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Research Article

Mathematical Model Design of the Traditional Dress Recognition Algorithm Based on Digital Watermarking Technology

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According to the characteristics of traditional clothing, clothing identification is studied, and clothing identification and clothing culture learning are effectively combined to find a new method for the inheritance of national culture and strive to make contributions to the inheritance of national culture. According to the requirement of the traditional garment identification watermark monitoring system, a self-synchronous digital watermarking algorithm is designed and implemented. Watermark is embedded in the time domain, and feature information is extracted from traditional clothing by means of mean filtering and replaced by watermark to achieve the purpose of embedding information. Blind detection is realized without the participation of the original image. The difference between the traditional costume embedded with watermark and the original traditional costume is almost imperceptible. It can effectively resist synchronous attacks including clipping and time shifting, showing good robustness. Imperceptibility and robustness can be adjusted freely by embedding strength. The HOG + SVM algorithm is applied to minority clothing classification and recognition. By comparing different classifiers, it is concluded that the classifier trained by the support vector machine algorithm has the best classification effect on ethnic clothing. In order to improve the classification effect, the classical algorithm of color, texture, and shape feature extraction was combined with SVM to conduct experiments on the clothing database collected and sorted out in Yunnan ethnic minority communities, and finally, we verified that the HOG feature combined with the SVM classification algorithm achieved good results in the classification of ethnic clothing.

1. Introduction

In the mining and analysis of traditional cultural data, it is urgent to interpret and annotate a large number of digital graphic data to improve the inheritance and innovative application of excellent traditional culture, and a large number of methods for rational organization and management of cultural resources have been proposed [1, 2]. However, compared with flowers, grass, trees, birds, clouds, mountains, and seas in natural scenes, the research objects in traditional cultural data have rich cultural connotations as their high-level semantics in addition to visual features and entity names. How to construct a set of large-scale and professional cultural resources tagging thesaurus has become a key problem that needs to be solved urgently.

Accurate and automatic extraction of garment contour is very important in the fields of content-based garment image retrieval and garment style recognition. The reason is that most of the clothes have printed patterns and have texture, while clothing images have natural shadows, uneven illumination, or artificial watermarks due to illumination. When the gray value near the contour of clothing with a printed pattern is similar to the background, texture noise will be generated when the contour is extracted. At present, garment design and production enterprises still use manual or human-computer interaction depiction to extract garment outline or style drawing. A fiber image segmentation algorithm combining K-means and the GVF snake model is proposed [3], and contour tracking is adopted to remove the burr of the contour. The so-called burr refers to an arbitrary curve segment of 1 pixel width, with only one end connected

to the contour. However, the texture noise in the garment contour is a concave curve, which is embedded in the contour curve and cannot be identified by contour tracking. Horizontal scanning of a garment style image is adopted to determine contour points [4]; that is, the garment style image with the background color removed is horizontally scanned from left to right line by line to locate contour points. This method can only be applied to simple clothing style images without textures and clothing parts. There is no relevant literature on other research of garment contour extraction.

Since the clothing pattern map has no color and texture, only the shape features of the pattern map image can be extracted. Three descriptors are used to describe the shape feature extraction, and the single scale wavelet Fourier descriptor is used for comparison. Then, the dimension reduction method of LDA is adopted. The feature data after dimensionality reduction were input, and part of the data were trained with SVM and ELM classifiers, respectively, and the performance of the classifier was tested with the remaining data. This paper designs a scheme of digital watermarking information encryption technology. After the watermark information is processed by the encryption algorithm designed in this paper, even if the attacker steals the digital works containing watermark information, it is difficult to decode it, so as to strengthen the security of digital watermarking products. At the same time, error correction code technology is added in the process of watermark information processing, which improves the stability of the system.

2. Related Work

Literature [5] uses the wavelet DFT transform method to embed the watermark into the image. The difference between the two is that the latter watermark is embedded into the dc coefficient of each block of DST transform, which uses the spread spectrum watermark method [6], and literature [7] also reported similar spread spectrum watermarking method with them. Literature [8] used first-order wavelet decomposition and a linear programming method to design an optimal watermark under visually perceptible difference closure (JND). Embedding watermarks in wavelet approximation coefficients are very straightforward and also accord with the principle of embedding watermarks in the most important data. Some methods of ACT domain spread spectrum watermarking can be used for reference directly. To embed the watermark into the wavelet detail coefficient, we carefully select the embedded sub-band, the embedded wavelet coefficient, and the intensity of the embedded watermark. As for the wavelet detail coefficients of each sub-band, their distribution is mostly in Laplacian distribution [9]; that is, except for a few coefficients, most coefficients are relatively small in value, and the watermark embedded in the detail coefficients is easy to be removed by high-pass filtering. In literature [4], watermarks are embedded in each sub-band coefficient of wavelet decomposition. By analyzing the perceptual significance, the embedding method adaptively selects the position of embedded watermarks and the embedding intensity in different sub-bands. Literature [10] used the multiscale characteristics of wavelet decomposition to embed a self-similar watermark into the first and second level detail coefficients of wavelet decomposition, respectively. A method of embedding watermarks in the wavelet coefficients of visual importance was proposed [11]. The algorithm searched for the coefficients of visual importance and embedded watermarks successively. A private and public watermarking algorithm based on wavelet transform was proposed [12]. The image and the watermark information to be embedded are decomposed by wavelet, respectively, and data are fused according to visual characteristics. In this method, the original image is required for watermark extraction. The latter is a special quantization of wavelet coefficients to embed information, and this method does not need the original image to extract watermarks. Combining watermarking technology into wavelet image coding can reduce the extra computational load caused by watermarking operation.

The data of traditional costume cultural resources are an important source for human beings to know the world and themselves and have high aesthetic value and inheritance value. However, due to the high professional threshold of annotation and interpretation, manual annotation is mainly relied on the basis of standard metadata at present. However, in some natural scenes in nontraditional cultural fields, scholars at home and abroad have performed a lot of exploration and research on image annotation methods combined with text and text mixing information [13], and the core of which is how to fuse multimodal information such as images and associated texts. At present, the annotation methods of mixed text and text can be divided into theme-based model, matrix model, text mining, deep learning, and so on. The method based on the topic model is a common method to fuse image and text features. This method regards labeled images as samples of a specific topic combination, where each topic is the probability distribution of image features and tag words. Typical algorithms include LSA [14] and LDA [15]. Matrix model-based methods mainly include the proposed CCA model and the proposed DCCA model. The core is to build a fusion consistent space of image semantic features and text features [16]. However, the most representative method based on text mining is the method of word extraction based on associated text with different weights of images. Detection technology based on digital image processing has been increasingly mature in the field of textile, but the application in the field of clothing is very little. Now, clothing technologists have found that digital image processing can reduce the influence of human factors. For example, digital image processing and pattern recognition technology were used to study the identification and classification of garment sewing process defects so as to realize the automatic detection of garment defects [17]. The sample image of a men's shirt was collected by taking photos, and the image was enhanced and denoised; then, the min value was segmented. Specific detection algorithms are designed for single line trace and double line trace and

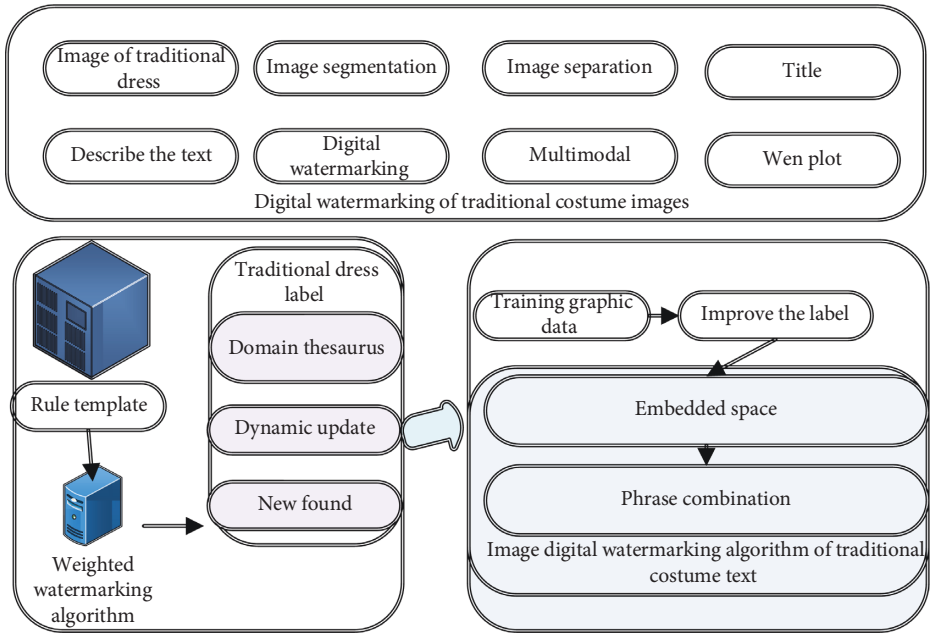

Figure 1: Structure diagram of the traditional costume text-plotting algorithm with text and text mixed arrangement.

symmetry feature, respectively [18]. The image of lining rubber particles was preprocessed, and the image morphology was analyzed. In order to digitally describe the visual effect of garment surface wrinkles, an evaluation index system based on the gray scale was proposed by processing garment surface wrinkle images [19]. Clothing image segmentation methods can be divided into methods using the clothing model and methods without the clothing model. For the model approach, it is generally required to train a sample of tagged clothing and then compare clothing extracted from the image with the model. In an attempt to achieve the detection of dressed personnel through the classification based on the segmentation region of color clothing, a probability model of a tree structure is established for efficient retrieval (the retrieval speed of the human body shape region combination block is faster than that based on pixels) [20]. This structure represents the symmetrical parts of the human body in the form of functions, including relative position, relative size, and connection. However, someone in formal dress is not as easy to identify as someone in a bathing suit. Obviously, the recognition of personnel cannot be achieved through a single-tree structure [21]. However, the feature extraction area is often very rough segmentation, and the difficulty of segmentation is due to clothing and other items highly associated, such as personnel. To overcome the problem of unconstrained posture, a segmentation method based on a mass component detector was proposed. This method can divide the image of the person into the upper and lower clothing areas, while taking into account the posture of the person [22]. For each part, they learned the person's posture by segmenting the model, A method of skin detection and clothing selection based on color is proposed [23] to achieve automatic segmentation of clothing area. To achieve both ends, color description extraction is achieved through an iterative energy minimization approach and an automatic initialization strategy through learning geometric constraints and shape cues.

3. Traditional Costume Recognition Algorithm Based on Digital Watermarking Images and Text Mixing

3.1. Traditional Clothing Recognition Algorithm. This paper focuses on clothing, clothing patterns, and other categories. In order to facilitate the multimodal text mapping of the layout image, it is necessary to identify the image and its associated text and other information in the page accurately. In format recognition, problems such as extracting text, distinguishing and locating title and text, and relocating format multiple times are solved. This algorithm refines the position and image scale level and automatically identifies data bodies such as images, location titles, and text descriptions in books in the field by using spatial relations. The structure of the graph algorithm is shown in Figure 1. The pattern recognition module is responsible for automatic detection and extraction of image, text, and associated text in text and text data and providing basic data for the text-plotting algorithm. In Figure 1, the traditional cultural pattern semantic label library module provides semantic metadata and domain dictionary for cultural domain image learning annotation and provides domain expert knowledge through multi-modal text mapping algorithm aggregation. The multimodal text rendering algorithm module makes full use of multimodal association information, semantic annotation system, and domain knowledge to extract and annotate image semantics.

There are potential relationships between images of traditional costumes: there are dragons on dragon robes, and

Table 1: Traditional clothing image label system fields.

Field	Field definition
Traditional dress	It covers the traditional national costume patterns of all Chinese ethnic costumes
Pattern/name	The name of the pattern is generally designated by the field experts, such as the dragon pattern, honeysuckle pattern, and triangle pattern
Moral	The cultural connotation carried by the patterns is generally determined by people's living environment and humanistic beliefs
Configuration	Geometric composition of the configuration, such as symmetry, continuous quadrilateral
National	People associated with ornamentation
Regional	A local area associated with an ornamented pattern
Ages	The period of the ornamentation
Color	The color characteristics of the pattern
Arts and crafts	Design of the clothing using technology and art techniques

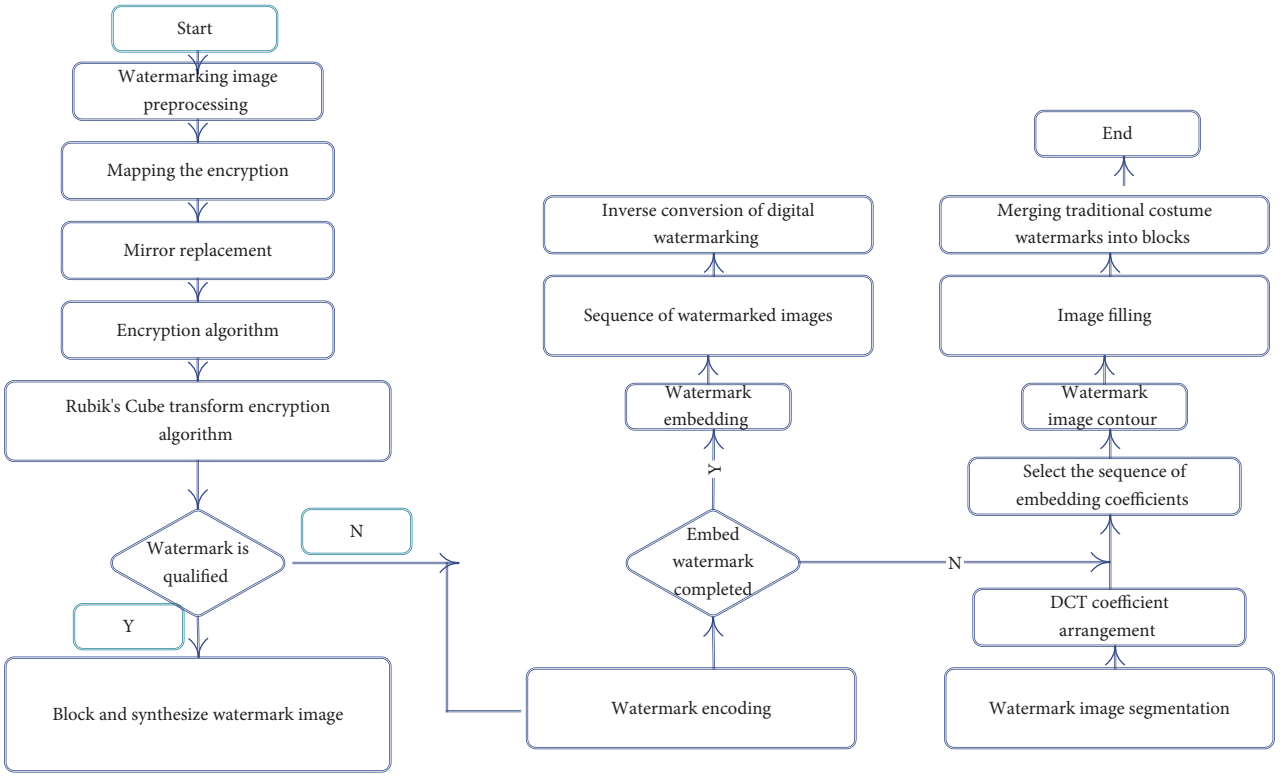

Figure 2: Flowchart of traditional costume recognition based on image scrambling encryption watermarking.

there is a high probability of auspicious clouds around dragons. Based on domain expert knowledge, this kind of association is extensively explored so that the label system can fully reflect the cultural value of clothing. The fields of the semantic label system of traditional clothing images are shown in Table 1.

3.2. Extraction of the Traditional Clothing Style Map. For the garment image with printed patterns, the point whose gradient value is greater than a certain threshold cannot be simply selected as the contour line. To this end, it is necessary to remove the points and wrinkles caused by wrinkles and printed textures in the collar, sleeve, pocket, front, and other parts of the garment by morphological method. The block diagram of the initial contour extraction algorithm is shown in Figure 2, which can also be further described by the algorithm in Table 2.

In the test, we selected two points, namely (1, 1) point and (0, 2) point, and the watermark intensity parameter $a = 0.5$. 450 random Gaussian sequences were selected, including two sequences of 150 and 350 points. The detection results are shown in Figure 3, indicating that the embedded watermark information can be correctly detected at this time.

4. Traditional Costume Culture Pattern Recognition Algorithm Based on Digital Watermarking

How you extract the domain vocabulary is key to building PatternNet. There are a large number of professional terms

Table 2: Initial contour extraction algorithm.

Enter: clothing image
Output: initial outline
(1) After the original image is transformed into a grayscale image, the Sobel operator is
used to detect the horizontal and vertical edges of the image
(2) Using structural elements to perform expansion operation on the image
(3) Image filling operation
(4) Use structural elements to carry out corrosion calculation on the image
(5) Extract the initial contour

and words with special cultural meanings in graphic books, such as "Qiuci dress," "grass pattern," "cao eating pattern," and "vortex pattern." It is difficult to cut and extract more accurate professional terms in the cultural field with the help of the current classical word segmentation tools. Therefore, this paper takes annotations by field experts, historical documents, professional books, and other materials as data sources. After digital collection, more than 4000 pictures and texts are obtained through cleaning and sorting. Then, guided by the traditional clothing image label system, the field terms of name, meaning, configuration, nation, age, region, color, arts and crafts, and other fields are described to build PatternNet. In order to enrich the domain vocabulary, first, we expand the number of books collected and sorted manually and introduce Word2vec to extend the synonyms of the initial domain vocabulary. Finally, the semantic label library oriented to domain specialty is constructed through iterative optimization. PatternNet is built without aggregation reuse of the information up front, instead using a dynamic update pattern to accommodate more usage scenarios. To some extent, it solves the problem that automatic tagging requires a large number of text and text tagging samples and provides basic data and technical path for the construction of domain professional corpus. With the iterative optimization of the dataset, a cultural image semantic tag library with resource association and semantic association can be realized. This paper focuses on the combination of graphics and textbooks of clothing and patterns, and the keywords of each category are shown in Table 3.

Before the SVM classification method is used to classify the clothing style map, digital attributes (characteristic parameters) are normalized to the interval of "0, 1." The main advantage of normalization is to avoid the digital attributes in the larger range dominating the digital attributes in the smaller range. This normalization also improves the efficiency of fashion pattern classification by limiting the problem of large kernel computation caused by large number ranges. The classifier takes the shape feature (invariant moment) of the garment pattern diagram as the input and the category label of the garment pattern diagram as the output.

$$\min\left(\frac{1}{2}w^T w\right) + C\sum_i \delta^2. \tag{1}$$

In the construction of style diagram classifiers, radial basis kernel functions are used as follows:

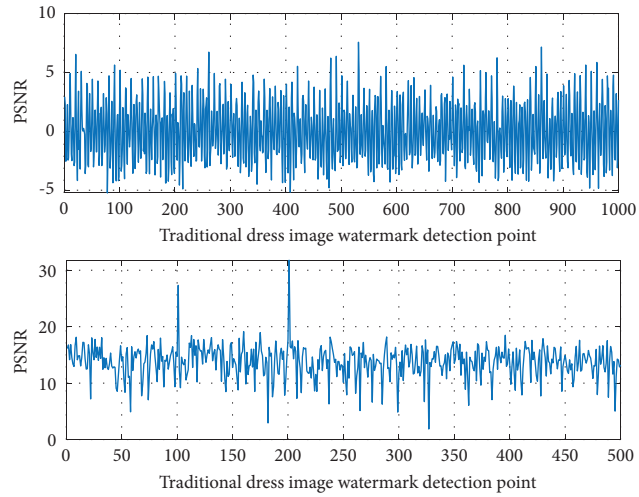

Figure 3: Detection results of each embedded bit information of the two points.

$$T(x, y) = e^{-g\|x-y\|^2}. \tag{2}$$

In the experiment, different gradient operators were compared to carry out convolution operations on the image, and finally, the one-dimensional centrosymmetric template had the best effect. After the convolution operation on the image, the gradient components in horizontal and vertical directions can be obtained as follows:

$$T(x, y) = T(x+1, y) - T(x, y+1). \tag{3}$$

For a good image, the authentication system generally needs to meet six aspects.

Sensitivity: sensitive to malicious data manipulation

Robustness: ability to withstand operations such as lossy compression or other operations that do not destroy data content

Security: embedded information cannot easily be forged or manipulated

Mobility: the ability to directly verify the integrity of obtained multimedia data without having to send additional authentication data

Location performance for tampered regions: the ability to locate tampered image regions

Repair of tampered data: the ability to repair tampered data

A $256 * 256$ degree Lena graph is used to test the robustness of the watermarking algorithm. The results are shown in Table 4.

5. Example Verification

A clothing 140 database is adopted in this experiment, which contains clothing style maps of 7 categories, and each category contains 20 pictures. The invariant moment of each sample is calculated according to the method. The first 10

Table 3: Partial keywords of domain thesaurus.

Category	Keywords (part)
Grain appearance	Geometric pattern, plant pattern, figure pattern, animal pattern, sun, moon and stars pattern, totem pattern
Moral	Happiness, longevity, festival, abundance, good, peace, wealth, many children, into school, official
Configuration	Independent (single pattern), continuous (continuous pattern)
National	Han, Zhuang, Uygur, Miao, Manchu, Hui, Tujia, Yi, Mongolian, Tibetan
Regional	Central plains, Wuling, Shaoling, Jiangdong, Hedong, Kansai, Sanqin, Huguang, western regions, Jiangbiao
Ages	Primitive society period, Xia and Shang, spring and autumn and warring states, Qin and Han, Wei, Jin and southern and northern dynasties, Sui and Tang, five dynasties and ten states, two Song dynasties, Liao, Jin, Yuan, Ming, and Qing dynasties
Color	According to the traditional color spectrum of clothing, the main colors and intermediate colors are divided into categories, such as yellow, and divided into dragon robe bright yellow, color painting realgar, old paint yellow, Beijing embroidery beige
Arts and crafts	Flat embroidery, random needle embroidery, seed embroidery, lock embroidery, pan gold embroidery, patch embroidery, double-sided embroidery, hand push embroidery, pearl embroidery, hair embroidery, horsetail embroidery, tin embroidery, Su embroidery, Guangdong embroidery, Hunan embroidery, Shu embroidery, three blue embroidery, ink embroidery

Table 4: Watermark robustness test results of the 256 ∗ 256-level gray Lena image.

Operations on images	1024 error bits	Error rate
JPEG compression (mass factor) = 0	112	11.05
JPEG compression (mass factor) = 5	85	8.03
JPEG compression (mass factor) = 10	53	4.97
JPEG compression (mass factor) = 15	38	3.54
JPEG compression (mass factor) = 20	26	2.43
JPEG compression (mass factor) = 30	13	1.35
Mosaic treatment	9	1.07
Image smoothing	34	0.34
Image Gaussian smoothing	3	3.45
Image sharpening	12	1.06
Enhanced image sharpening	16	1.32
Add evenly distributed noise	32	3.05
Add Gaussian distributed noise	12	3.78
Histogram equalization	16	1.25

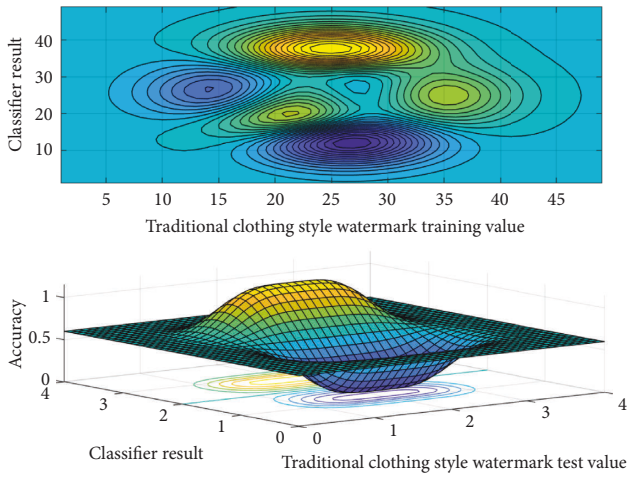

Figure 4: Results of rough parameter selection for clothing140 database cross validation.

samples of each category were used as the training set, and the last 10 samples were used as the test set. By using the

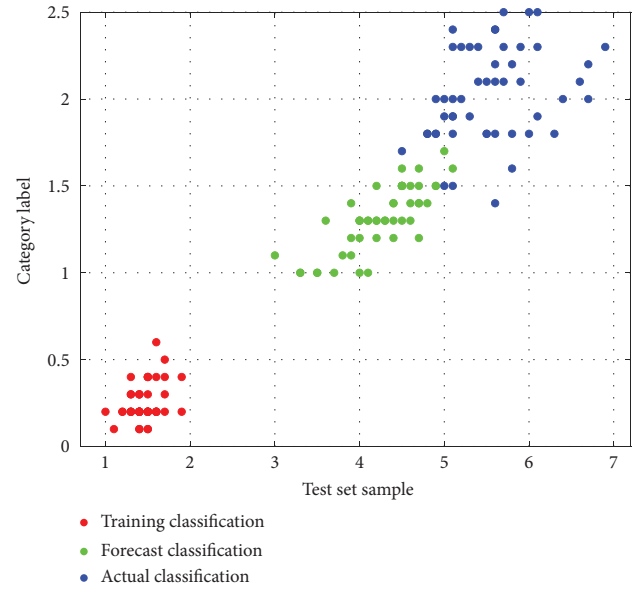

Figure 5: Classification result diagram of the clothing140 database test set.

method of cross verification, a rough parameter selection result figure for the RBF kernel support vector machine classifier is first obtained, as shown in Figure 4.

The optimal parameter of fine selection is (1, 64). An SVM (support vector machine) classifier was used for classification. The classification results obtained are shown in Figure 5. The classification accuracy reached 80%; that is, 56 samples in the test set (70 samples) were correctly classified.

After data collection, different ethnic groups were classified and numbered. In this paper, 100 pictures of each ethnic group were selected as sample data and numbered from 1100 to different folders, respectively. In order to facilitate MATLAB operation, the pictures were processed in pg format with a size of 96 ∗ 144 (see Figure 6).

SVM was combined with the classical feature extraction algorithm for the experiment. Parameter selection of the

Figure 6: Traditional dress sample library.

Table 5: Accuracy of different image features under SVM.

Feature	Classifier	Accuracy (%)
Pixel	SVM	94.43
CH	SVM	94.21
LBPu (8, 1)	SVM	94.88
LDP ($k = 3$)	SVM	33.23
LLCM	SVM	80.12

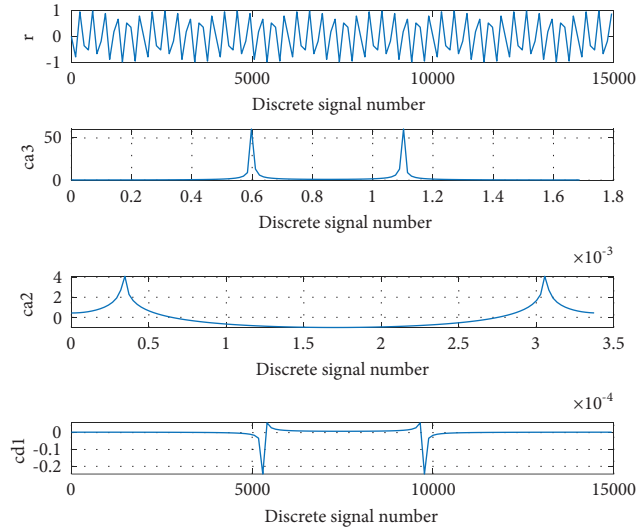

Figure 7: DBL wavelet digital watermarking decomposition of traditional clothing.

feature extraction algorithm was based on the research team's previous experiment on the feature algorithm of ethnic clothing images. The experimental results are shown in Table 5.

Figure 7 shows that the signal uses DBL wavelet three-stage decomposition, which consists of three levels of detail wavelet coefficients and third-order approximate wavelet coefficients.

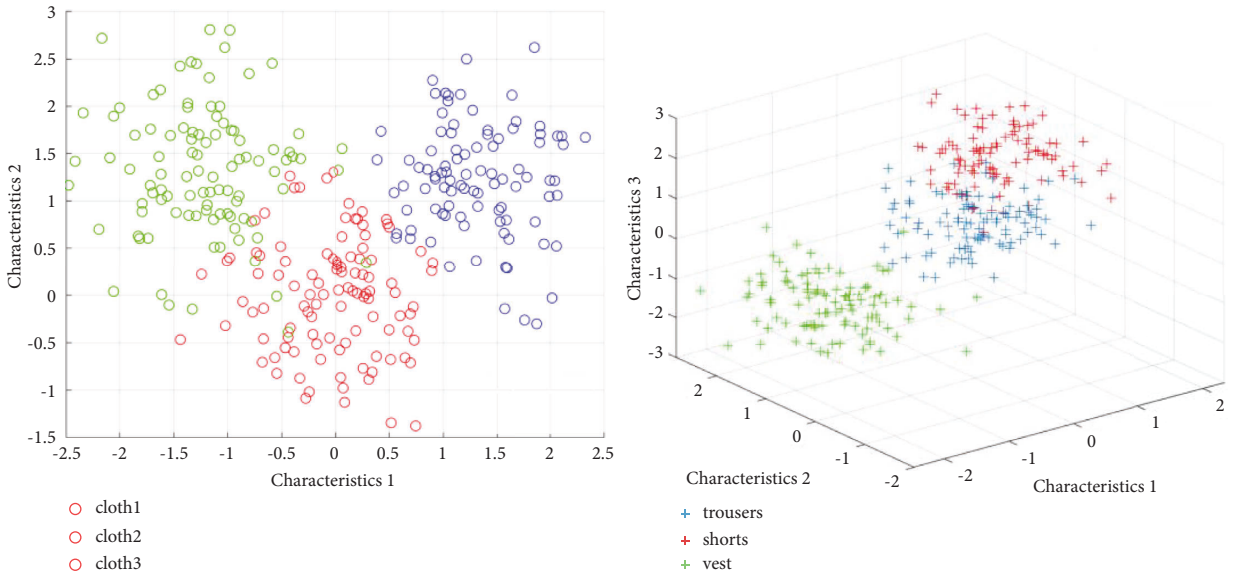

Figure 8: Visualization of traditional clothing style drawing samples projected into a two-dimensional space after dimensionality reduction by PCA.

In this experiment, the samples described by FD 120 are projected into a two-dimensional space through LDA and PCA, respectively. Figure 8 shows the visualization result of projecting the sample of the traditional clothing pattern into a two-dimensional space after PCA dimensionality reduction. As can be seen from Figure 8, interclass crossing occurs in many places except for trouser and cloth 1 categories.

6. Conclusion

The security of ciphertext is enhanced through multiple iterations. The practical effect of the encryption scheme is verified by relevant experiments. Watermark information of different properties can be transformed into a two-dimensional data matrix by dimensionality enhancement or dimensionality reduction to apply the algorithm. To a certain extent, the efficiency of the algorithm will be affected. In the future, the development direction of scrambling technology should be to find more excellent scrambling effects and less resource consumption. In addition, the simulation results show that the quality of the original digital works will be affected in the process of embedding watermark information. The embedding position, the amount of embedded watermark information, and the intensity parameters will affect the original quality of the carrier works to varying degrees, which must be considered in the practical application of digital watermarking technology. By comparing the classical feature extraction algorithm and the classification algorithm, HOG + SVM is applied to the classification of minority clothing. Taking Hani, Kan, and Yi nationalities as examples, this paper conducted experiments on the classical algorithms and classification algorithms of clothing color, shape, and texture features and verified that the gradient information of traditional clothing was well represented in the clothing database. Combined with SVM, the best classification effect was obtained. In the next step, texture features were divided into global texture and three local textures: collar, front flap, and hem. Wavelet moments were used as global or local texture feature descriptions. Shape features and various texture features were optional combinations, and some style maps that cannot be retrieved by shape and global texture alone will be found [24–26].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] H. Xue, "False image recognition based on digital watermarking technology[J]," *Optoelectronic Technology*, vol. 32, no. 2, pp. 127–130, 2021.

[2] K. W. Tang, R. S. Liu, and D. U. Hui, "A novel dimensionality reduction method based on tensor and lorentzian geometry," *Acta Automatica Sinica*, vol. 37, no. 9, pp. 1151–1156, 2021.

[3] H. Qiu, H. Duan, and Y. Shi, "A decoupling receding horizon search approach to agent routing and optical sensor tasking based on brain storm optimization," *Optik*, vol. 126, no. 7-8, pp. 690–696, 2015.

[4] T. Chun, "Integrating conjoint analysis with TOPSIS algorithm to the visual effect of icon design based on multiple

users' image perceptions," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 3, pp. 439–465, 2017.

[5] J. Zhuang, S. Xu, and G. Li, "Intelligent decision method of multi-agricultural commodity model based on machine learning," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 36, no. 08, pp. 105703–105721, 2022.

[6] X. Liu, "Design of the digital watermarking concealment and the detection algorithm based on wavelet transform," *Natural Science Edition*, vol. 18, no. 3, pp. 152–160, 2018.

[7] J. Li and C. Xiang, "Digital watermarking algorithm based on tujia brocade design of haar wavelet transform," *Journal of Nanjing Normal University (Natural Science)*, vol. 33, no. 4, pp. 153–156, 2020.

[8] Y. Xiong, Y. Chen, C. Chen, X. Wei, and P. Wang, "An odor recognition algorithm of electronic noses based on convolutional spiking neural network for spoiled food identification," *Journal of the Electrochemical Society*, vol. 168, no. 7, pp. 077519–077532, 2021.

[9] Z. Xing, "Driver's intention recognition algorithm based on recessive Markoff model," *Journal of Intelligent and Fuzzy Systems*, vol. 38, no. 12, pp. 11–32, 2019.

[10] W. U. Lidan, Y. Xue, and T. Tong, "Image colorization algorithm based on foreground semantic information," *Journal of Computer Applications*, vol. 41, no. 7, pp. 2048–2053, 2021.

[11] L. Zhou and Q. Zhang, "Recognition of false comments in E-commerce based on deep learning confidence network algorithm," *Information Systems and E-Business Management*, pp. 112–128, 2021.

[12] Z. Xiang, Z. You, and M. Qian, "Metal stamping character recognition algorithm based on multi-directional illumination image fusion enhancement technology," *EURASIP Journal on Image and Video Processing*, vol. 2018, no. 1, pp. 342–365, 2018.

[13] C. Zhou, "Algorithm design of early warning seatbelt intelligent adjustment system based on neural network and big data analysis," *Mathematical Problems in Engineering*, vol. 2020, pp. 21–37, 2020.

[14] J. Chen, J. Sun, L. Ye, and S. Zhao, "Research on image digital watermarking algorithm based on matlab," *IOP Conference Series: Materials Science and Engineering*, vol. 677, no. 4, pp. 042073–042088, 2019.

[15] W. Ding, H. Li, and H. Jiao, "Research on the design of a new type of digital image processing algorithm and its reliability based on GPU," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 171–173, 2017.

[16] L. Wen, M. Nie, and P. Chen, "Integrated structure for recognition of different joint motion states with the assistance of a deep learning algorithm," *Microsystems and Nanoengineering*, vol. 8, no. 1, pp. 14–35, 2022.

[17] C. Zhang, H. Li, X. Chen, and X. Shi, "Research on watermark printing technology of STL model based on Menger curvature," *Journal of Physics: Conference Series*, vol. 1848, no. 1, pp. 012075–012085, 2021.

[18] T. Chen, L. Wang, Y. Li, and S. Duan, "Research and implementation of breast cancer intelligent recognition algorithm based on deep convolutional neural network," *Journal of Physics: Conference Series*, vol. 1634, no. 1, pp. 012176–112086, 2020.

[19] A. Sharif, "Smart structural algorithm (SSA) based on infeasible region to solve mixed integer problems," *International Journal of Applied Metaheuristic Computing*, vol. 8, no. 1, pp. 24–44, 2016.

[20] X. U. Ke, W. Gai, and Y. Deng, "Comparative analysis model on similarity of emergency decision-making texts based on LCS," *Journal of Safety Science and Technology*, vol. 177, pp. 105703–105721, 2019.

[21] Y. Bing, D. Jiang, and Y. Liang, "Design and analysis of three-phase digital phase-locked loop based on filtering algorithm with anti harmonic and asymmetry distortion function[J]," *Electronic Technology*, vol. 7, no. 3, pp. 242–249, 2018.

[22] Q. Cai, X. Tang, and H. E. Yuting, "A Digital Blind Audio Watermarking Algorithm Based on DWT-SVD and Optimizing of SNR," *Journal of Hangzhou Dianzi University(Natural Sciences)*, 2017.

[23] T. Yu and Q. Zhang, "Digital image matting model based on fast segmentation kernel function," *Bulletin of Science and Technology*, vol. 43, no. 6, pp. 3421–3435, 2016.

[24] X. Shen, G. Shi, Y. Zhang, and S. Weng, "Wireless volatile organic compound detection for restricted internet of things environments based on cataluminescence sensors," *Chemosensors*, vol. 10, no. 5, p. 179, 2022.

[25] X. Shen, G. Shi, H. Ren, and Wu. Zhang, "Biomimetic vision for zoom object detection based on improved vertical grid number YOLO algorithm," *Frontiers in Bioengineering and Biotechnology*, vol. 10, no. 5, Article ID 905583, 2022.

[26] G. Shi, Y. He, and C. Zhang, "Feature extraction and classification of cataluminescence images based on sparse coding convolutional neural networks," *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1–11, 2021.