Realization of remote sensing image segmentation based on K-means clustering

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Realization of remote sensing image segmentation based on K-means clustering

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Abstract: Segmentation of remote sensing image is the key technology of positioning system. Firstly, we transform the remote sensing image from RGB pace to Lab space. Then, three centres are iterated by using K- means algorithm. Finally, in order to eliminate the influence, the closed operation of mathematical morphology is used to correct the segmented image. The results show that it can segment the road from the remote sensing image in lab mode, by using K-means clustering algorithm. Moreover, Lab mode is more suitable for k-mean than other modes.

1. Introduction

Computer vision is a new and popular subject. It can be divided into three tasks: image segmentation, feature extraction and target recognition. Among them, image segmentation is the basic part of feature extraction and target recognition. And the quality of segmentation results will directly affect the process of target recognition and feature extraction. Common there are three methods of image segmentation, including threshold method, region growing method and clustering analysis method. The threshold method separates the object from the background by selecting the valley of gray histogram as the threshold of segmentation. This method is greatly influenced by noise and brightness. Region growing method uses the spatial properties of the image to search for pixels with similar properties for region division. It can also achieve good results for images with complex scenes, but the cost of this algorithm is huge space and time overhead. K-means algorithm has been successfully applied to the field of remote sensing image analysis, and essentially it's a kind of relatively mature clustering analysis method. In this paper, K-means clustering has been applied to segment remote sensing image, and good image segmentation results are obtained.

2. K-means clustering analysis

K-means algorithm is a clustering algorithm which was based on partition[4]. It performs clustering through continuous iteration process. When the algorithm converges to an end condition, the iteration process is terminated and the clustering results are output. Because of its simple idea and easy implementation, K-means algorithm has become one of the most commonly used clustering algorithms[5].

K-means algorithm divides set $X = \{x_1, x_2, \cdots, x_n\}$ containing N data points into k classes C_j among them *j = 1, 2,…,k*. First, we randomly selected k data points as the initial class centres of K classes. Every data point of the set will be divided into classes nearest to the class centre. And then the K clusters initial distribution is formed. A new class centre is computed for each class allocated, then the data allocation process continues. After several iterations, if the class centre does not change, the data objects are allocated to their own classes, and the functions are proved to be convergent. In each iteration, the allocation of all data points should be adjusted. Then the class centre is recalculated, and the next iteration process is done. If the location of all data points and the class centre do not change during an iteration, this marks the end of the algorithm. Let the data set consisting of n points be $X = \{x_i \,|x_i \in R, i = 1, 2, \cdots, n\}$. K-means is to divide the n data points into K-classes to form clustering $C = \{c_k \,|k = 1, 2, \cdots, K\}$, where the class centre of c_k is set to μ_k. The Euclidean distance from the point x_i to the centre of the class μ_k is as shown in Formula (1).

$$D(x_i, \mu_k) = \sqrt{(x_i - \mu_k)^2} \quad x_i \in c_k \tag{1}$$

Then, the sum of the Euclidean distances for all points x_i to the class centre of c_k is as shown in Formula[6] (2).

$$M(c_k) = \sum_{x_i \in c_k} D(x_i, \mu_k) \tag{2}$$

The sum of Euclidean distances of the subclass of k is counted in formula (2). Then, by counting each subclass, using all points x_i to calculate the sum of Euclidean distances to the centre of the class to
which they belong is obtained. This is as shown in Formula[7] (3).

$$S(x_i) = \sum_{k=1}^{K} M(c_k) = \sum_{k=1}^{K} \sum_{x_i \in c_k} D(x_i, \mu_k) = \sum_{k=1}^{K} \sum_{i=1}^{n} \lambda_i D(x_i, \mu_k) \tag{3}$$

Among them, the $\lambda_i = \begin{cases} 1, if \;\; x_i \in c_k \\ 0 \; if \;\; x_i \notin c_k \end{cases}$.Thus, in order to minimize the value of $S(x_i)$ in formula (3), the central μ_k should take the average value of each data point in subset c_k.

We can describe the iterative process of K-means clustering as follows.

Step 1: According to the principle of maximization and minimization, first we can select k points data as the initial class centre of K subclasses.

Step 2: For each points data x_i to the class center, calculate the Euclidean distance. According to the nearest principle, each point is divided into sub-classes and K sub-class sets are obtained.

Step 3: Calculate the average value of each point in subclass, and take the average value as the new class center of the subclass.

Step 4: Using all data points to Calculate the sum of Euclidean distances *$S(x_i)$ to the class center*, and determine whether the values of class centers and $S(x_i)$ have changed. If so, move to Step 2; if not, move to Step 5.

Step 5: Terminate the iteration and end the algorithm.

3. image enhancement

The histogram of a city multi-spectral remote sensing image is analyzed, and the remote sensing image is enhanced by contrast enhancement and de-correlation stretching. There are many methods of remote sensing image enhancement.

Histogram equalization is to stretch the image nonlinearly and redistribute the image pixels. The number of pixels in a certain range is approximately equal. In this way, the contrast of the peak part in the middle of the original histogram is enhanced, while the contrast of the valley bottom part on both sides is reduced. The histogram of the output image is a relatively flat histogram. If the value of the segment of the output data is small, it will produce a rough effect[8].

Histogram matching is a mathematical transformation of an image to make the histogram of one image similar to that of another. Histogram matching is often used as a pretreatment for dynamic change research of remote sensing images. Histogram matching can partially eliminate the effect difference of adjacent images caused by solar or atmospheric effects.

Resolution fusion is the fusion processing of remote sensing images with different spatial resolutions. The fused remote sensing image has good spatial resolution and multi-spectral characteristics, so the purpose of image enhancement is achieved. The key of this process is the selection of the fusion method in the fusion process.

The methods of enhancement are often targeted, and the results of enhancement are only evaluated by people's subjective feelings. Therefore, image enhancement methods can only be used selectively.

4. Remote sensing image segmentation

There are many image segmentation methods, among which threshold segmentation, NDVI segmentation and mathematical morphology segmentation are commonly used[9].

In this paper, we used a multi-spectral remote sensing image of a city to segment image. Firstly, we studied the characteristics of NDVI (Normalized difference vegetation index) value, and the image is segmented by NDVI threshold processing to obtain vegetation image. Normalized vegetation index is usually designed by combining visible red band(0.6-0.7 um) and near infrared spectral band (0.7-1.1 um). The calculation formula is as follows:

$$NDVI = \frac{NIR - R}{NIR + R} \tag{4}$$

Among them, the reflectivity in infrared band was expressed in NIR and the reflectivity in red band was denoted R. Vegetation images are segmented by selecting appropriate thresholds. Finally, vegetation images are displayed.

When the remote sensing image is a road image, we can extract the color feature, and the image is segmented to obtain the road extraction image by using the method of color feature extraction.

Generally, RGB space is first transformed into XYZ space, and then into Lab color space[10]. The transformation formula is as follows:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.490 & 0.310 & 0.200 \\ 0.177 & 0.812 & 0.011 \\ 0.000 & 0.010 & 0.990 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{5}$$

$$\begin{cases} L = 116f(Y) - 16 \\ a = 500\left[f(\frac{X}{0.982}) - f(Y) \right] \\ b = 200\left[f(Y) - f(\frac{Z}{1.183}) \right] \end{cases} \tag{6}$$

Among, $f(x) = \begin{cases} 7.787x + 0.138(x \le 0.008856) \\ x^{\frac{1}{3}}(x > 0.008856) \end{cases}$ (7)

Each pixel of remote sensing image is regarded as a data point, which constitutes data set X. Each data point contains L, a and b three feature components, and then these pixels are clustered by K-means.

In the process of K-means clustering, images are marked with numbers 1, 2 and 3. Each pixel may belong to three regions. The pixels of the three regions are distinguished by white, grey and black respectively. Finally, the binary image is corroded and expanded to obtain the target region. Figure 1 is the flow chart of the algorithm.

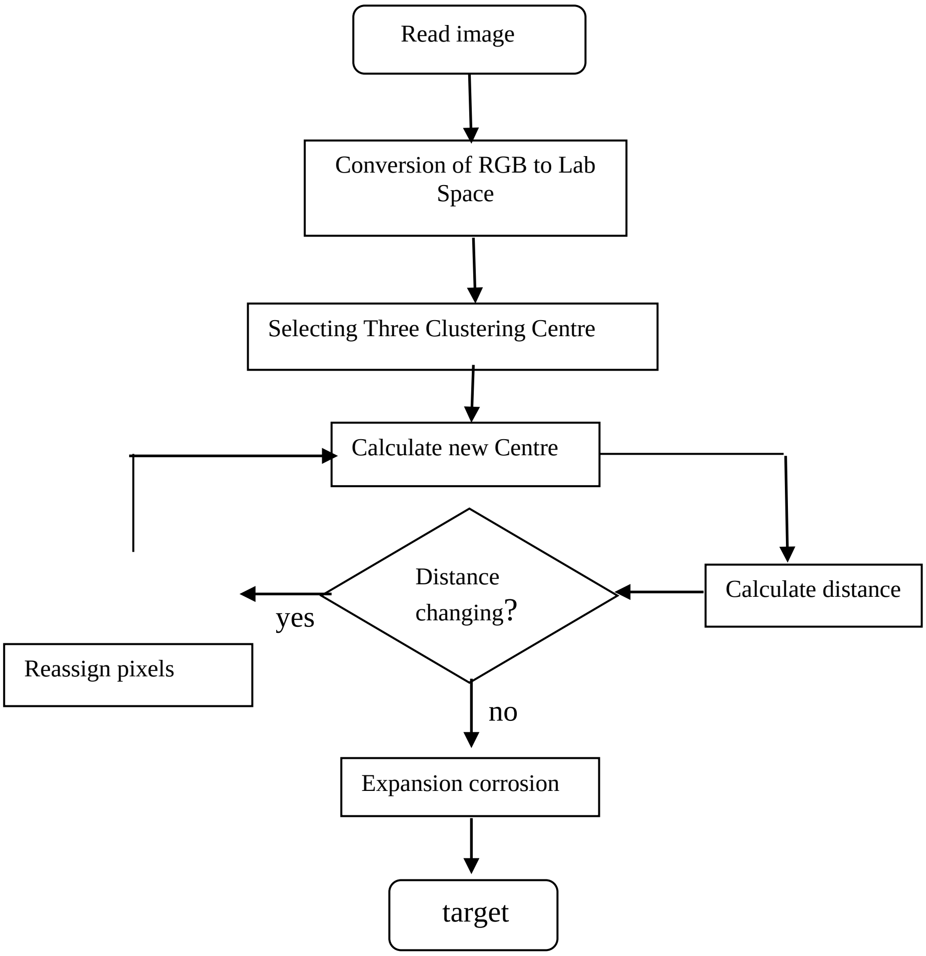

Figure 1. Algorithm flow chart

5. Experimental results and analysis

The remote sensing image is collected from the sample image, and simulated by using MATLAB 7.0 programming. Clustering and segmentation experiments are carried out under Lab mode. The original sample image contains roads, Ground and vegetation, etc.

Figure 2-6 is the experimental result. Figure 2 is the original image. Figure 3 is the Lab color model of the image. Figure 4 is the clustering results. Figure 5 are three segmentation regions of three clustering centers. Figure 6 presents further road information through morphology.

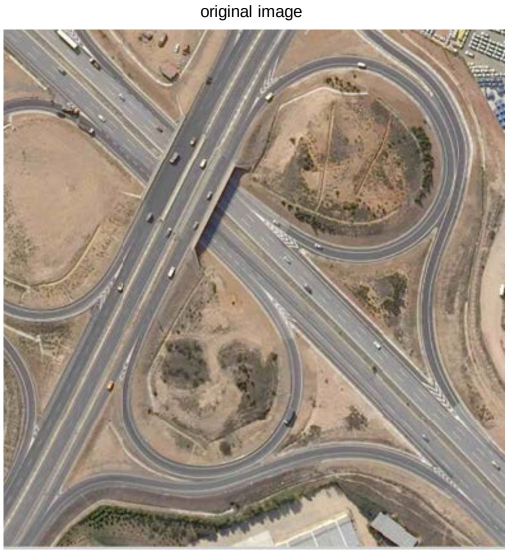

Figure 2. Original image

Figure 3. Three Vectors in Lab Space

Figure 4. Clustering results

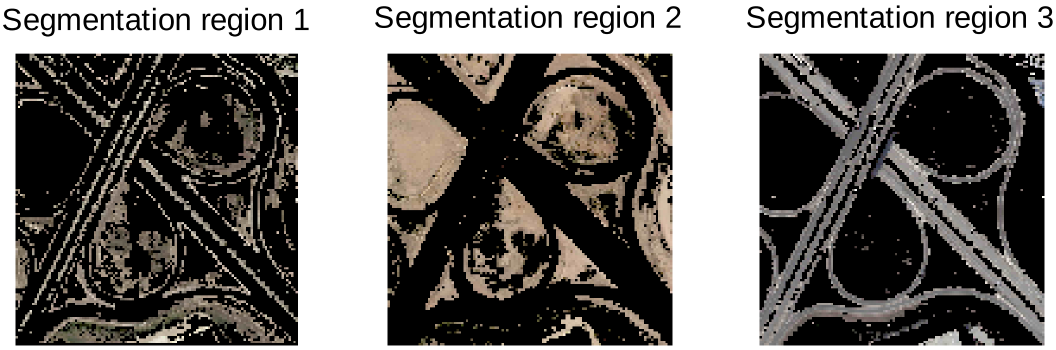

Figure 5. Three segmentation regions in three clustering

Figure 6. Road extraction

From the results of clustering region segmentation, Lab pattern clustering segmentation has a better effect. This is because the most uniform color mode is the laboratory color mode at present. Lab color is less depend on light. In order to be more adaptive, clustering images are collected under different illumination conditions.

6. Conclusion

According to the characteristics of urban roads in remote sensing images, K-means clustering has been applied to road recognition in remote sensing images under Lab color model, and segmentation experiments are carried out. The segmented road is processed by erosion and expansion operation of mathematical morphology, which removes small holes and makes the segmented image more uniform and the boundary smoother.

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