Image based on histogram and K-Means clustering segmentation algorithm

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Abstract*—The traditional K-Means algorithm is mainly used for image segmentation with large differences in color. Since the traditional K-Means clustering algorithm is easy to be sensitive to noise and it is difficult to obtain the optimal initial cluster center position and number, a method based on histogram and K-Means clustering is proposed. The median value is used. Filtering and histogram averaging preprocess the image to reduce the influence of noise on the pixel; then estimate the number of centers based on the number of peaks appearing in the histogram obtained after preprocessing, and then determine the aggregation in the Lab color space. At the center of the class, the cluster center is continuously iterated and updated until the algorithm finally converges to realize the clustering operation. The experimental results show that the improved algorithm shortens the time of the clustering process and can effectively extract the target object and improve the image segmentation effect.

***keywords*—K-Means clustering; histogram; median smoothing; image segmentatio**

I. INTRODUCTION

Image segmentation is one of the key technologies in image processing and computer vision. It is widely used in some military and civil fields [1]. In recent years, some new technologies such as semantic segmentation [2], object detection [3] have emerged. Because the effect of image segmentation directly determines the accuracy of subsequent image recognition and application, the research of image segmentation technology is particularly important.

K-Means clustering algorithm has been widely used in image segmentation because of its simple principle and easy implementation, but its shortcoming is to determine the number of clustering centers in advance, and the selection of initial clustering centers has a great impact on the classification results. In addition, when using this algorithm to segment images, only the RGB color space information of the pixels is used, but no other color space information is used, so it is sensitive to noise and leads to over segmentation. In order to overcome these shortcomings, researchers proposed improved K-Means algorithm, such as Chen et al. proposed hierarchical hesitant fuzzy K-Means clustering algorithm [4], Mu et al. proposed a fuzzy K-Means target classification algorithm based on particle swarm optimization [5], Siddiqui et al. proposed an enhanced mobile K-Means clustering algorithm [6]. However, the complexity of these improved algorithms is high, the segmentation time is too long, and it is not easy to achieve. Therefore, further research is needed to solve the problem of K-means clustering.

To solve these problems, a method of image segmentation based on histogram and K-Means clustering is proposed. Firstly, median filtering and histogram equalization are applied to the image. Then, according to the peak number of the preprocessed histogram, the appropriate number of clustering centers is determined, and the RGB image is transferred to the Lab color space to determine the location of clustering centers, and then clustering is carried out to obtain the final segmentation results. Experiments show that this method improves the efficiency and accuracy of segmentation, reduces the complexity of the algorithm, and largely solves the shortcomings of the traditional K-Means algorithm.

II. IMPROVED K-MEANS CLUSTERING ALGORITHM

A. Description of Traditional K-Means Algorithms

The main idea of K-Means clustering algorithm is to divide a given sample set into K clusters according to the distance between samples. And let the point distances in the same cluster gather together as far as possible, and let the distance between different clusters as large as possible [7].

If there is a set of data objects S, it should be divided into K parts. The steps of traditional K-Means algorithm are as follows:

1. Randomly select K samples from data object set named S as initial clustering centers $C = \{c_1,c_2,c_3,\ldots,c_k\}$;

2. For each sample x_i in the object set, compute its distance to K clustering centers and divide it into corresponding classes corresponding to the shortest clustering centers;

3. For each class c_k, the cluster centers are recalculated. The formulas are as follows:

$$c_k = \frac{1}{|C_k|}\sum_{x_i \in C_k} x_i \tag{1}$$

4. Repeat steps 2 and 3 to iterate continuously to get new clustering centers;

5. The conditions for termination of iteration are as follows: firstly, the iteration number T is set to terminate the iteration when the iteration number T is reached; secondly, it is judged by the error square and the criterion function, and the function model formula is as follows:

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$$J = f(z) = \sum_{k=1}^{K} \sum_{x_i \in C_k} \|x_i - c_k\|^2 \qquad (2)$$

6. When the difference between the two iterations J is less than a threshold value, that is, J < delta, the iteration is terminated, and the cluster is the final clustering result.

B. *Pretreatment*

Because the initial image obtained in natural environment will be disturbed by external noise such as illumination and electromagnetic wave, it will have a great impact on the subsequent image segmentation. In order to minimize the interference caused by noise and outliers to reduce the probability of false segmentation, the image is preprocessed first.

Firstly, the image is processed by median smoothing filter to eliminate noise and outliers as far as possible. Median filtering is a kind of non-linear signal processing technology which can effectively suppress noise based on ranking statistics theory. It has good adaptability and is very suitable for some applications of digital image processing where linear filtering is not competent [8]. Its basic principle is to replace the value of a point in a digital image with the median value of each point in its neighborhood, and to replace the value of the pixel to be processed with the median value, the effect of noise elimination can be achieved.

And the details of the image are not clear, histogram equalization is used to improve the contrast of the image, highlight the object being segmented and avoid false segmentation. Histogram equalization is to increase the dynamic range of gray value by non-linear transformation of gray level of the original image, so as to enhance the overall contrast of the image and make the image clearer [9].

C. *Determining the Number of Clustering Centers*

The histogram of the preprocessed image is detected by peak value to determine the number of clustering centers. $Q(i)$ is the longitudinal coordinate of the histogram, that is, the probability corresponding to different gray values. Peak detection is judged between two adjacent values, and the peak value can be found by calculating the difference between two adjacent values. The formula is as follows:

$$\begin{cases} Q(i) - Q(i-1) > T \\ Q(i+1) - Q(i) < T \end{cases} \quad i = 1,2,3,4,\ldots,255 \qquad (3)$$

D. *Determining the Location of Cluster Center Equations*

The three color components in RGB color space are highly correlated. If a certain color variable changes, the color will change, and the sensitivity of human eyes to common red, green and blue is different, that is to say, the uniformity of RGB color space is very poor [10]. On the contrary, Lab color space is not only a device-independent color system, but also a color system based on physiological characteristics. It uses digital methods to describe human visual perception. Therefore, the A and B components in Lab color space are better than the three color components in RGB space to locate the clustering center.

After transforming the processed image into Lab's color space, A and B components are extracted to generate two-dimensional sample space distribution. The generated sample space is shown in Fig. 1.

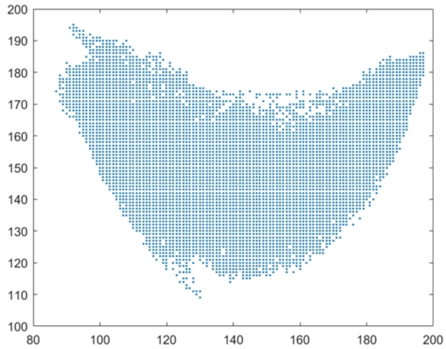


Fig. 1. Two-dimensional spatial distribution

In order to solve the problem of randomness of initial clustering centers, K-Means algorithm is used to initialize K clustering centers, and then clustering segmentation is carried out. The idea of improving K-Means algorithm is to assume that n initial clustering centers (0<n<K) have been selected. When selecting n+1 clustering centers, the farther away from the current n clustering centers, the higher probability will be selected as N + 1 clustering centers. The first cluster center (n=1) is also selected by random method. The steps of the improved K-Means algorithm are as follows:

1. A sample is randomly selected from the two-dimensional sample space S as the initial clustering center c_1;

2. Firstly, the shortest distance between each sample and the existing clustering center (i.e. the distance from the nearest clustering center, expressed by D(x) is calculated. Then, the probability of each sample being selected as the next clustering center is calculated. The formula is as follows:

$$\frac{D(x)^2}{\sum_{i=1}^{n} D(x_i)^2} \qquad (4)$$

The next cluster center is selected according to the roulette method.

3. Repeat step 2 until K clustering centers are selected from the statistical histogram;

4. The following procedure is the same as the second to fourth steps in the traditional K-Means algorithm.

Finally, the clustering based on the improved algorithm is shown in Fig. 2.

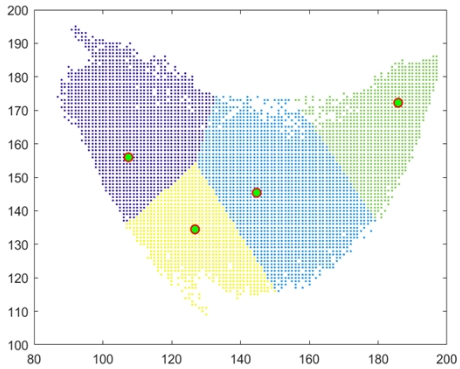


Fig. 2. Clustering of improved K-Means algorithm

E. Algorithmic flow

The improved K-Means algorithm firstly performs median smoothing filtering on the input image to eliminate noise, and then performs histogram equalization on the image to eliminate pseudo-peaks so that the number of histogram peaks can be accurately found to determine the number of clustering centers, and then the initial clustering centers can be determined in the Lab color space to cluster. The segmentation effect is better. The steps of the improved image segmentation method are as follows:

1. Input the image to be segmented and preprocess it with median smoothing filter and histogram equalization;

2. Obtain the gray histogram of the image;

3. Detecting the peak of histogram, the number of peaks is K value;

4. Transform the image from RGB color space to Lab color space and generate two-dimensional sample space;

5. For all points in the sample space set S of Lab color space (j = 1,2,3... K initial clustering centers are found, and the distances to various centers are calculated in turn. It will be classified as the nearest class;

6. Recalculate the clustering center;

7. Judge the convergence of clustering centers. If it does not converge, it turns to step 5;

8. Finally, output clustering results to achieve image segmentation.

III. ANALYSIS OF EXPERIMENTAL RESULTS

Firstly, the image is filtered by median smoothing. The result is shown in Fig. 3 The median smoothing filter has a good denoising effect on the image, and it does not blur the edge of the object, which effectively improves the image quality and facilitates the subsequent image segmentation. the original image is shown in Fig. 3(a), the image after median filtering is shown in Fig. 3(b).

(a) (b)

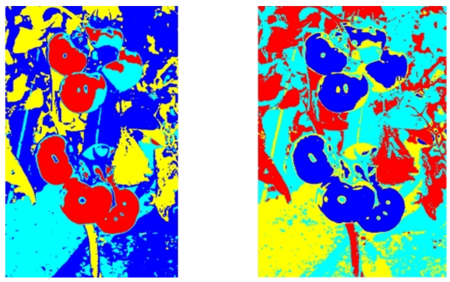
Fig. 3. Median smoothing filtering for original images

After denoising by median smoothing, the details of the dark part of the image are not clear. Then histogram equalization is applied to the image. The equalization can improve the contrast and the details of the bright part. At the same time, the pseudo-peaks of the histogram are eliminated. The processing results are shown in Fig.4. The filtered image is shown in Fig. 4(a) and the histogram equalized image is shown in Fig.4(b).

(a) (b)

Fig. 4. Image histogram equalization processing

After the pre-processing is completed, in order to prove the effectiveness of K-Means algorithm based on histogram improvement, two algorithms are experimented and the segmentation results are compared, the results are shown in Fig. 5. The segmentation results show that the improved K-Means clustering segmentation algorithm, Fig. 5(b) , has a better effect on image segmentation than the traditional K-Means clustering segmentation algorithm, Fig. 5(a). The former avoids noise interference, and can better separate the target from the background. At the same time, the target in the dark can also be better segmented.



(a) (b)

Fig. 5. Comparison of clustering results

At the same time, as can be seen from TABLE I, the proposed algorithm consumes less time than the traditional K-Means clustering algorithm in image segmentation, which greatly improves the efficiency of K-Means clustering algorithm.

TABLE I . Comparisons between the proposed algorithm and the traditional K-Means algorithm in time-consuming segmentation

Algorithm	The algorithm in this paper	Traditional K-Means algorithm
Experimental images	10.688s	17.647s

IV. CONCLUSIONS

In this paper, an image segmentation algorithm based on histogram and K-Means clustering is proposed to solve the shortcomings of traditional K-Means algorithm in image segmentation. First, the number of clustering centers is determined by preprocessing operation, then the number of peaks of histogram is used to determine the number of clustering centers, and the initial clustering centers are determined by changing the color space. The improved K-Means algorithm is used to complete image segmentation. Experiments show that the improved algorithm is simple and effective for image segmentation, has better segmentation effect, improves the accuracy significantly, and is robust to noisy image processing. However, the effect of this algorithm on complex and poor quality image segmentation is not ideal, which needs further study.

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