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A chroma texture-based method in color image retrieval

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ABSTRACT

Texture is an important feature generally used in the content-based image retrieval (CBIR). Traditional methods of calculating texture features ignore the texture features caused by chroma differences. A new method of calculating chroma texture features is proposed in this paper. Large numbers of experiments were performed and proved that the chroma texture feature was a very important complement to the traditional luminance texture. The effectiveness of the image retrieval is improved significantly by combination of luminance texture and chroma texture with a lower-dimensional vector. The average ranking ratio is improved by 14.57%, and there is an obvious improvement of the average recall-precision curve.

1. Introduction

With the development of computer vision and image databases, image retrieval, and especially the content-based image retrieval (CBIR), have become a hot issue. The key step in CBIR is the extraction of low-level features, such as color, texture, shape, and spatial relation [1–3].

Texture feature is a common characteristic of all objects, which includes important information about the surface characteristics and their relationship with the surroundings. Each object has its own texture in nature, so texture is one of the most important features in image retrieval system.

Previous researchers generally considered the gray-scale image texture, such as gray-level co-occurrence matrix, Tamura texture and wavelet texture [4,5]. The methods are based on the truth that large quantitative differences lead to obvious visual differences; however, it is only applied in gray-scale images. For color images, relevant methods usually collect the luminance information by converting the color image into gray-scale image. Researchers explored retrieval methods combining texture and color in these years [6–9]. In fact, the texture caused by color differences can be also considered as another important feature.

In this paper, a new method of calculating chroma texture feature is proposed and introduced in detail. The effectiveness of image retrieval is improved significantly by using the luminance texture and the chroma texture with the feature of only 20 dimensions.

2. Algorithm

2.1. Selection of the color space

For color images, the first thing considered by most algorithms is to choose a proper color space. The *Lab* color space is chosen in this paper because it can achieve the separated luminance information and chroma information. Unlike the RGB and CMYK color models, which model the output of physical devices, *Lab* color space is designed to approximate human vision. Its *L* component closely matches human perception of lightness, and the chroma components, *a* and *b*, are more in line with the perception of color, which is conducive to the calculation in the co-occurrence matrix.

The conversion from the *RGB* color space to the *Lab* color space needs the *XYZ* color space as a transitional space. The whole transformation process is shown in the following Eqs. (1)–(4).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.490 & 0.310 & 0.200 \\ 0.177 & 0.813 & 0.011 \\ 0.000 & 0.010 & 0.990 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \tag{1}$$

$$L = \begin{cases} 116\left(Y/Y_0\right)^{\frac{1}{3}} & Y/Y_0 > 0.008856 \\ 903.3\left(Y/Y_0\right)^{\frac{1}{3}} & Y/Y_0 \le 0.008856 \end{cases}, \tag{2}$$

$$a = 500\left[f\left(X/X_0\right) - f\left(Y/Y_0\right)\right], \tag{3}$$

$$b = 200\left[f\left(X/X_0\right) - f\left(Z/Z_0\right)\right]. \tag{4}$$

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where

$$f(x)=\begin{cases} x^{\frac{1}{3}} & x>0.008856 \\ 7.787x+0.138 & x\le 0.008856 \end{cases}. \tag{5}$$

X_0, Y_0, and Z_0 are CIE XYZ tristimulus values of the reference white point.

2.2. Quantification of chroma components

Color quantization is a process that can reduce color scales used in an image. An image is considered as a digital matrix in processing in the computer. Quantification of a color image should meet the following two requirements at least: a reduced dimension for fast processing and a proper matrix whose difference should coincide with human's visual perception.

For an image in *Lab* space, its color components, *a* and *b*, can be quantified equally. Here, we come up with a method of quantification and produce a new matrix named *C* containing the information of *a* and *b*, which will be used as a new image to calculate its gray-level co-occurrence matrix, Tamura texture and wavelet texture.

First, the gray levels of *a* and *b* are quantified equally into 16 gray levels, numbered 0, 1, 2,. . .,15. *A* and *B* are the quantified results of *a* and *b*, respectively.

Second, a matrix *C* is calculated by Eq. (6),

$$C=16\times A+B. \tag{6}$$

Thus, the chroma matrix *C* with 256 gray levels is produced by mixing chroma information in the image. By this encoding method, the generated gray levels in *C* coincide with the condition that the larger difference in visual perception, the larger difference should be in numerical levels.

Fig. 1 shows histograms in the procedure of calculating the chroma matrix *C* of a color image. Where, (a) is the original image, (b) and (c) are the histograms of quantified results of the chroma components *a* and *b*, respectively, in which color components are quantified into 16 gray levels, (d) is the histogram of $16\times$A, and the histogram of the final integrated matrix *C* is shown in (e). It can be seen that the matrix *C* includes the information of two chroma components and its gray levels range from 0 to 255, which makes *C* be regarded as a gray image. Therefore, the texture information of *C* can be extracted similar to that of gray images.

2.3. Calculation of texture features

Three kinds of texture features, gray-level co-occurrence matrix, Tamura texture and wavelet texture, are used in this paper. They are calculated in the following, in which textures with luminance and chroma information can be obtained based on *L* component and matrix *C*, respectively.

2.3.1. Calculation of the gray-level co-occurrence matrix

Gray-level co-occurrence matrix is a classical method to describe texture features. There are 14 kinds of features, and we only use the following five ones according to Ref. [10].

(1) Angular Second Moment (ASM)

$$ASM=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}(p_\delta(i,j))^2. \tag{7}$$

(2) Contrast

$$Con=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}(i-j)^2p_\delta(i,j). \tag{8}$$

(3) Correlation

$$Cor=\frac{\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}(i-\mu_x)(j-\mu_y)p_\delta(i,j)}{\sigma_x\sigma_y}. \tag{9}$$

where

$$\mu_x=\sum_{i=0}^{L-1}i\sum_{j=0}^{L-1}p_\delta(i,j),\ \mu_y=\sum_{j=0}^{L-1}j\sum_{i=0}^{L-1}p_\delta(i,j),$$

$$\sigma_x=\sum_{i=0}^{L-1}(i-\mu_x)^2\sum_{j=0}^{L-1}p_\delta(i,j),\ \sigma_y=\sum_{j=0}^{L-1}(j-\mu_y)^2\sum_{i=0}^{L-1}p_\delta(i,j).$$

(4) Entropy

$$Ent=-\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}p_\delta(i,j)\log_2p_\delta(i,j). \tag{10}$$

(5) Equality

$$Equ=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}\frac{1}{1+(i-j)^2}p_\delta(i,j). \tag{11}$$

ASM, contrast, correlation, entropy, and equality in four directions, 0°, 45°, 90°, and 135°, are calculated, respectively. Finally, the mean and variance of four directions of each feature are calculated. Thus, we have 10 texture features altogether marked as textureGMFeature.

$$\text{textureGMFeature}=\{\mu_{Asm},\mu_{Con},\mu_{Cor},\mu_{Ent},\mu_{Equ},\sigma_{Asm},\sigma_{Con},\sigma_{Cor},\sigma_{Ent},\sigma_{Equ}\}. \tag{12}$$

2.3.2. Calculation of Tamura texture

Tamura texture was developed based on the psychological studies of human visual perception [11]. The typical ones are coarseness, contrast, and directionality.

(1) Coarseness

The coarseness of an image is calculated as follows:

First, calculate the average of gray levels within a window, $2^k\times2^k$, *k* is set to 1, 2, 3, 4, and 5.

$$A_k(x,y)=\sum_{i=x-2^{k-1}}^{x+2^{k-1}}\sum_{i=y-2^{k-1}}^{y+2^{k-1}}\frac{Gray(i,j)}{2^{2k}}. \tag{13}$$

For every pixel, calculate its difference of average gray levels between two nonoverlapping windows in horizontal and vertical directions.

$$\begin{cases} E_{k,h}(x,y)=\left|A_k\left(x+2^{k-1},y\right)-A\left(x-2^{k-1},y\right)\right| \\ E_{k,v}(x,y)=\left|A_k\left(x,y+2^{k-1}\right)-A\left(x,y-2^{k-1}\right)\right| \end{cases}. \tag{14}$$