K-Means and Morphology Based Feature Element Extraction Technique for Clothing Patterns and Lines

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***Abstract*—In the process of clothing design and production, the traditional artificial feature element extraction method has the problems of low efficiency and insufficient precision, which is difficult to meet the automation and intelligent needs of modern clothing industry. In order to solve this problem, this paper proposes a technology that combines K-means clustering algorithm and morphology method to extract clothing pattern and line feature elements. This technology uses K-means clustering algorithm to preprocess clothing images to realize feature extraction of clothing pattern elements, and then introduces morphology method to realize feature extraction of image line elements. This technology not only improves the accuracy and efficiency of feature element extraction, but also retains the details of clothing images, which provides a strong support for automatic and intelligent processing in clothing design and production.**

***Keywords*—K-means; morphological algorithm; feature extraction**

I. Introduction

In the digital age, the field of clothing design and manufacturing is undergoing unprecedented changes. With the rapid development of computer vision, machine learning and image processing technology, automatic extraction and recognition of clothing pattern and line feature elements has become one of the key technologies to improve design efficiency and optimize production process. In 2017, Zhang Peng [1] compared and analyzed the applications of K-Dimensional tree's two nearest neighbor matching algorithm and random sampling agreement algorithm (RANSAC) in the field of image matching retrieval based on scale invariant feature transform (SIFT) algorithm. The results show that although K-Dimensional tree's NNN algorithm is superior in applicability and better in retrieval, RANSAC algorithm is superior in matching accuracy. In 2020, Jia Xiaojun [2] and his team successfully extracted feature elements from blue printed cloth through a series of image processing techniques, including gray level processing, corrosion, expansion, binarization and contour extraction, and built a database containing 12 elements accordingly, with an accuracy rate of 98.66%. At the same time, Chen Kaiqing [3] et al. deeply explored human preference feature extraction methods by using evolutionary matrix functions based on evolutionary strategies, and further studied how to combine deep learning with evolutionary strategies.

However, despite the remarkable progress in this field, there are still many problems. Traditional extraction methods are often inefficient and difficult to accurately capture the complex features of clothing patterns and lines, so it is particularly important to explore more efficient and accurate extraction techniques. K-means clustering algorithm and morphological analysis, as two powerful tools, have shown great potential and application value in the extraction of clothing feature elements. As a classical unsupervised learning method, K-means clustering algorithm has been widely used in many fields such as data analysis and image processing because of its simplicity and high efficiency. The algorithm divides the data into K clusters iteratively, so that the similarity of data points within the same cluster is high and the similarity of data points between different clusters is low [4]. In the feature extraction of clothing patterns, K-means algorithm can effectively group pixels or feature points in images according to their similarity, so as to identify the basic units of patterns and the direction of lines, providing strong support for subsequent design analysis and optimization. Morphological analysis is a shape-based image processing technology, which extracts the key features of the image by describing and analyzing the shape and structure in the image. In line feature extraction, morphological analysis can optimize and enhance the extracted feature elements through morphological operations, such as corrosion, expansion, open operation, close operation, etc., so that it is more in line with the design requirements and production requirements. This paper aims to explore the extraction technology of clothing pattern and line feature elements based on K-means clustering algorithm and morphological analysis, and demonstrate the application potential and practical effects of this technology in the field of clothing design and manufacturing through theoretical analysis and experimental verification [5].

Firstly, this paper gives a brief overview of K-means clustering algorithm and morphology algorithm, and then deeply discusses the extraction technology of clothing pattern and line feature elements based on these two algorithms. Specifically, the technical framework covers the K-means algorithm to extract pattern features from clothing images and the morphological algorithm to extract line feature elements in images. In order to verify the effectiveness and superiority of this comprehensive technology, a set of targeted experiments were designed and implemented in the end, and image data including clothing patterns were selected for testing.

II. K-means Algorithm and Morphology Algorithm

A. K-means Algorithm

K-means algorithm, also known as K-means clustering algorithm, is a widely used partitioning based clustering technology. Its core lies in the pre-set k value, which directly determines the number of initial cluster centers and thus affects the partitioning of the whole data set. The K-means algorithm iteratively optimizes a cluster objective function, aiming to minimize the similarity between different clusters, while the data points within the same cluster show the greatest similarity [6]. The flexibility and effectiveness of K-means algorithm make it widely used in many fields. In the field of market segmentation, the algorithm can automatically divide the customer base into multiple market segments with different characteristics according to the customer's purchasing behavior or preference pattern, helping enterprises to develop more accurate marketing strategies. In the field of image processing, K-means algorithm is used in image segmentation tasks, which can realize automatic analysis and understanding of images by dividing pixels in images into different regions according to color, texture and other features, providing strong support for image recognition, image compression and other applications. In addition, K-means algorithm also plays an important role in text clustering, data mining, bioinformatics and other fields [7].

B. Morphology Algorithm

Mathematical Morphology is an algorithm system pioneered by French scholars J. Serra and Marceron in 1964, and has been deeply applied to many frontier fields such as computer vision, pattern recognition, image analysis and processing. As a powerful tool, it is widely used to analyze all kinds of complex images, such as the accurate identification of ground buildings in high-resolution satellite images from a high altitude, and the in-depth exploration of the structural mysteries of cells, bacteria, viruses and even lizard red blood cells in the biological microscopic world. Morphology has a series of basic operations, including expansion, corrosion, open operation and close operation. These operations not only play a significant role independently, but also can be skillfully combined and derived into a variety of practical algorithms such as top cap and bottom cap transformation, hit and miss transformation, watershed transformation, morphological gradient and particle analysis, which greatly enrich the means of image processing. Make image analysis more accurate and efficient [8]. As a core concept in morphology, the design and application of Structure Element directly determine the effect and efficiency of morphological processing. When applying mathematical morphology algorithm to process images, selecting the appropriate structural element is a crucial step, which determines how the algorithm "senses" and "transforms" the morphological structure in the image. With the continuous progress of technology and in-depth research, the application prospect of mathematical morphology will be broader, bringing more innovations and breakthroughs to the field of image analysis and processing [9].

III. EXTRACTION OF CLOTHING PATTERN AND LINE FEATURE ELEMENTS BASED ON K-MEANS AND MORPHOLOGY

A. Clothing Pattern Extraction Based on K-means Algorithm

1) Cluster analysis: Cluster analysis aims to divide a large data set into multiple categories, ensuring that similar objects are highly similar and different categories are significantly different. This analysis technology has been widely used in many fields such as data compression, image segmentation, text retrieval and bioinformatics. Over the years, the research of cluster analysis has spawned many classical theories and algorithms, including hierarchical clustering, model clustering, grid clustering and partition clustering, etc. Each algorithm has its own characteristics and limitations. Hierarchical clustering can realize data grouping by building a tree structure, and the hierarchy is clear but difficult to trace back [10]. Model clustering depends on the strong robustness of the model set by the researcher; Grid clustering is efficient in spatial data processing and suitable for incremental implementation and high dimensional processing. Partitioning clustering is based on the distance between classes and is often limited to finding round or spherical clusters [11].

Clustering is significantly different from classification in that classification requires predictive training sets to extract classification rules and then apply them to unknown data, which is supervised pattern recognition. Cluster analysis, however, does not have such prior knowledge and automatically divides data into various categories by function or statistical method, which belongs to unsupervised pattern recognition.

The basic flow of cluster analysis covers the following key steps:

a) Data preprocessing: The core of this stage lies in the standardized data processing and feature dimension reduction. Standardization aims to eliminate the influence of different dimensions on the clustering results and ensure that each feature has the same weight in the clustering process. Feature dimensionality reduction reduces the dimensionality of the data set through methods such as principal component analysis (PCA) [12], while retaining key information in the original data as much as possible to improve the clustering efficiency and effect.

b) Feature screening: The process of identifying and selecting the most critical features in the original feature set helps reduce noise and redundant information, and makes the clustering process more focused on the essential characteristics of the data. The filtered features are converted into vector form, which is convenient for subsequent processing [13].

c) Feature refining: The selected features are further processed and extracted to obtain a more refined and effective feature representation for cluster analysis [14]. This step may involve advanced techniques such as feature transformation and feature fusion to improve the accuracy and stability of clustering.

d) Formulation of clustering strategies: According to prior knowledge, actual demand and data characteristics, the appropriate clustering criterion function is selected, which will guide the whole clustering process and ensure that the clustering results meet the expectations[15]. Under the guidance of criterion function, combined with mathematical tools and statistical theory, we perform clustering algorithm to divide data into different categories.

e) Evaluation of clustering results: After the clustering is completed, the quality of the clustering results needs to be evaluated, and the evaluation criteria mainly include intra-class validity evaluation, inter-class validity evaluation and correlation test [16]. Through comprehensive evaluation, we can judge the advantages and disadvantages of clustering results, and provide support for subsequent data analysis and decision making.

2) K-means clustering algorithm analysis: In this study, the K-means clustering algorithm is used to extract pattern feature elements from clothing images [17]. The algorithm aims to effectively divide n pixels in the image into K clusters, where k represents the number of preset color clusters. According to its RGB color value, each pixel is assigned to the cluster with the cluster center with the smallest Euclidean distance. The Euclidean distance is calculated as shown in Eq. (1).

$$d(X,C_i)=\sqrt{\sum_{j=1}^{m}(X_j-C_{ij})^2} \tag{1}$$

In formula 1, X is the data object; C_i is the i th cluster center. m is the dimension of the data object; X_j, C_{ij} is the JTH attribute value of X and C_i.

In the execution process, the distance between each pixel in the image and all clustering centers is first calculated, and each pixel is classified to the nearest clustering center based on this distance [18], and then the clustering center of each color cluster is iteratively updated by calculating the average value of RGB values of all pixels in the cluster as the new clustering center. This process is repeated until the convergence condition is met, that is, the location of the cluster center remains basically unchanged in successive iterations, which marks the completion of the clustering process. The algorithm flow chart is shown in Fig. 1.

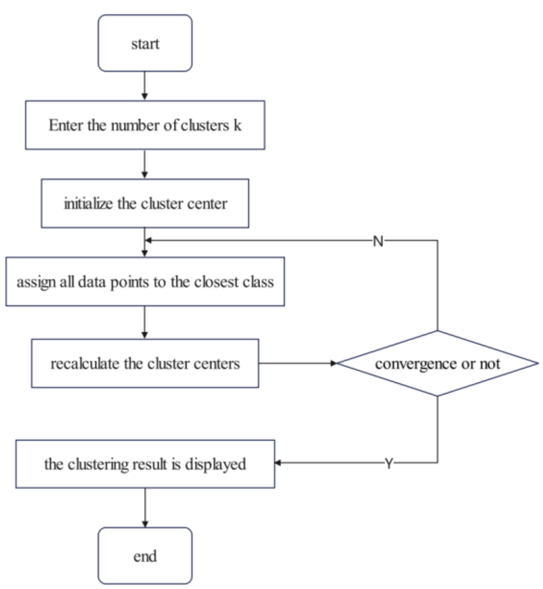

Fig. 1. K-means algorithm implementation flow.

The specific implementation steps of K-means clustering algorithm are as follows:

a) Initialization phase: Determine the number of clusters k and prepare a dataset with n data points X={x_1, x_2, x_3,... x_n}. These data points can be pixels in an image, whose properties are RGB color values.

b) Select the initial clustering center: k data points are randomly selected from data set X as the initial clustering center, denoted as m_1, m_2,... , m_k [19]. Each data point is then assigned to the nearest cluster center based on its distance to these cluster centers, resulting in k initial clusters C={c_1, c_2,... , c_k}.

c) Calculate and update the cluster center: For each cluster c_i (i=1,2,... ,k), calculates the mean of the RGB color values of all data points in the cluster and uses this mean as the new cluster center m_i. The purpose of this step is to allow the cluster center to more accurately reflect the characteristics of the data points within its cluster.

d) Reassign data points to clustering: Iterate over each data point in the dataset again, calculating their distance to each new cluster center and reassigning each data point to the cluster to which the nearest cluster center belongs.

e) Iterative optimization: Repeat steps 3 and 4, that is, continuously compute new clustering centers and redistribute data points until a stop condition is met [20]. The commonly used stopping condition is that the change of cluster center is very small or the Sum of Squared Errors SSE (Sum of Squared Errors) no longer changes significantly, which indicates that the clustering results have become stable.

f) Output clustering results: The algorithm ends when the stop condition is reached, at which time k clusters are obtained, and each cluster contains a series of data points with high similarity in color features. The final output of this k subset is as clustering results, which can be used for subsequent pattern analysis, recognition, or other related applications.

The calculation formula of the squared error and SSE of the whole data set is Eq. (2).

$$SSE=\sum_{i=1}^{k}\sum_{X\in C_i}\left|d(X,C_i)\right|^2 \tag{2}$$

In Eq. (2), SSE represents the quality of clustering results; k is the number of clusters.

B. *Garment Line Feature Element Extraction Based on Morphological Algorithm*

In this study, morphological algorithm is used to accurately extract line feature elements in clothing. In the specific implementation process, corrosion and expansion operations in morphological processing are used to realize efficient identification and extraction of clothing line features [21].

Erosion is an image processing technique that removes pixels from the edges of the image so that the edges of the image shrink inward. This process can not only fine-tune the edge shape of the image, but also effectively eliminate those objects in the original image whose size is smaller than a specific structural element, so as to remove noise and smooth the image edge. Corrosion operations are represented by a specific operator, denoted Θ. When A corrosion operation is applied to an image A to be processed, the selected structural element is S, and the operation can be expressed as A Θ S, meaning that S is used to corrode A. The concrete implementation of corrosion operation is shown in Eq. (3).

$$A \Theta S = \{x : S + x \subset A\} \tag{3}$$

The main purpose of image processing by etching operation is to make the image boundary to be processed to shrink inward evenly, this shrinkage effect is usually manifested as the overall image shrinking a circle, and the specific size of this circle, that is, the degree of image shrinking inward, is directly affected by the shape and size of the selected structural elements [22]. As a key parameter in the corrosion operation, the structure element determines which boundary pixels will be removed, thus affecting the image shape after corrosion. Fig. 2 below shows the simulation effect of the corrosion operation, which intuitively shows the phenomenon of the inward contraction of the boundary after the image has been corroded.

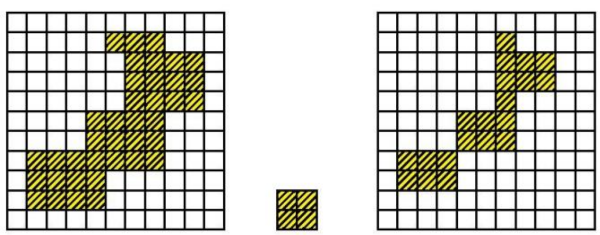

Fig. 2. Corrosion operation simulation diagram.

The principle of Dilation is the opposite of corrosion, it is an operation to expand the boundary of the target image by increasing the pixel points of the image boundary. The main function of the expansion operation is to connect the original discontinuous and breakpoint boundaries in the image, so as to restore or form a complete and smooth image boundary [23]. This is because the breakpoint on the image boundary may interfere or affect the subsequent computational statistical operations on the complete area of the image, and the expansion operation can effectively solve this problem. In expansion operations, the operator used is usually expressed as $\oplus$. When the expansion operation is performed on an image A to be processed, the selected structural element is S, and the operation can be expressed as A $\oplus$ S, that is, S is used to expand A. The concrete implementation of the expansion operation is shown in Formula 4, which defines how to extend the boundary of image A based on the shape and size of the structural element S.

$$A \oplus S = \{a | A + S \cup A \neq \phi\} \tag{4}$$

In the dilation operation, an important property is that it satisfies the exchange rate of the operation, which means that the result of inflating image A with the structural element S (denoted as A $\oplus$ S) is the same as that of "inflating" image A with the structural element S, as shown in Equation 5. After expansion processing, the boundary of the image to be processed will expand outward evenly for a circle, and the specific size of this circle is also affected by the shape and size of the selected structural elements [24]. Dilation operation can not only help to connect the original discontinuous boundaries in the image, but also fill the small holes or missing parts in the image to a certain extent, making the overall shape of the image more complete and coherent. Fig. 3 below shows the simulation effect of the expansion operation, and intuitively shows the phenomenon of the image boundary expanding outward after the expansion processing.

$$A \oplus S = S \oplus A \tag{5}$$

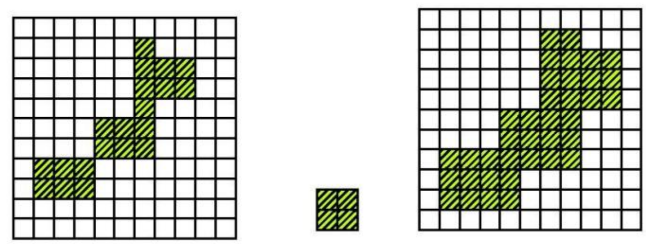

Fig. 3. Simulation diagram of expansion operation.

The corrosion operation effectively reduces the area of the target region by making the image boundary shrink inward, the essence of which lies in the removal of image edge pixels. On the contrary, the expansion operation increases the coverage of the target region by extending the image boundary outwards, making the object in the image look more expanded [25]. It is worth noting that whether it is corrosion or expansion, their changes to the image are mainly concentrated in the edge area, and the impact on the interior of the image is relatively small. Based on this property, when we subtract the corroded image from the original image, we can highlight the edge pixels that disappear due to corrosion and recover due to expansion, so as to effectively extract the edge outline of the object in the image.

The algorithms for edge detection using morphology generally include the following:

1) BM edge detection optimization technology: The core of BM edge detection technology is to reduce the noise effect by preprocessing. The strategy applies fuzzy filtering technology to reduce the noise in the image, and then performs the basic operation of morphology. In this process, the width of the carefully designed structural element B matches the size of the local average processing window, aiming to capture the edge information more accurately and reduce the noise interference at the same time, which is expressed as Eq. (6).

$$BM(f) = \min\{f_{av} - (f_{av} \Theta B), (f_{av} \oplus B) - f_{av}\} \tag{6}$$

In Formula 6, B represents the structural element to be used, and f_{av} represents the gray value of the image after fuzzy processing.

2) ATM edge detection strategy: ATM edge detection method introduces α-adjustment mechanism, the core of which is to optimize the input image by adjusting parameter α, so as to effectively suppress the noise in the image. This α-adjustment strategy provides a clearer and less noisy input environment for image edge detection, thus improving the accuracy and reliability of edge detection. The expression of α-adjustment is Eq. (7).

$$f = \sum_{l=\alpha+1}^{k-\alpha} \frac{f(l)}{k-2\alpha} \tag{7}$$

The formula expression of edge detection is shown in equation 8.

$$ATM(f) = \min\{(f \bullet B) - (f \Theta B), (f \oplus B) - (f \circ B)\} \tag{8}$$

3) ASF multi-directional edge detection: ASF edge detection method is a multi-dimensional analysis method. It adopts the structural elements in the four directions of 0°, 45°, 90° and 135° with the X-axis, and performs the combination of open γ_l operation and close φ_l operation on the image to capture the edge features in different directions, and then implements corrosion operations on the processed image to further refine and strengthen the edge information. The formula is shown in Eq. (9).

$$f = (\gamma_l \varphi_l \Theta B) - \gamma_l \varphi_l \tag{9}$$

In the field of morphological edge detection, the size and shape of structural elements are directly related to the detection effect. Larger structural elements can effectively suppress noise, but may be at the expense of edge details, while smaller structural elements can capture edge features more finely, but may not completely eliminate noise. Therefore, the ideal structural element should be able to remove noise while retaining the edge details. The directivity of the edge is also significantly affected by the shape of the structural element, with different shapes having higher sensitivity to edges of a particular shape. In order to overcome this limitation and improve the anti-noise ability of edge detection, an effective strategy is to use multi-structural elements combined with multi-scale morphological edge detection operators. By combining structural elements of different sizes and shapes, this method can capture edge information in images more comprehensively and enhance the robustness to noise, so as to achieve high-precision image edge detection. In practical applications, in order to obtain detailed elements such as clothing line outline more accurately, the image will be preprocessed first, including noise elimination to reduce interference, binary processing to simplify image information and possibly reverse the light and dark areas in the image by taking the inverse operation, and then combined with expansion and corrosion operations to further emphasize and extract the clothing line outline elements.

IV. Experiment

This experiment aims to extract key pattern and line feature elements from a set of image data containing clothing patterns by K-means clustering algorithm. The main objective of the experiment is to verify the practicability and effectiveness of K-means algorithm in image processing and feature extraction tasks, and to explore its potential value in practical application scenarios such as clothing design and automatic image classification and recognition.

The experiment first imports the image dataset into a Python environment, and performs a series of pre-processing steps on these images, including but not limited to conversion to grayscale, resizing the image to ensure consistency, and normalization of pixel values. After feature processing, the image data is converted into a format suitable for K-means algorithm. The K-means clustering algorithm is applied to perform cluster analysis on these feature vectors, and similar pattern and line elements are grouped into different clusters through the iterative process. After the clustering is completed, visualization technology is used to visually present the clustering results, as shown in Table I.

TABLE I. Results of Pattern Line Extraction

Master drawing	
Pattern extraction	
Line extraction	

After the experimental application of K-means clustering algorithm to cluster the feature vectors of image data, the experiment successfully groups similar pattern and line elements into different clusters, which shows that K-means algorithm has strong effectiveness and accuracy in image feature extraction and grouping. At the same time, visualization technology is used to visually present the clustering results, and the differences and similarities between different clusters can be clearly seen from Table I, which further verifies the effectiveness of K-means clustering algorithm in image feature extraction and grouping.

Experiments show that in the complex and changeable background environment, K-means algorithm not only has remarkable clustering effect, but also has strong anti-noise property, ensuring the accuracy of segmentation results. However, the automation degree of this algorithm is still insufficient, and its performance is highly dependent on the setting of key parameters by experienced operators. Meanwhile, the long operation time also limits its application potential in the pursuit of efficient processing scenarios. In contrast, morphology algorithm stands out for its short operation time and high processing efficiency, but its effect is easily affected when processing images containing noise, especially when processing color images, complexity and timeliness become challenges. Nevertheless, the advantages of morphology algorithm in spatial and frequency domain image recognition cannot be ignored. It can effectively retain the original information of the image while filtering the noise, which lays a solid foundation for the subsequent image processing. The limitations of a single algorithm in extraction accuracy, efficiency or specific target recognition are obvious, so exploring a new path of algorithm fusion has become the key to improve the ability of image feature extraction. By organically combining and optimizing different algorithms to build a multi-level recognition and extraction system, more accurate and efficient image feature extraction can be achieved. This fusion strategy can not only make full use of the advantages of each algorithm, but also make up for each other's shortcomings, so as to improve the overall performance. In addition, with the rapid development of deep learning technology, its application in the field of pattern segmentation and extraction undoubtedly opens up a new way to improve the extraction accuracy and automation level. Deep learning algorithms have strong feature extraction and pattern recognition capabilities, and can automatically learn and adapt to complex image features, which also puts higher requirements on the technical requirements of computing equipment. More computing power is needed to support the operation of complex algorithms and programs. Nevertheless, I think this challenge is worthwhile, because the introduction of deep learning technology will greatly promote the development of clothing pattern and line feature element extraction technology, and bring more intelligent and efficient solutions to the field of clothing design and manufacturing.

V. CONCLUSION

This paper deeply discusses the extraction technology of clothing pattern and line feature elements based on K-means clustering algorithm and morphology method, expounds the basic principle of K-means algorithm and morphology algorithm in detail, and focuses on how to use K-means algorithm to perform pixel-level clustering analysis of clothing images. The morphology algorithm is introduced to achieve fine extraction of line feature elements. This paper describes the implementation process of the whole feature extraction technology in detail, and finally verifies the effectiveness and superiority of K-means and morphology algorithm in the extraction of clothing pattern and line feature elements through experiments. The experimental results show that this technology can accurately and efficiently identify and extract key patterns and line features in clothing images. It provides powerful technical support for clothing design, analysis, retrieval and other fields. Looking forward to the future, with the continuous development of artificial intelligence technology and the continuous optimization of algorithms, the extraction technology of clothing pattern and line feature elements based on K-means and morphology will have a broader application prospect. It can help fashion designers quickly capture trends, innovative design ideas, but also to provide strong support for the automation and intelligence of the clothing production process, while the technology is also expected to play an important role in personalized customization, virtual reality fitting, intelligent collocation recommendation and other fields, to promote the entire fashion industry to more efficient, intelligent, personalized direction.

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