepancies between the images, such as yellowing of the paper, inconsistent brightness, or variations in local lighting.

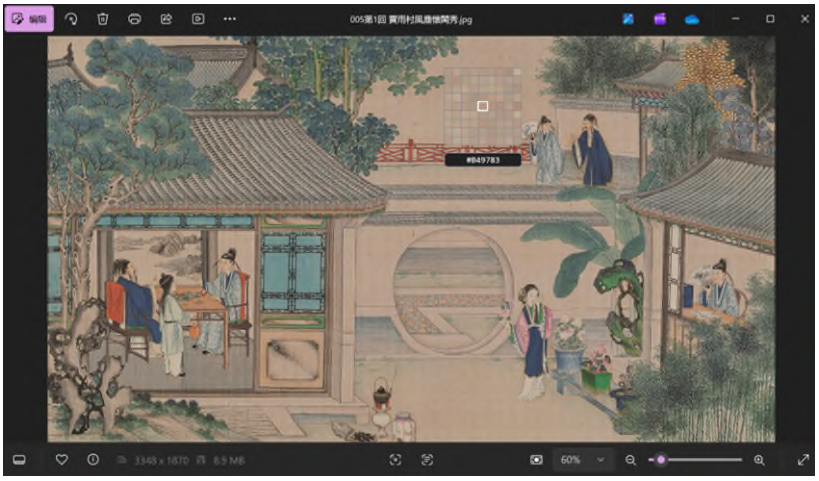


Fig. 2 Chapter 1 of Volume 005: Jia Yucun, Amidst the Hustle and Bustle, Longs for His Beloved

These factors may affect the stability and comparability of subsequent colour statistical results; therefore, it is necessary to perform colour normalisation on the images before conducting the analysis of costume colours.

This paper employs a colorless cards correction method based on paper colour anchoring, and combines it with the Von Kries colour adaptation model to perform comprehensive colour bias correction on images [14-18].First, an image with relatively uniform lighting conditions and stable colour representation is selected from the dataset, as shown in Figure 2, and the colour of the background sky is extracted as the global anchor:

$$C_{\text{anchor}} = (R_a, G_a, B_a) \tag{6}$$

In particular, C_{anchor} represents the standard background colour used as a common reference for all image corrections. Next, the Alpha channel generated from the previous step's human segmentation is used to remove the human region, retaining only the background pixels; the median value of the RGB channels is then calculated to serve as the actual background colour for that image:

$$C_{bg} = \text{Median}\left(\text{Pixels}_{\text{background}}\right) \tag{7}$$

C_{bg} represents the estimated background colour of the current image. This paper uses the median rather than the mean in order to reduce the interference caused by anomalous pixels—such as stamps, text and stains—on the background colour

estimation. Subsequently, colour scaling factors are calculated separately for the three RGB channels based on the Von Kries model:

$$S = \frac{C_{anchor}}{C_{bg} + \varepsilon} \tag{8}$$

Here, $S = (s_R, s_G, s_B)$ represents the scaling factors corresponding to the three colour channels, and $\varepsilon = 10^{-5}$ is a small constant introduced to prevent division-by-zero errors. The scaling factors reflect the degree of offset of the current image's background colour relative to the global reference colour: when the image background is darker, the scaling factor for the corresponding channel is typically greater than 1; when a certain channel exhibits a strong colour cast, the scaling factor for that channel will compensate for it accordingly.

Finally, the scaling factors are applied channel-wise to the original pixel colors of the human region to achieve pixel-level color correction.

$$C_{\text{corrected}} = \min\left(\max\left(C_{\text{raw}} \odot S, 0\right), 255\right) \tag{9}$$

Here, C_{raw} represents the RGB colour values of the original pixels, $\odot$ denotes a channel-by-channel multiplication operation, and $C_{\text{corrected}}$ represents the corrected pixel colour. A clipping operation is applied to ensure that the result always falls within the valid colour range $[0,255]$.

A quantitative evaluation of colour consistency before and after correction was performed, using the background colour of the images as the target. The background pixels of each image were randomly divided into two parts: 70% were used to estimate the background RGB median and calculate the per-channel correction coefficients, whilst the remaining 30% served as an independent validation set to evaluate the proximity between the corrected background colour and the global anchor colour. The global anchor colour is set to RGB [180,151,131] and converted to the CIELAB colour space to serve as a comprehensive colour difference comparison benchmark.

This paper selected eight sets of image samples(see Table 1); the average total colour difference ΔE between the background colour and the anchor colour was 18.24 prior to correction, falling to 0.63 after correction; the median ΔE decreased from 18.50 to 0.64, and the standard deviation fell from 3.68 to 0.26. At the same time, the

standard deviation of the background paper colour in the L^*、a^*、b^*dimensions decreased significantly, falling from 3.15, 3.31 and 3.86 to 0.10, 0.18 and 0.50 respectively. These results indicate that the corrected background paper color converges markedly toward a unified reference paper color, and the overall colour deviation between images was effectively reduced.

Tab. 1: Evaluation results of background paper colour consistency before and after colour correction

target	Before Correction	After correction
Average ΔE	18.24	0.63
MedianΔE	18.50	0.64
ΔE standard deviation	3.68	0.26
L^*standard deviation	3.15	0.10
a^*standard deviation	3.31	0.18
b^*standard deviation	3.86	0.50

Figure 3 illustrates the distribution difference of ΔE before and after correction; Figure 4 shows the clustering of background paper colours in the a^*-b^* plane of the Lab colour space; and Figure 5 compares the changes in mean values and dispersion across the three dimensions of L^*、a^*、b^*. Judging from the graphical results, the distribution of samples in the composite colour space was relatively dispersed prior to correction, whereas after correction, it contracted as a whole towards the anchor colour. Therefore, the colour-matching method without a colour chart adopted in this paper is capable of effectively suppressing overall colour bias within the current sample range and improving the reliability of colour comparisons between different images.

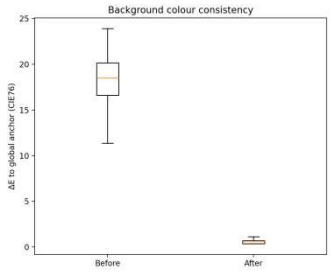


Fig. 3 Box-and-whisker plot showing the total colour difference (ΔE)

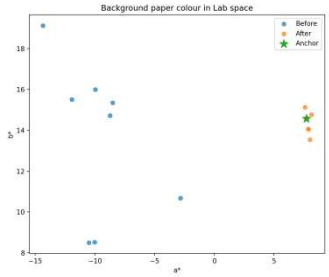


Fig. 4 Comparison of the distribution of the background paper colour

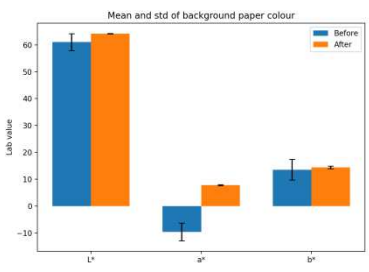


Fig. 5 Comparison of the mean and standard deviation of the background paper

between the background paper colour before and after correction and the global anchor colour

in the Lab space a^*-b^* plane before and after correction

colour in all dimensions of the Lab space before and after correction

Dominant Color Extraction (Palette Extraction)

This paper extracts dominant colours from the clothing regions of individuals to construct colour features that can be used for subsequent comparison and clustering analysis. Since the Euclidean distance between colours in the RGB colour space does not fully correspond to human visual perception, this paper converts the pixel colours of the human regions from the RGB colour space to the CIELAB colour space[4-6].Let the set of pixels within the human region be denoted by $\mathrm{P}_{\mathrm{rgb}}$, whose representation in the Lab space can be written as:

$$P_{lab} = f_{\mathrm{RGB}\to\mathrm{LAB}}(P_{rgb}) \tag{10}$$

The CIELAB colour space offers good perceptual uniformity; the calculation of colour distance more closely approximates the human eye's actual perception of colour differences, making it more suitable for colour clustering and the extraction of dominant colours. After completing the color space conversion, the K-means clustering algorithm is employed to cluster the pixel colours within the clothing regions of the subjects, in order to extract several representative dominant colours.

This paper conducts a comparative evaluation of the number of candidate dominant colours k in the dominant colour extraction stage and the number of candidate categories c in the colour palette classification stage. In Figure 6(a), the horizontal axis represents the number of candidate primary colours *k*, whilst the vertical axis represents the clustering evaluation metrics for different values of kkk; In Figure 6(b), the horizontal axis represents the number of candidate categories *C*, whilst the vertical axis represents the clustering evaluation metrics for different numbers of categories. Taking into account inter-class separation, intra-class compactness and interpretability of results, this paper ultimately selects *k*=5 for the primary colour extraction stage and *C*=6 for the colour palette classification stage.

$$k=5 \tag{11}$$

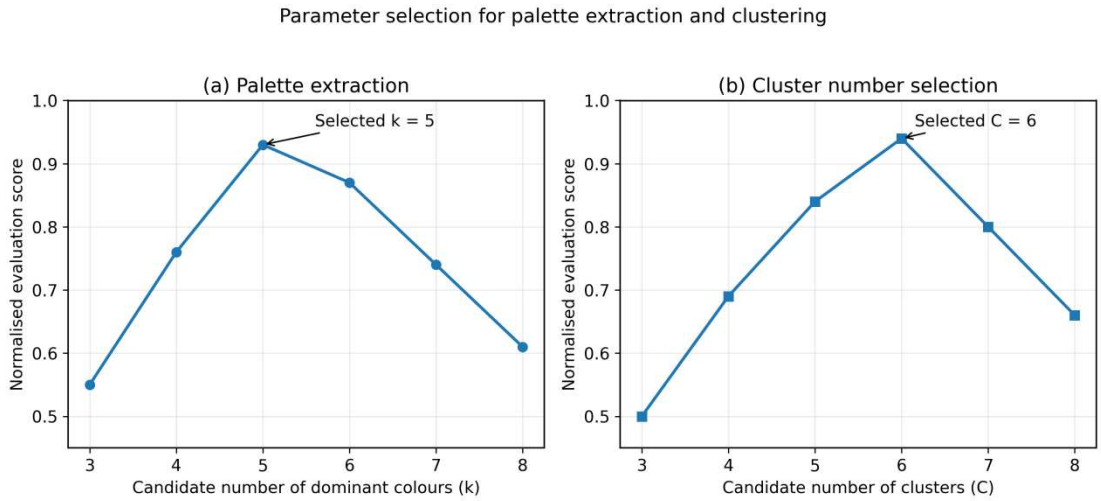


Fig. 6 Schematic diagram of the parameter selection logic

That is, five representative colours are extracted from each person's attire. The optimization objective of K-means is to minimize the sum of squared distances between all pixels and their corresponding cluster centers, which can be expressed as:

$$\arg\min_{\mathrm{C}} \sum_{i=1}^{N} \min_{j\in\{1,\ldots,k\}} \| p_i - c_j \|^2 \tag{12}$$

Here, p_i denotes the colour vector of the *ith* pixel in Lab colour space, c_j represents the *jth* cluster centre, and $C = \{c_1, c_2, \ldots, c_k\}$ denotes the set of all cluster centres. Upon completion of the clustering process, each cluster centre c_j corresponds to a primary colour of the garment.

To characterise the relative importance of different dominant colours in the characters' clothing, this paper counts the number of pixels in each cluster and calculates the corresponding area weight. Let the number of pixels contained in the *jth* colour cluster be $\mathrm{N_j}$, and its weight is defined as:

$$w_j = \frac{N_j}{\sum_{m=1}^{k} N_m} \tag{13}$$

Here, w_j represents the relative area proportion of the *jth* dominant colour within the character's clothing region. By combining the colour centres with the area weights, we can obtain a representation of each character's colour scheme, that is:

$$\text{Palette} = \{(c_1, w_1), (c_2, w_2), \ldots, (c_k, w_k)\} \tag{14}$$

c_i denotes the cluster centre of the *ith* dominant colour, whilst w_i denotes its corresponding area proportion. After processing preserves both the main colour information of the garments and the structural relationships between different colours within the overall colour scheme, thereby providing foundational features for subsequent colour scheme style mapping and cluster analysis.

Colour Scheme Style Mapping

In order to further reveal the overall distribution structure and latent type relationships among clothing color schemes,this paper performs style mapping and typological classification of colour scheme features based on the extraction of individual character palettes[19-20].Since each character's colour scheme is composed of five dominant colours and their corresponding weights, it can be represented as a 20-dimensional feature vector, where each colour L^*, a^*, b^* comprises three colour attributes and one area weight attribute, ultimately forming: $F_i \in \square^{20}$, where $\mathrm{F_i}$ denotes the high-dimensional colour scheme features of the *ith* character.

Direct comparison and clustering within this high-dimensional space are prone to issues such as high-dimensional distance failure and the difficulty of observing local structures. Therefore, this paper adopts a strategy of 'dimension reduction mapping—hierarchical clustering—intra-cluster secondary pooling' to analyse the palette styles of character costumes.

First, in the style mapping stage, UMAP（Uniform Manifold Approximation and Projection） is used to perform non-linear dimensionality reduction on the high-dimensional palette features. Let the colouring features of all characters constitute a feature set $\mathrm{F} = \{F_1, F_2, \ldots, F_M\}$; the two-dimensional embedding results can be represented as:

$$E = f_{\mathrm{UMAP}}(\mathrm{F}), \qquad E \in \square^{M \times 2} \tag{15}$$

Here, M represents the total number of character samples, and E denotes the corresponding two-dimensional manifold embedding results. UMAP is capable of

preserving the local topological relationships of high-dimensional data as much as possible during the dimension reduction process, ensuring that character samples which were originally similar in terms of palette structures remain closely distributed on the two-dimensional plane. Consequently, the UMAP embedding results can be regarded as a "colour style map" that intuitively illustrates the continuous distribution of character clothing palettes and their underlying clustering structure.

Secondly, in the two-dimensional embedding space, Agglomerative Clustering is employed to classify the colour schemes of the characters. Ward linkage is selected as the merging criterion, ensuring that the increase in intra-cluster variance is minimised during each merging step. For any two clusters A and B to be merged, the merging cost is defined as:

$$\Delta(A,B) = \frac{|A||B|}{|A|+|B|} \| \mu_A - \mu_B \|^2 \tag{16}$$

Let $|\mathrm{A}|$ and $|\mathrm{B}|$ denote the number of samples in clusters A and B, respectively, μ_A and μ_B denote the centroid vectors of the corresponding clusters. To further generalise the macro-representative colours of each palette style category, this paper employs a method combining intra-cluster macro-colour secondary pooling with weighted K-means clustering. Specifically, for any style cluster c, we first aggregate the five dominant colours of all characters within the cluster to form a cluster-level colour pool:

$$P_c = \{\mathrm{LAB}_{1,1}, \mathrm{LAB}_{1,2}, \ldots, \mathrm{LAB}_{n_c,5}\} \tag{17}$$

$\mathrm{n_c}$ denotes the number of characters in the *ith* cluster, and $\mathrm{LAB}_{i,j}$ denotes the colour vector in Lab space of the *jth* dominant colour of the *ith* character. Aggregate the area weights corresponding to these dominant colours into a weight set W_c. Within this cluster-level colour pool, perform a weighted K-means clustering to extract the macro-representative colour centre C_C for that style cluster. The optimisation objective can be expressed as:

$$\arg\min_{C_c} \sum_{x \in P_c} W_c(x) \cdot \min_{j \in \{1,\ldots,k\}} \| x - C_{c,j} \|^2 \tag{18}$$

x denotes any dominant colour sample in the cluster-level colour pool; $W_c(x)$ denotes the area weight corresponding to that colour; and $C_{c,j}$ denotes the centre of the *jth* macro-representative colour center in the *cth* style cluster. In this paper, k=5.

Through the above operation, the problem that small-area accent colors and large-area dominant colors are treated equally can be avoided, thereby providing a more accurate summary of the palette structure within each cluster.

palette Clustering

Having obtained the results of the two-dimensional palette embedding, this paper further employs Agglomerative Clustering to classify the palettes of characters' attire, with the aim of identifying different types of palette styles [21-22]. Unlike methods that assign predefined cluster centres, hierarchical clustering progressively merges similar samples in a bottom-up manner, making it more suitable for exploring hierarchical relationships among character costume palettes. This study employs Ward linkage as the merging criterion, with the objective of minimising the increase in intra-cluster variance at each merging step. For any two clusters A and B to be merged, the merging cost is defined as:

$$\Delta(A,B) = \frac{n_A n_B}{n_A + n_B} \| \mu_A - \mu_B \|^2 \tag{19}$$

Here, n_A and n_B denote the number of samples in the two clusters, whilst μ_A and μ_B represent the centres of the corresponding clusters. Through this method, the palettes of the characters' attire were classified into several distinct clusters, and the classification results were visualised using scatter plots and dendrograms. The clustering results indicate that the palettes of the characters' attire in Sun Wen's illustrated edition of *Dream of the Red Chamber* are not entirely discretely distributed, but rather exhibit several relatively stable clustering structures, reflecting the existence of identifiable palette styles. To enhance the transparency and reproducibility of the research methodology, Table 2 summarises the key parameter settings used in this study for human detection, edge segmentation, colour correction without a colour chart, dominant colour extraction, UMAP dimensionality reduction, and hierarchical clustering analysis.

Tab. 2 Main Parameter Settings

Module	Parameter	Set Value	Description
YOLO Person Detection	Model	YOLOv8x	Person object detection
YOLO Person Detection	Detection category	0	Person class
YOLO Person Detection	Confidence Threshold	0.05	Controls detection boxes for retaining the threshold
YOLO Person	IoU Threshold	0.50	Controls the suppression of

Detection			overlapping boxes
SAM Edge Segmentation	Model	SAM	Fine-grained segmentation of person boundaries
SAM Edge Segmentation	Prompt mode	Bounding box prompt	Uses YOLO detection boxes as prompt input
ROI Output	Output Format	RGBA	Alpha channel used for background removal
Colour Correction	Method	Paper colour anchoring + Von Kries transformation	Comprehensive colour bias correction without a colour chart
Colour Correction	Global Anchor Colour	[180,151,131]	Reference image background colour
Colour Correction	Background Colour Estimation	Median	Take the median value of the background pixel RGB
Colour Correction	Stabilisation Term	10^{-5}	Prevent division by zero
Dominant Colour Extraction	Colour Space	CIELAB	Perceptually uniform colour representation
Dominant Colour Extraction	Clustering Algorithm	K-means	Extract dominant colours of the subject's clothing
Dominant Colour Extraction	Number of Dominant Colours	5	Extract 5 dominant colours per character
Dominant Colour Extraction	Weight Calculation	Pixel Proportion Normalisation	Calculate the area proportion of each dominant colour
Style Mapping	Dimension Reduction Algorithm	UMAP	Map the high-dimensional palette to two dimensions
Style Mapping	Output Dimensions	2	Construct a colour style map
palette Classification	Clustering Algorithm	Agglomerative Clustering	Classify the two-dimensional embedding results
palette Classification	Linkage Method	Ward	Minimise the increment in intra-cluster variance
palette Classification	Number of Clusters	6	Set at the current analysis scale
Cluster-Level palette Induction	Clustering Algorithm	Weighted K-means	Re-induct dominant colours within each cluster
Cluster-Level palette Induction	Number of Macro-Representative Colours	5	Induct each cluster into 5 representative colours

Results

Results of Character ROI Extraction

This paper performs human segmentation on images from Sun Wen's illustrated edition of *Dream of the Red Chamber* and generated RGBA images retaining only the characters in the foreground. The results indicate that the combined YOLO and SAM approach is capable of reliably extracting human regions from the illustrated images，whilst effectively mitigating the interference of non-target elements—such as the background, architecture, rocks, artefacts and inscriptions—on subsequent colour analysis. As shown in Figure 7, following segmentation, the main body of the characters is preserved relatively intact, the background areas are rendered transparent, and the colour information of the clothing is presented with greater clarity.

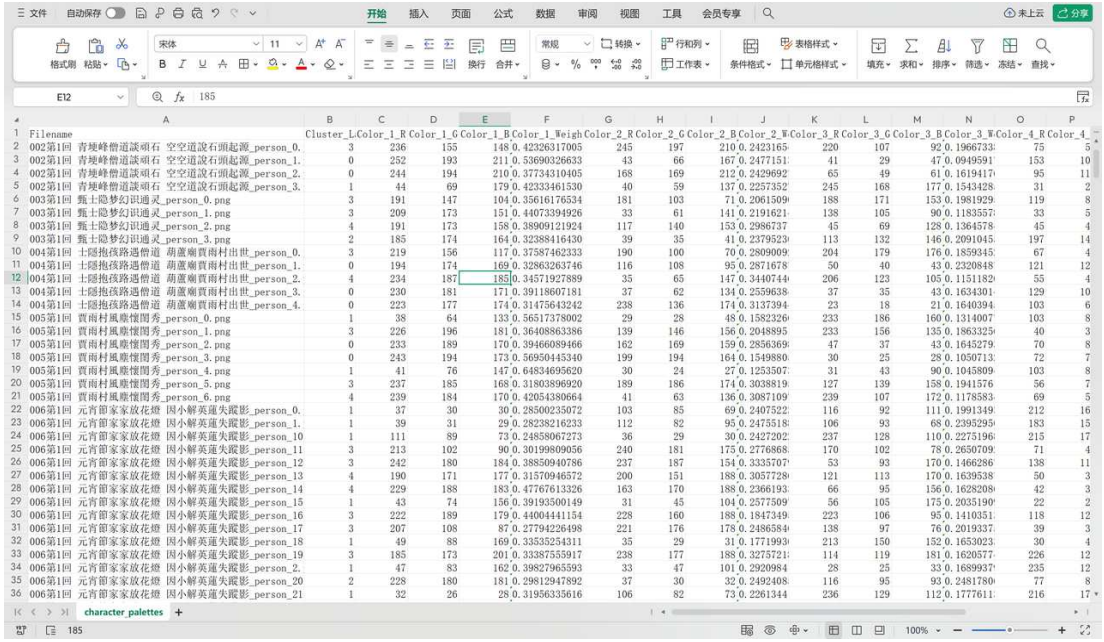


Fig. 7 Schematic diagram of human ROI extraction results

A total of 3,709 human samples were extracted , forming the data foundation for subsequent colour analysis. This method performs well in scenes where human outlines are clear and the scale of the subjects is moderate; however, in scenes featuring overlapping individuals, blurred boundaries, or complex local structures, a small number of missed detections, false detections, and edge truncation still occur. This paper focuses on the overall colour structure of the subjects' attire rather than the fine segmentation of localised clothing features; consequently, these errors have a limited impact on subsequent macro color statistics. Overall, the current ROI extraction results are sufficient to meet the requirements for subsequent colour correction, dominant colour extraction and palette clustering analysis.

Palette statistics

Following the extraction of human regions and colour correction without colour charts, dominant colours were extracted from each subject's clothing region, and corresponding palette results were generated. Each sample consists of five dominant colours and their area weights, which are used to characterise the comprehensive colour structure of the character's attire. Figure 8 illustrates the palette extraction results for a typical character sample. It can be seen that this method is able to effectively distinguish between the dominant, secondary and accent colours in the character's attire, and presents the relative proportions of each colour within the overall palette in a quantitative form.



Filename	Cluster_L	Color_1_R	Color_1_G	Color_1_B	Color_1_Weigh	Color_2_R	Color_2_G	Color_2_B	Color_2_W	Color_3_R	Color_3_G	Color_3_B	Color_3_W	Color_4_R	Color_4_
002第1回 青埂峰僧道談頑石 空空道說石頭起源_person_0.	3	236	155	148	0.423263170	245	197	210	0.2423165	220	107	92	0.1966733	75	5
002第1回 青埂峰僧道談頑石 空空道說石頭起源_person_1.	0	252	193	211	0.53690326633	43	66	167	0.2477151	41	29	47	0.0949591	153	10
002第1回 青埂峰僧道談頑石 空空道說石頭起源_person_2.	0	244	194	210	0.37734310405	168	169	212	0.2429692	65	49	61	0.1619417	95	11
002第1回 青埂峰僧道談頑石 空空道說石頭起源_person_3.	1	44	69	179	0.42333461530	40	59	137	0.2257352	245	168	177	0.1543428	31	2
003第1回 甄士隱夢幻識通灵_person_0. png	3	191	147	104	0.35616176534	181	103	71	0.2061509	188	171	153	0.1981929	119	8
003第1回 甄士隱夢幻識通灵_person_1. png	3	209	173	151	0.44073394926	33	61	141	0.2191621	138	105	90	0.1183557	33	5
003第1回 甄士隱夢幻識通灵_person_2. png	4	191	173	158	0.38909121924	117	140	153	0.2986737	45	69	128	0.1364578	45	4
003第1回 甄士隱夢幻識通灵_person_3. png	2	185	174	164	0.32388416430	39	35	41	0.2379523	113	132	146	0.2091045	197	14
004第1回 士隱抱孩路遇僧道 葫蘆廟賈雨村出世_person_0.	3	219	156	117	0.37587462333	190	100	70	0.2809009	204	179	176	0.1859345	67	4
004第1回 士隱抱孩路遇僧道 葫蘆廟賈雨村出世_person_1.	0	194	174	169	0.32863263746	116	108	95	0.2871678	50	40	43	0.2320848	121	12
004第1回 士隱抱孩路遇僧道 葫蘆廟賈雨村出世_person_2.	4	234	187	185	0.34571927889	35	65	147	0.3440744	206	123	105	0.1151182	55	4
004第1回 士隱抱孩路遇僧道 葫蘆廟賈雨村出世_person_3.	0	230	181	171	0.39118607181	37	62	134	0.2559638	37	35	43	0.1634301	129	10
004第1回 士隱抱孩路遇僧道 葫蘆廟賈雨村出世_person_4.	0	223	177	174	0.31475643242	238	136	174	0.3137394	23	18	21	0.1640394	103	6
005第1回 賈雨村風塵懷閨秀_person_0. png	1	38	64	133	0.56517378002	29	28	48	0.1582326	233	186	160	0.1314007	103	8
005第1回 賈雨村風塵懷閨秀_person_1. png	3	226	196	181	0.36408863386	139	146	156	0.2048895	233	156	135	0.1863325	40	3
005第1回 賈雨村風塵懷閨秀_person_2. png	0	233	189	170	0.39466089466	162	169	159	0.2856369	47	37	43	0.1645279	70	8
005第1回 賈雨村風塵懷閨秀_person_3. png	0	243	194	173	0.56950445340	199	194	164	0.1549880	30	25	28	0.1050713	72	7
005第1回 賈雨村風塵懷閨秀_person_4. png	1	41	76	147	0.64834695620	30	24	27	0.1253507	31	43	90	0.1045809	103	8
005第1回 賈雨村風塵懷閨秀_person_5. png	3	237	185	168	0.31803896920	189	186	174	0.3038819	127	139	158	0.1941576	56	7
005第1回 賈雨村風塵懷閨秀_person_6. png	4	239	184	170	0.42054390664	41	63	136	0.3087109	239	107	172	0.1178583	69	5
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_0.	1	37	30	30	0.28500235072	103	85	69	0.2407522	116	92	111	0.1991349	212	16
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_1.	1	39	31	29	0.28238216233	112	82	95	0.2475518	106	93	68	0.2395295	183	15
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_10	1	111	89	73	0.24858067273	36	29	30	0.2427202	237	128	110	0.2275196	215	17
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_11	3	213	102	90	0.30199809056	240	181	175	0.2776868	170	102	78	0.2650709	71	4
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_12	3	242	180	184	0.38850940786	237	187	154	0.3335707	53	93	170	0.1466286	138	11
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_13	4	190	171	177	0.31570946572	200	151	188	0.3057728	121	113	170	0.1639538	50	3
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_14	4	229	188	183	0.47767613326	163	170	188	0.2366193	66	95	156	0.1628208	42	3
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_15	1	43	74	156	0.39193500149	31	45	104	0.2577509	56	105	175	0.2035190	22	2
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_16	3	222	189	179	0.44004441154	228	160	188	0.1847349	223	106	95	0.1410351	118	12
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_17	3	207	108	87	0.27794226498	221	176	178	0.2486584	138	97	76	0.2019337	39	3
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_18	1	49	88	169	0.33535254311	35	29	31	0.1771993	213	150	152	0.1653023	30	4
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_19	3	185	173	201	0.33387555917	238	177	188	0.3275721	114	119	181	0.1620577	226	12
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_2.	1	47	83	162	0.39827965593	33	47	101	0.2920984	28	25	33	0.1689937	235	12
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_20	2	228	180	181	0.29812947892	37	30	32	0.2492408	116	95	93	0.2481780	77	8
006第1回 元宵節家家放花燈 因小解英蓮失蹤影_person_21	1	32	26	28	0.31956335616	106	82	73	0.2261344	236	129	112	0.1777611	216	17

Fig. 8 Examples of character color palettes

It can be seen that the palette structures of different character samples exhibit distinct differences. Some characters feature a single dominant composite colour, complemented by a small number of low-saturation transitional colours, resulting in a relatively concentrated overall colour palette; other samples exhibit more complex multi-color combinations, with richer proportional relationships between dominant and auxiliary colors.This indicates that palette representation is not only capable of extracting the primary colour information of the characters' attire but also preserves the structural relationships between different colours; the results of the dominant colour extraction effectively reflect the composite colour composition of the characters' attire in Sun Wen's illustrated edition of *Dream of the Red Chamber*.

UMAP colour map

The colour scheme results for each character are represented as a unified high-dimensional feature vector. Each individual is represented by the L^*,a^*,and b^* values of five dominant colours, together with their corresponding area weights, forming palette features for comparison between samples. As these features contain multiple colour attributes and proportional information, resulting in a high dimensionality that makes it difficult to directly observe their overall distribution patterns, this paper employs the UMAP method to map the high-dimensional colour palette features onto a two-dimensional space, thereby obtaining low-dimensional visualisations of the characters' costume colour palettes. Then hierarchical clustering is applied to classify the two-dimensional embedding results, yielding the UMAP colour style map shown in Figure 9.

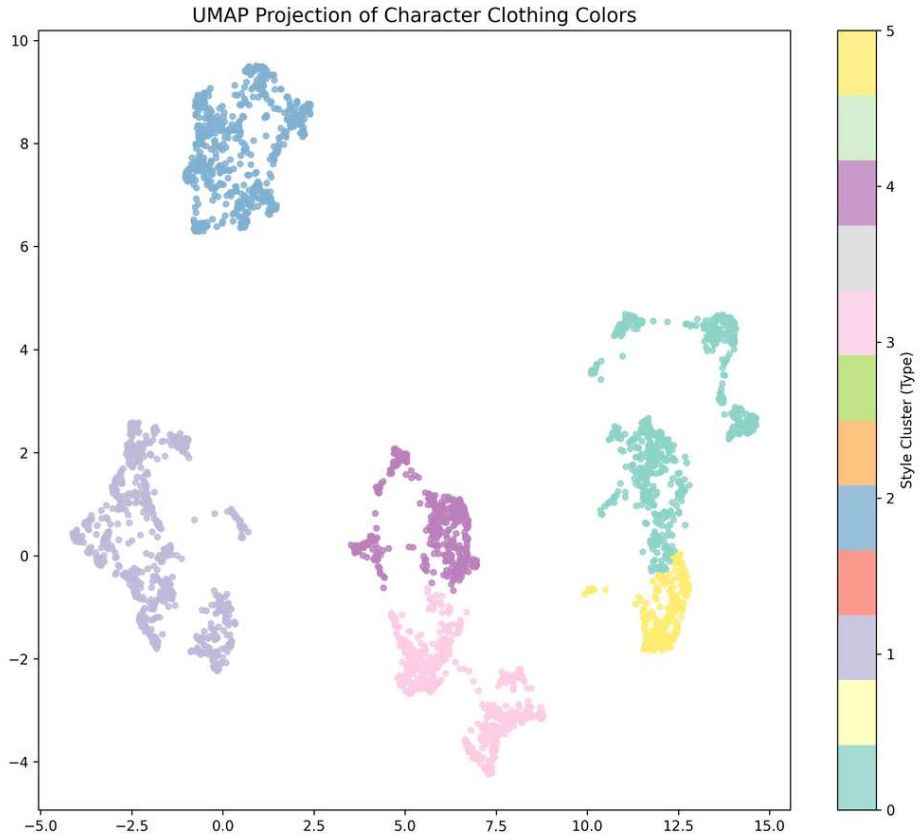


Fig. 9 UMAP color style map

From Fig. 9, the samples of different characters are not uniformly distributed in the two-dimensional space, but rather form several relatively concentrated clusters. This indicates that the colour palettes of the characters' costumes in Sun Wen's illustrated edition of *Dream of the Red Chamber* are not randomly distributed, but rather exhibit a relatively clear structural differentiation overall. The multiple clustered regions in the figure indicate that the colour palettes of the characters' attire exhibit distinct typological differentiation; furthermore, this distribution displays a

certain hierarchical structure, meaning that at a coarser granularity, they can be grouped into several major clusters, whilst at a finer granularity, they can be further subdivided into several sub-types. Overall, the UMAP colour style map reveals the spatial organisational patterns of the characters' attire in Sun Wen's *Dream of the Red Chamber* illustrated book in terms of dominant colour combinations, area proportions and overall colour tones.

Hierarchical Clustering Results

After obtaining the UMAP two-dimensional embedding of garment color palettes, hierarchical clustering was performed on the samples using the Ward agglomeration method to examine the hierarchical relationships between different colour palette samples, and a dendrogram was plotted, as shown in Figure 10.

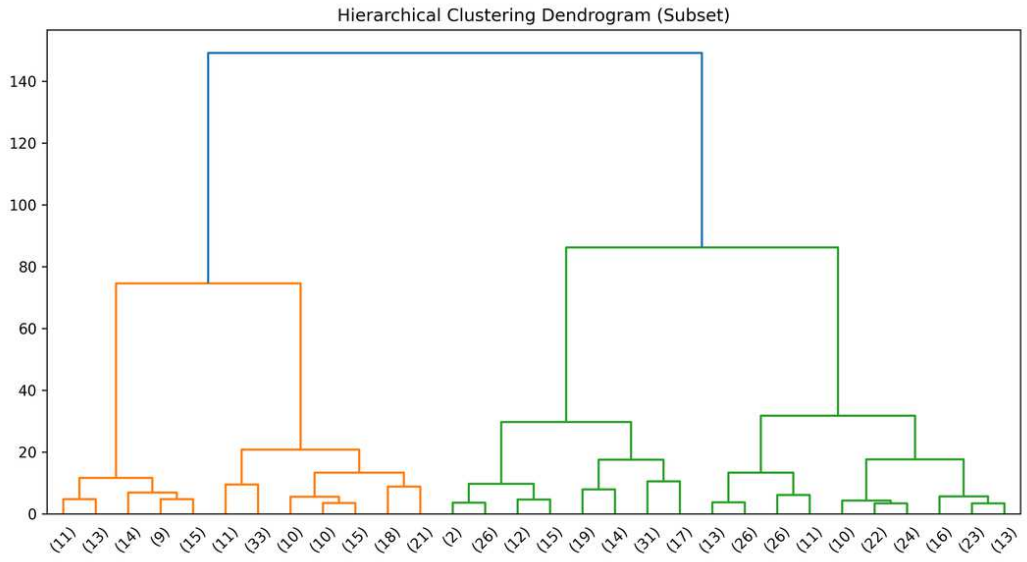


Fig. 10 Hierarchical clustering dendrogram of colour palettes

Fig. 10 shows the aggregation relationships of color palettes at a high level.The horizontal axis represents terminal clusters or cluster groups, whilst the vertical axis represents the merging distance between clusters. The higher the branch connection point, the greater the difference in colour palettes between the corresponding clusters; conversely, the lower the connection point, the closer they are in terms of dominant colour composition and proportional relationships. Within each major group, several secondary branches are further differentiated, indicating that the colour palettes of the characters' attire exhibit not only macro-level typological differences but also fine-grained variations within each type.

Overall, the dendrogram demonstrates that the colour palettes of the characters' attire in Sun Wen's illustrated edition of *Dream of the Red Chamber* possess distinct hierarchical organisational characteristics and recognisable typological differentiation.

Colour composition analysis

First, the five dominant colours and their corresponding area weights for all individuals within the same colour palette type were aggregated into a cluster-level colour set. These were then summarised into five macro-representative colours using weighted K-means clustering, and the normalised proportions of each representative colour within that type were calculated. Based on the clustering results, the dominant colours of the characters' costumes within each type were summarised at the cluster level and their proportions statistically analysed, reflecting the comprehensive colour composition characteristics of the colour schemes at the cluster scale. The results are shown in Fig. 11.

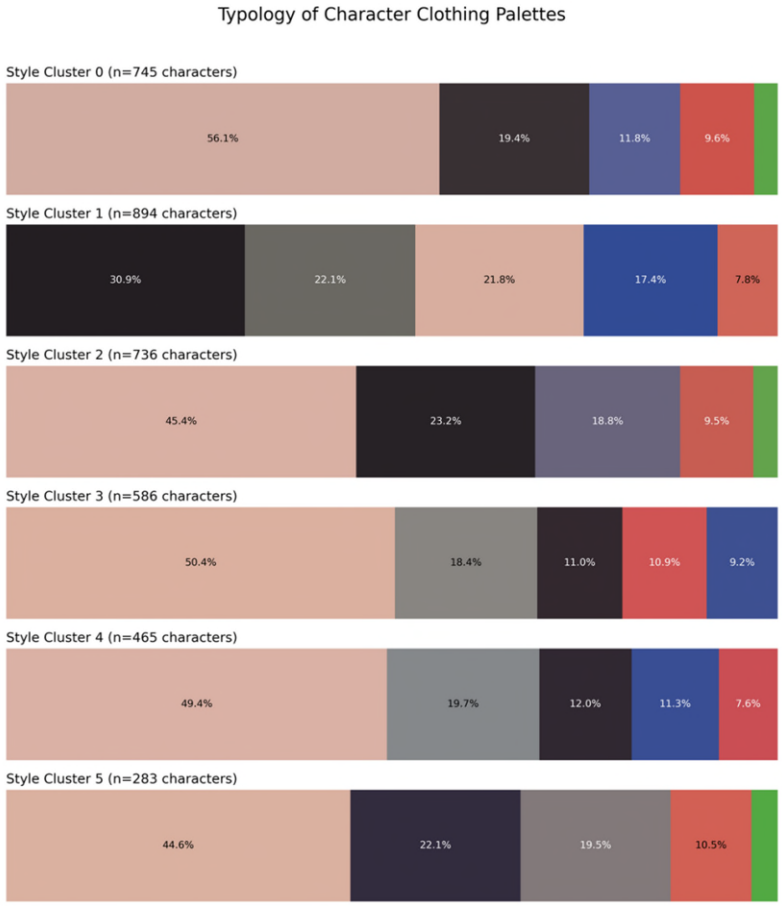


Fig. 11 Macro-level colour palette structures for each colour scheme type

As can be seen from Figure 11, the six colour palette types exhibit a relatively clear hierarchical structure, consisting of a dominant colour, an auxiliary colour and an accent colour; however, there are differences between the types in terms of the proportion of the dominant colour, the configuration of the auxiliary colour and the overall colour tone. Most types feature light pinkish-brown or light ochre as the dominant colour, accounting for approximately 44.6%–56.1%, indicating that low-saturation warm tones form the foundational colour layer of the character

costume colour palettes in Sun Wen's illustrated edition of *Dream of the Red Chamber*. Among these, Style Cluster 0 exhibits the highest concentration of the dominant colour, with the primary colour accounting for 56.1%; Style Cluster 3 and Style Cluster 4 have dominant colour proportions of 50.4% and 49.4% respectively, indicating that these types exhibit a strong unifying characteristic of the primary colour, with a relatively concentrated overall colour palette structure.

To further present the proportional relationships between different colour palette types at the cluster level, this paper summarises the five macro-representative colours obtained through secondary clustering within each type, along with their normalised proportions, in Table 3. This table corresponds to Figure 11 and provides a more intuitive reflection of the differences in the composition of dominant, secondary and accent colours across the various colour scheme types.

Tab. 3 Proportional statistics of each colour palette type

Colour palette Type	Sample number	Representat-ive Colour 1	Representati-ve Colour 2	Representati-ve Colour 3	Representat-ive Colour 4	Representati-ve Colour 5	Structural Characteristics
Style Cluster 0	745	56.1%	19.4%	11.8%	9.6%	3.1%	Highly concentrated single dominant colour type
Style Cluster 1	894	30.9%	22.1%	21.8%	17.4%	7.8%	Multicolor Equalization Configuration Type
Style Cluster 2	736	45.4%	23.2%	18.8%	9.5%	3.1%	Clear dominant colour with strong secondary colours
Style Cluster 3	586	50.4%	18.4%	11.0%	10.9%	9.2%	Dominated by warm light colours
Style Cluster 4	465	49.4%	19.7%	12.0%	11.3%	7.6%	Warm light colours dominant, relatively concentrated structure
Style Cluster 5	283	44.6%	22.1%	19.5%	10.5%	3.3%	Intermediate type, high involvement of secondary

Style Cluster 1 exhibits a more balanced multi-colour configuration. Its dominant colour accounts for 30.9%, whilst the second, third and fourth dominant colours account for 22.1%, 21.8% and 17.4% respectively, indicating that this type does not rely on a single dominant colour, but rather forms a comprehensive colour scheme through the combined use of multiple colours. It is evident that the differences between various colour palettes are manifested not only in the categories of dominant colours but also in the proportions of colours and the organisation of visual focal points.

The first dominant color proportions of Style Cluster 2 and Style Cluster 5 are 45.4% and 44.6%, respectively, whilst the proportions of the second and third dominant colours are relatively similar,showing an intermediate structure with clear dominant color and strong participation of auxiliary colors. Style Cluster 3 and 4 are based on a high proportion of warm, light colours, but differ in the configuration of auxiliary colours such as grey, dark brown, blue and red. This indicates that, whilst their their overall tones are similar, they can still form distinguishable subtypes through auxiliary color proportions.

It can thus be seen that Figure 5 demonstrates that the differences in the colour palettes of the characters' costumes in Sun Wen's illustrated edition of *Dream of the Red Chamber* are not primarily manifested as the substitution of individual colours, but rather as a reorganisation of the proportional relationships between different colours at the cluster level.

Discussion

Colour Characteristics of Costumes in Sun Wen's Illustrated Edition

The results indicate that the costumes of the characters in Sun Wen's illustrated edition of *Dream of the Red Chamber* generally exhibit a relatively consistent pattern of colour organisation. Firstly, in terms of the distribution of dominant colours, low-saturation warm tones predominate; light pinkish-brown, light ochre and their analogous hues form the base colour layer of most characters' costumes. It is thus evident that the costumes in Sun Wen's illustrated edition do not rely on high-purity colours to create strong visual contrasts, but are instead founded on a harmonious, coordinated palette with subtle tonal transitions. Secondly, in terms of the relationship between warm and cool colours, the warm colour dominates the overall colour palette, whilst cool colours predominantly appear as secondary or accent colours, serving to create visual balance and localised adjustments. This arrangement of warm and cool tones ensures that the colours of the costumes maintain overall unity whilst retaining a degree of variation. Furthermore, in terms of colour hierarchy, the characters' costumes generally exhibit a structural pattern of 'dominant colour—secondary

colour—accent colour', wherein one or two base colours covering a larger area control the overall tonal scheme, supplemented by several secondary colours in smaller proportions to enrich the details and create layers of depth.

Colour Schemes

In terms of colour schemes, Sun Wen's picture book characters' costumes feature several relatively consistent and typical colour combinations. Firstly, combinations of warm light colours with dark colours are quite common, such as pale ochre, pale pinkish-brown paired with dark brown or grey; such combinations enhance the sense of depth whilst maintaining an overall soft tone. Secondly, some types show warm–cool contrast configurations, whereby a certain proportion of blue, bluish-grey or green is added to a warm colour base, creating local variations within an otherwise unified overall tone. Furthermore, in a minority of types, more distinct composite colour schemes can be observed, such as red-green contrasts, blue-white combinations or yellow-brown pairings; These combinations are rarely represented in the illustrations as direct juxtapositions of high-saturation pure colours, but more often appear in low-saturation, transitional forms. To more clearly summarise the differences between various colour scheme types in terms of dominant colour tendencies, secondary colour arrangements, hierarchical relationships and overall colour tones. This paper has further summarised and organised the structural characteristics of each type; the results are shown in Table 4.

Tab. 4 Summary of Colour Scheme Characteristics

Colour Scheme Type	Dominant Colour Tendencies	Auxiliary Colour Characteristics	Colour Hierarchy	Overall Colour Tone Characteristics
Style Cluster 0	Warm light colours dominate	Small amounts of dark and blue as accents	Highly concentrated hierarchy	Clear dominance of a single primary colour
Style Cluster 1	No single dominant colour	Small amounts of dark and blue as accents	Relatively balanced hierarchy	Multi-colour composite type
Style Cluster 2	Dominated by warm light colours	Strong accents of dark and grey-purple	Clear distinction between primary and secondary colours	Multi-colour composite type
Style Cluster 3	Dominated by warm light colours	Gray, dark, and red participation	Concentrated primary colour	Distinct warm colour foundation
Style Cluster 4	Dominated by warm light colours	Gray, dark, and blue accents	Relatively concentrated	Unified warm tones with

			structure	localised cool colour adjustments
Style Cluster 5	Dominated by warm light colours	Significant proportion of deep cool colours and grey	Intermediate type	Clear primary colour but enhanced role of secondary colours

The clustering results show that these color patterns have certain repeatability and can be summarized,and can form relatively stable type structures at the cluster level.

Cultural and Artistic Significance

From a cultural and artistic perspective, the typological differences in the colour schemes of the characters' attire in Sun Wen's illustrated edition hold a certain interpretative value. Although picture books constitute artistic representations rather than institutionalised costume atlases, the choice of colour schemes may still be influenced to some extent by Qing dynasty aesthetic standards, notions of colour hierarchy, and everyday dressing habits. Differences among characters in terms of dominant colour selection, overall tonal quality, and colour concentration may not merely represent formal variations, but may also be related to the distinction of character identities, the shaping of personalities, and the construction of narrative contexts. In illustrated books, costume colour schemes serve not only a decorative function but also play a role in visual identification and narrative reinforcement [1-3].

From the perspective of painting style, Sun Wen's illustrated edition demonstrate a strong tendency towards overall control in the use of colour, namely maintaining the unity of the composition's tone through low-saturation warm colours, whilst creating local variations and layers of depth through the use of secondary and accent colours. This approach not only aligns with the visual characteristics of gongbi figure painting—which emphasises order, delicacy and harmony—but also indicates that the colour schemes of the costumes in these illustrated books possess distinct stylised organisational features.

Conclusion

This paper takes the character costume colours in Sun Wen's illustrated edition of *Dream of the Red Chamber* as its subject of study, and constructs a digital analysis workflow comprising character ROI extraction, colour correction without colour charts, dominant colour extraction, style mapping, and colour scheme clustering. Specifically, colour correction is based on von Kries' colour adaptation theory; dominant colour extraction employs K-means clustering; colour palette style mapping utilises UMAP; and typological classification adopts Ward's hierarchical clustering. This enables a continuous analysis from the original illustrated images to a

cluster-level colour palette structure. Building on this, this paper extracted the dominant colour structure of the characters' attire, finding that it is generally based on low-saturation warm tones and exhibits a hierarchical organisation comprising dominant, secondary and accent colours. Further clustering results indicate that the colour palettes of Sun Wen's illustrated edition character garments are not randomly distributed, but rather comprise several relatively stable and generalisable colour palettes categories. This paper demonstrates that digital image analysis methods can provide a quantifiable, comparable and scalable research pathway for the study of colour in traditional painting.

Author Declarations

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Conflicts of interest/Competing interests
The authors declare no competing interests.

Ethics approval/declarations
Not applicable.

Availability of data and material/ Data availability
The datasets generated during the current study are available from the corresponding author on reasonable request.

Author Contributions
Kaixuan Liu developed the research idea. Juan Chai and Haitao Wang wrote the manuscript. Chun Zhu、Ping Wang completed the data collection. All authors read and approved the final manuscript.

References

[1] Stork, D G. Computer vision and computer graphics analysis of paintings and drawings.*Computer Vision and Image Understanding*. 9-24(2009).

[2] Chen X, Liu Q, Chen Y, et al. ColorNetVis: an interactive color network analysis system for exploring the color composition of traditional Chinese painting. *IEEE Transactions on Visualization and Computer Graphics*. 30(6), 2916-2928(2024).

[3] Sujjada A, Fauzi M R, Suriawan A R A, et al. Recoloring Cartoon Images Based on Palette Mapping Using K-Means Clustering and Gradient Analysis. *Engineering Proceedings*. 107(1), 82(2025).

[4] Sharma G. Digital Color Imaging Handbook. *Boca Raton: CRC Press*.2003.

[5] Fair Child M D. Color Appearance Models. *3rd ed. Hoboken: Wiley.* 2013.
[6] Hunt R W G, Pointer M R. Measuring colour. *John Wiley & Sons.* 2011.
[7] Macqueen J. Some methods for classification and analysis of multivariate observations[C]//*Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*. *Berkeley: University of California Press.* 281-297(1967).
[8] Pavan Kumar P, Sharma A. Dominant color palette extraction by K-means clustering algorithm. *International Journal of Computer Applications*. 921-929(2020).
[9] Deeparani K, Sudhakar P. Efficient image segmentation and implementation of K-means clustering. *Materials Today: Proceedings*.45, 8076-8079(2021)
[10] Weingerl P, Hladnik A, Javoršek D. Development of a machine learning model for extracting image prominent colors. *Color research & application*. 45(3), 409-426(2020).
[11] Jardim S, António J, Mora C. Graphical image region extraction with k-means clustering and watershed. *Journal of Imaging.* 8(6), 163(2022).
[12] Kirillov A, Mintun E, Ravi N, et al. Segment anything. *Proceedings of the IEEE/CVF international conference on computer vision.* 4015-4026(2023).
[13] Talib M, Al-Noori A H Y, Suad J. YOLOv8-CAB: Improved YOLOv8 for Real-time object detection. *Karbala International Journal of Modern Science.* 10(1), 5(2024).
[14] Von Kries J. Die Gesichts-empfindungen und ihre Analyse. *Veit & Comp*. 1882.
[15] Worthey J A, Brill M H. Heuristic analysis of von Kries color constancy. *Journal of the Optical Society of America A*. 3(10), 1708-1712(1986).
[16] Bäuml K H. Simultaneous color constancy: how surface color perception varies with the illuminant. *Vision research.* 39(8), 1531-1550(1999).
[17] Van Trigt C. Von Kries versus color constancy. *Color Research & Application.* 35(3), 164-183(2010).
[18] Gao C, Li C. The von Kries chromatic adaptation transform and its generalization. *Color Research & Application*. 45(4), 732-738(2020).
[19] Healy J, McInnes L. Uniform manifold approximation and projection. *Nature Reviews Methods Primers.* 4(1), 82(2024).
[20] Blanco-Portals J, Peiró F, Estradé S. Strategies for EELS data analysis. Introducing UMAP and HDBSCAN for dimensionality reduction and clustering. *Microscopy and Microanalysis*. 28(1), 109-122(2022).
[21] Ward Jr J H. Hierarchical grouping to optimize an objective function. *Journal of the American statistical association*. 58(301), 236-244(1963).
[22] Landau S, Ster I C. Cluster analysis: overview. *International encyclopedia of education.* 3, 72-83(2010).