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Image Retrieval Based on Image Entropy and Regional Expansion

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Abstract

This paper uses the image entropy directly on the color image to express the integral color image information and color spatial distribution of the neighborhood, then the image is divided into blocks, for each block we use the Pelaez Aggregation to determine the seed, after that we use the regional expansion method for color image blocks to extract the color characteristic of color image. The centroid was extracted from the segmented image and combined with variance as the similarity metric standard. Result shows that, this method is not only simple and efficient, but also improves the performance of image retrieval.

Keywords: *content-based image retrieval; image entropy; color histogram; seed point*

1. Introduction

Color is an important image visual feature, it has been widely used in content based image retrieval. Color histogram [1] is one of the most commonly used image retrieval techniques, this method has the advantages of simple feature extraction, translation and rotation invariance. Color histogram only counts the global color histogram features, does not have the characteristics of spatial distribution, and the dimension is high, it is easy to cause the phenomenon of false detection. Therefore, the color image retrieval method based on color spatial feature has been proposed. John[2] proposed an algorithm that uses information entropy to describe the color features of image, it overcomes the problem of high dimensionality, but this method completely loses the spatial distribution information of the color. Fauqueurb[3] proposed a method that takes the main objects by segmentation and clustering algorithm, and then the color of each object and location feature are extracted as retrieval features of images in order to characterize the image color space. Because the image segmentation is difficult, at the same time when the object is not obviously in the image, clustering method will appear obvious deviation, so the general effect is sometimes not ideal. Lim[4] proposed Geographical statistics (Geostat) to describe the distribution of the image color space, it has a better retrieval effect, but it only describes the global distribution of color, therefore the retrieval performance needs to be improved. In this paper, a new kind of image retrieval algorithm based on image entropy and regional expansion is represented. Firstly, the color space HSV is quantified to seven-two intervals in order to reduce the computation. Secondly, the image entropy of one - dimensional and two - dimensional are computed, the image which has twenty percent difference is filtered. Thirdly, the image is blocked to eight regions which are overlapped, in each region, a seed point is selected, then the region begins expansing. Fourthly, the centroid and variance of the region are calculated. Finally, the same of distance of centroids and the variance of the regions is calculated to express the differences between images. The image retrieval experiments indicate that this method has a higher retrieval rate than the color histogram.

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2. The Proposed Algorithm

2.1. The Selection of Color Space

Color models are now used mostly in the face of hardware or the application. A hardware oriented for example is like a color monitor and printer. Application oriented for example is Photoshop processing. In digital image processing, the actual hardware model in the face of the most common is the RGB (red, green, blue) model. The RGB model is also known as additive mixture model [5]. It is a method with RGB three colors superimposed on each other to achieve color mixing, and it is suitable for display on the display of light. CMY (green, red, yellow) and CMYK (green, red, yellow, black) model are for color printer. The HSV color model is a suitable model for the naked eye vision, it is popular with content-based image retrieval. The model based on HSV (hue, saturation, brightness)is more appropriate to describe and explain the way of color. The HSV model divides the image into color and gray information to make it more suitable for the color image description. When people observe a color object, describe it in hue, saturation and brightness. So this paper uses HSV color model. Hue is the attribute to describe the pure colour (pure yellow, orange or red), hue is identified by the color name for example red, green and blue etc. -180° ~ 180° or 0°~360°metric corresponds with the angle on the color wheel (color wheel). Saturation gives a metric of white dilution degree, it is usually measured in percentage saturation. Brightness is a subjective descriptor, which embodies the strength concept of colorless, it is a key parameter to describe the color sensation. Brightness is usually measured in percentage saturation, from 0% to 100% corresponds with that from black to white. H is measured by the angle from 0° to 360°, so H and S can construct a color wheel. In the color wheel, the main colors are along a circular uniform distribution and the secondary colors are located between the main colors. For example, we use yellow and blue to produce green, so green is located between yellow and blue. Each color and its complementary color are opposite on the wheel. The major axis shows the brightness of V, the distance from the major axis to this point represents the saturation S, so the HSV color space can be easily expressed using an inverted cone. The HSV color model has two characteristics: first, the components are independent of each other in the vision; second, the spatial distance accords with the visual characteristic of human eyes. It is suitable for image processing algorithm which perceives the color features by the human visual system [6].

2.2. Quantification of HSV Color Space

Each pixel in the true color image is divided into R, G, B three color components. Each color component directly determines the color intensity. True depth of color image is twenty-four. It uses R:G:B=8:8:8 to represent the color, each component of R, G, B occupies 8 bits to represent each primary color strength, strength grade of each color component is for 2^8,equals to 256. Image can accommodate 2^{24} colors (24 bit color). The human eye can distinguish very limited colors. Several major colors cover most of the pixels in the actual color of the image. If we use the main colour to represent the image, though the image quality will decline, it does not affect the understanding of image content. The image color quantization is that it extracts some representative color to express the image which can not significantly reduce the quality of image, so as to reduce the storage space and improve the processing speed. Experiments show that increasing the dimension of color histogram can effectively improve the retrieval performance. Increasing the dimensions and improving the performance are not directly proportional relationship. When the dimension increases to a certain extent, the improvement of the retrieval accuracy is not significant or even decline. Therefore, we can reduce the color dimension to improve the efficiency of retrieval on the premise of keeping with a certain precision. A good quantitative method is very important for color image processing. The quantized color space includes two aspects:

1) The quantified color set can well represent the original image and reduce the distortion as far as possible,

2) Construct the quantitative color look-up table.

The number of the quantized colo r handlers has a significant impact on the image retrieval. If the quantification is rough, using only a few colors to show will cause the retrieval effect bad, because it loses a lot of the color information. If quantification is very precise, the calculation quantity will increase efficiency of indexing and retrieval will reduce. When we quantify the HSV color space, we must consider the color similarity. Because the color space of human perception is not uniform, the color distribution along the axis is roughly divided into 6 spaces after the analysis of the color space, the saturation S is divided into 4 spaces, the brightness of V is divided into three spaces. Let S ∈[0,1], V ∈[0,1],then the quantitative results are as follows:

$$H=\begin{cases}0, H\in[331,25]\\1, H\in[26,85]\\2, H\in[86,150]\\3, H\in[151,210]\\4, H\in[211,260]\\5, H\in[261,330]\end{cases} \quad S=\begin{cases}0, S\in[0.0.25]\\1, S\in[0.26,0.45]\\2, S\in[0.46,0.65]\\3, S\in[0.66,1]\end{cases} \quad V=\begin{cases}0, V\in[0,0.30]\\1, V\in[0.31,0.80]\\2, V\in[0.81,1]\end{cases} \tag{1}$$

HSV color space is diveded into the LH*LS*LV intervals, among them, LH, LS and LV respectively indicate H, S and V quantization levels. It means that it is divided into 72 representative color interval, subsequent retrieval will divide the color of the image according to the method above. In order to reduce the handler number of feature vectors, we can synthesize the three color components, L=HQsQv+SQv+V[7], Where Qs and Qv are the quantification series, S and V of Qs=4, Qv=3, L is for the synthesis of the final results. Therefore, L=12H+3S+V. So H, S, V the three components distribute in the one-dimensional vector, we reach the goal of dimension reduction. After that we get the quantized color image histogram that the horizontal axis represents color interval, the vertical axis represents proportion of the pixels's numbers which have the same color value in the image.

2.3. Pretreatment Using Information Entropy

This method calculates an arbitrary discrete information source entropy (average self information) using the concept of information entropy in information theory. Self-information is a random variable, it refers to the amount of information sent by an information. The amount of information of a message and its uncertainty has a direct relationship. The message is different, the amount of information they contain is different. The amount of self-information of any message can not represent the average information that the information source contains. It can not be used as the measure of the source information[8]. Therefore we define the mathematical expectation of self-information for the average amount of self information of the source which shows as below:

$$H(x)=E[\log\frac{1}{p(a_i)}]=-\sum_{i=1}^{n}p(a_i)\log p(a_i) \tag{2}$$

The information entropy of source H is from the statistical characteristics of the source. It is the overall characteristic of sources. For a particular source, the information entropy is only one. Different sources have the different entropy, because they have different statistical characteristics. The information entropy is represented by the symbol H generally, measured in bit. The uncertainty of the variable quantity is bigger, the entropy is bigger. For digital image, image entropy reflects how much the average amount of information is in the image. One dimensional information entropy of color image indicates the amount of information which is included by the aggregation of the image's color distribution features. Let P_i denote the ratio of pixels that the image color feature value is i. One dimensional entropy of image can be expressed as below:

$$H = -\sum_{i=0}^{71} p_i \log p_i \tag{3}$$

The biggest problem of histogram is that it does not express the space distribution characteristic of the image. In order to characterize the space image better, 2-D entropy is introduced to image. This method adopts the mean of color eigenvalue in the neighborhood as the spatial features of the color distribution of the image pixel intensity, and it forms the two tuples with the pixel gray level of the image denoted by (i, j), where i denotes the color pixel values (0 < = i <=71), j (0 < = j <=71)represents the color eigenvalue in the neighborhood.

$$P_i = f(i, j) / N^2 \tag{4}$$

The above formula shows the integrated features of the pixel's color value and the surrounding pixels's color value, where f (i, j) is for the frequency of the characteristics of two tuples (i, j), and N is image's scale, so the entropy of two-dimensional discrete image is as below:

$$H = -\sum_{i=0}^{71} P_{ij} \log P_{ij} \tag{5}$$

The 2-D image entropy reflects the comprehensive characteristics of the color distribution of the pixel's color information and the color distribution of pixel neighborhood.

2.4. The Use of Regional Expansion Method

To use the regional expansion method, we must solve three problems:

First, determine the number of region segmentation, and in each region select or determine a pixel to represent the correct color value, it is known as the seed point;

Second, select the meaningful features and neighborhood;

Third, determine the similarity criterion.

Among them, the first problem is to determine the number of rough segmentation before areas, and in each region we specify an initial growth point, for the color image, its basic feature is the color value. Neighborhood mode is the regional growing mode, generally refers to the pixel mode and neighborhood mode. Pixel method is generally four adjacent, regional mode is generally neighborhood. Similarity criterion is a region growing (or adjacent small region merging) condition. Finally, there is a growth arrest condition.

The following are instructions on how to solve the problem.

First, the number of selected area

In order to further strengthen the spatial information, we use the overlapped block mode of the image block as shown in Figure 1:

p1	p6	p11	p16	p21
p2	p7	p12	p17	p22
p3	p8	p13	p18	p23
p4	p9	p14	p19	p24
p5	p10	p15	p20	p25

Figure 1. The Blocked Image

The image is divided into blocks of 5*5. The E, F, G, H are located on the left, on the top, on the right and on the bottom representative background. The body of the image is divided into A, B, C, D four parts, representing the image of the left part, the top part, the right part and the bottom part. In order to enhance the role of central region, A, B, C, D four parts are overlapped each other when division. The central part of the image P13 is contained in the four blocks repeately, it keeps the integrity. The width of E, F, G, H is narrow, generally speaking, the edge of the image does not contain a lot of useful information.

A=(p7、p8、p12、p13、p17、p18)

B=(p8、p9、p13、p14、p18、p19)

C=(p7、p8、p9、p12、p13、p14)

D=(p12、p13、p14、p17、p18、p19)

E=(p1、p6、p11、p16、p21)

F=(p2、p3、p4)

G=(p5、p10、p15、p20、p25)

H=(p22、p23、p24)

Second, the selection of the seed points

There are two ways to select the seed points: one is selected randomly; another is selected according to the feedback method. In this paper, in order to reduce the interference of noise pixel, we propose an algorithm to compute a seed point value according to the Pelaez which is the majority aggregation process. The method assigns the value of the same point large weights, to avoid the impact from the aggregation of a few different values. For example[9],there is a set of data as follows: {5, 5, 5, 5, 4, 3, 1, 1, 1}, We find large differences in the values, the data that has the maximum value is most. The arithmetic mean of value nine pixels is 3.333, However, it can be found that more than half of the data are bigger than 4 after carefully analysis, We can obtain the comprehensive value of 4.014 after the majority of the aggregating process.

The majority aggregation process is as follows:

(1) Sort all the points according to the value and rank them as a group which has the same value;

(2) We take out a number from each group, then, we get the average value after average, and define the new number as a new group;

(3) delete a number from each group (not including the group generated on the second step), if there is only one number in the group ,then the group contains none element after deleting, remove the group;

(4) Repeat steps (2) and (3), until there is only one group which has only one element, that element is the required seed point value.

We select the point which has the minimum difference from the seed point, grow from the start. According to predetermined similarity criteria[10], growing point receives (or mergers) its neighborhood (here the 8 neighborhood pixels), then the region grows. After growth the pixel is becoming a new growing point. We repeat this process until the region can not expand. So far, the process is over. The similarity criterion of the growth method is shown below:

$$| f(m,n) - f(s,t) | <= T_1 \tag{6}$$

$f(s,t)$ is the color value of the growing point (s, t), $f(m,n)$ is the color value which is the neighborhood of point (m, n), T_1 is the similarity threshold, because the color space is quantified, we take it 1.

For the segmented regions, we can calculate the centroid of the region. If we use the color value of each point (x, y) as the quality of the point, we can determine the centroid of the region, it is shown below:

$$\bar{x} = \frac{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} xf(x,y)dxdy}{\int_{-\infty}^{+\infty}\int\int_{-\infty}^{+\infty} f(x,y)dxdy}$$
$$\bar{y} = \frac{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} yf(x,y)dxdy}{\int_{-\infty}^{+\infty}\int\int_{-\infty}^{+\infty} f(x,y)dxdy} \tag{7}$$

For each region, we calculate the variance of the color values in the region to represent the color distribution. In the calculation of variance, we take the seed point found above as the mean value. So we can get that shown below:

$$D_i^2 = \frac{\sum (f_i(x,y) - \overline{f_i(x,y)})^2}{n}, (i = 1, 2 \ldots\ldots 8) \tag{8}$$

$\overline{f_i(x,y)}$ is the value of the seed point within the region, $f_i(x,y)$ is the value of the pixel within the region.

The image retrieval steps based on color are in the following order:

(1) Convert the images in the image library from RGB color space to HSV space;

(2) Extract the color feature vector of image according to the spatial quantization method described previously;

(3) Calculate 1-D entropy and 2-D entropy of image;

(4) We use a sample image when retrieval, one-dimensional entropy and two-dimensional entropy are calculated, here we can set the user feedback, in this study we set the difference of entropy between the image in the image library and the sample image 20%;

(5) Calculate the seed points of the sample image and images in the library;

(6) Calculate the centroid and the variance of each block of the image.

2.5. Criterion of Similarity Measure

In order to express the similarity between images, we use the sum of distance of centroids and the variance of the regions.

Suppose that there are I1 and I2 two images, $(\overline{x_{i1}}, \overline{y_{i1}})$ (i=1,2……8)is the centroid of I1, D_{i1}^2 (i=1,2……8)is the variance of the regions. $(\overline{x_{i2}}, \overline{y_{i2}})$ (i=1,2……8)is the centroid of I2, D_{i2}^2 (i=1,2……8)is the variance of the regions. The distance between I1 and the I2 is that:

$$L = \sum\left(\sqrt{\left(\overline{x_{i1}} - \overline{x_{i2}}\right)^2 + \left(\overline{y_{i1}} - \overline{y_{i2}}\right)^2} + \sqrt{\left|D_{i1}^2 - D_{i2}^2\right|}\right), (i = 1.2 \ldots\ldots 8) \tag{9}$$

3. Experimental Verification

In order to test the effect of the algorithm, we use the standard test images from Corel image database. we choose 968 images as the test images and divide them to ten groups: people, seaside, building, bus, dinosaur, elephant, flower, deer, mountain, food. We use precision and recall to evaluate the effectiveness of the algorithm. We compared the proposed algorithm with Geostat algorithm in this paper. Figure 2 shows a retrieval result of two algorithms on the flowers. Figure 3 shows a retrieval result of two algorithms on the deer. Figure 4 shows the experimental data for two algorithms, here horizontal coordinate denotes the groups, the vertical coordinate denotes the precision or the recall.

Figure 2. The Retrieval Result of the Flowers

Figure 3. The Retrieval Result of the Deer

It can be seen that the retrieval precision and recall are improved through the survey results. This proves the effectiveness of the improved algorithm, but the algorithm is not effective for all image retrieval. For the flowers, deer which have the single color it has a good effect.

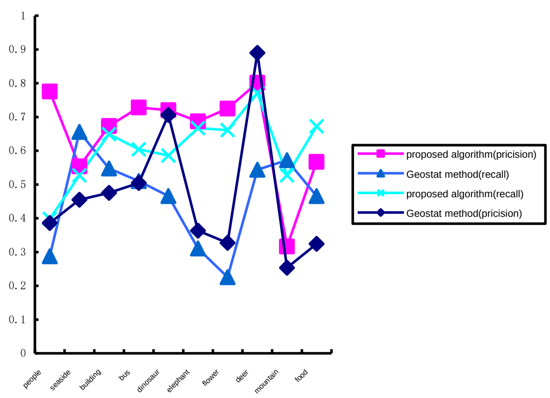

Figure 4. The Comparison of Two Methods

Because these background and image subject of the two types of image are clearer which is with the characteristics of block, and the difference between the background and main color is bigger, so the retrieval effect is better. On the contrary the retrieval effect on images of seaside, mountain is not ideal. Because the color distribution of these two types of images is complex, it can not fully reflect the true information of the image relying only on color histogram, so it needs the combination of texture and shape information.

4. Conclusion

We proposed an image retrieval method which adds a preprocessing step to the traditional method based on the color histogram. Through the comparison of the image entropy, it filters the images which have more difference from the sample image. We extract the significant region from the overlapped block by the regional expansion method, calculate the centroid in the region and the variance to show the distribution characterization of the color image uniformity which can increase the spatial distribution information. The new similarity representation is adopted. The result of the experiments shows that the method compared with the Geostat histogram has been significantly improved in precision and recall.

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