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Application research of local binary pattern in fabric color card image retrieval

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ABSTRACT

The aim of this work is to find the best local binary pattern for describing a given texture in order to meet the needs of effectiveness in the domain of fabric color card image retrieval. Firstly, four different local binary pattern (LBP) descriptors are introduced. We are conducted in-depth research on four local binary patterns, including conventional LBP, rotation invariant LBP, uniform pattern LBP and rotation invariant uniform patterns LBP. Secondly, texture feature extraction algorithms based on the four LBP descriptors are designed and a corresponding approach to retrieving the fabric color card images is proposed by using local binary pattern. The proposed retrieval algorithm is used for finding k-nearest neighborhoods that match each tested image. Finally, the proposed retrieval approaches based on four different LBP modes are tested and compared on the public image texture data sets and the real fabric color card data set in details. By analyzing the experimental results, we select an approach that performs well on the real fabric color card data set, which can satisfy the actual need of fabric color card retrieval.

KEYWORDS

LBP; Image texture feature; Image retrieval; Fabric color card image.

INTRODUCTION

Fabric is a kind of raw material, which is closely related with people's daily lives. Fabric products and its processing industry play an important role in people's daily lives and the development of our country. However, currently fabric products processing industry also has the following problems that affect production and processing efficiency: (1) hard to find raw fabric materials needed at a market; (2) hard to checking whether the materials selected are good or not; (3) hard to make recognition from similar raw fabric materials; (4) hard to typeset and cut from a raw fabric material. With the development of computer technology and digital image processing techniques, an effective way to solve the problems is to use computer to retrieve and classify fabric images.

Although a lot of progress has been made and some applications have been developed with regard to domestic and international research in the field of fabric texture recognition and retrieval, many problems still exist. Thus, many new methods are appearing in recent years. Ren Youting[1] proposed a new method of fabric pattern extraction based on color measurement and texture recognition ---- the main line, and put forward corresponding design scheme of fabric color management system. Xu Qi[2] put forward a new texture description method ----- Multiscale Blob Features, MBF for short. The method uses multi-scale analysis methods, doing space scale and grayscale decomposition to texture image at the same time, and can fully analyze the complex texture structure contained in an image. Zhao Yang [3] proposed a series of local texture description operators which play a key role in the local texture information for identifying images, in the meantime, tried to find a local operator that can improve the ability of distinguishing but does not lose its rotational invariant property. Ge Jingxiang[4] aimed at analyzing effects of the image scale changes and angle rotation by using logarithmic polar coordinate transformation method with a rotation invariant texture. Song Chungang[5] studied the color and texture classification methods of leather.

Because each method has its own drawbacks and limitations, thus none of existed algorithms for fabric texture recognition and retrieval is universal so far. In other words, none of the existed algorithms is suitable for most of the recognition and retrieval texture images. Researching new texture recognition method of a fabric color card image recognition and retrieval to meet the needs of those luggage companies and fabric suppliers has important theoretical significance and applicable value.

FOUR LBP DESCRIPTORS

In computer graphics, texture refers to the surface of objects with regard to its uneven grooves, it also refers to different color patterns on a smooth surface[6-8]. Currently, there are two main methods in a field of image texture analysis, including statistical analysis method and structure analysis method. Local binary pattern (LBP, for short)[9,10] is a combination of statistical analysis method and structure analysis method. LBP, first proposed by Ojala, Pietikainen, and Maeenpaa of Finland Oulu University in 1996[9-11], is one of the most widely used descriptors because of its resistance to lighting changes, low computational complexity, and ability to code fine details. It is simple, but powerful, can well reflect the local texture of an image. Numerous variants of LBP descriptors have been proposed within the last several years, such as uniform patterns, rotation invariant patterns, and so on.

Conventional LBP operator

The conventional LBP operator is originally defined by using a 3 × 3 window, and the LBP operator, namely LBP code's value, is calculated by the following formula [11]:

$$LBP_{P,R} = \sum_{p=0}^{P-1} s(g_p - g_c)2^p \qquad (1)$$

$$s(x) = \begin{cases} 0, x < 0 \\ 1, x \geq 0 \end{cases} \qquad (2)$$

Where g_p represents the gray value of neighboring pixel location p around a central pixel location c . and g_c represents the gray value of a center pixel location c , and P represents the total number of pixels in neighborhood with the central pixel location c and radius R . In this paper, we set $P = 8$ and $R = 1$. Finally, by calculating all values of the neighborhood local areas LBP code in a image, we can get the LBP code value histogram of the entire image. This histogram can be used as texture features of the image.

Rotation invariant LBP operator

In order to eliminate or mitigate the effects of rotation to LBP code value, Mäenpää et al [11] introduced a rotation invariant LBP operator. The calculation formula is shown in the following:

$$LBP_{P,R}^{i} = \min\{ROR(LBP_{P,R}, i) \mid i = 0,1,...,P-1 \qquad (3)$$

Where $ROR(x,i)$ means x rotated right by i bits, and $\min\{x\}$ represents selecting minimum the element of set x .

Although the operator can eliminate the effect of rotation to LBP code value, it will become different LBP patterns to a class of LBP pattern, reduces the number of LBP patterns, and may lose a lot of texture information of an image.

Uniform pattern LBP operator

In conventional LBP operator, the number of LBP patterns N is determined by P, namely $N = 2^P$. N determines the size of LBP code value histogram in an image. As P increases, N increases exponentially, corresponding feature data also increases. It will result in increasing the time complexity and space complexity. And it does not conform to the requirements of high efficiency and high speed in the areas of image classification and retrieval.

Ojala found in experiments that the roles of LBP patterns with different coded values in recognize processing of an image are different. Some LBP coded values appear in a low frequency while some LBP coded values appear in a high frequency. Number of changes between 0 and 1 in a LBP coded value can be calculated by the following formula [11]:

$$U(LBP_{P,R}) = | s(g_{P-1} - g_c) - s(g_0 - g_c) | + \sum_{i=1}^{P-1} | s(g_i - g_c) - s(g_{i-1} - g_c) | \quad (4)$$

And a LBP pattern in which $U \le 2$ called an uniform pattern LBP. The uniform pattern LBP can abandon the number of LBP patterns, namely N changing from 2^P to $P(P-1)+2$.

Rotation invariant uniform pattern LBP operator

Combining the rotation invariant LBP operator with the uniform pattern LBP operator LBP, we can get a rotation invariant uniform pattern LBP operator, indicated by $LBP_{P,R}^{ri}$. A LBP code's value in a rotation invariant uniform pattern is calculated by the following formula [11]:

$$LBP_{P,R}^{riu2} = \begin{cases} \sum_{i=0}^{P-1} s(g_i - g_c), U(LBP_{P,R}) \le 2 \\ P+1, else \end{cases} \quad (5)$$

IMAGE TEXTURE FEATURE EXTRACTION ALGORITHM BASED ON LBP

Image texture feature extraction algorithm based on the conventional pattern LBP operator

Rotation invariant LBP, uniform pattern LBP, rotation invariant uniform pattern LBP, all kind of LBP are based on conventional LBP. So, an image texture feature extraction algorithm based on the conventional pattern LBP operator is the most important algorithm. In this paper, the algorithm is described by using java language as follows.

Algorithm 1: Image texture feature extraction algorithm based on the conventional pattern LBP operator

Function name: GetLBPValue

Input: images' gray information of images: ImageGrayInfo[][], a small circular neighborhood with radius r, and the number of neighboring pixels P.

Output: The feature string of an image's LBP coded values: LBPStr.

Algorithm description:

(1) Create one-dimensional array of integers LBPHistogram [], length is 2^P, and is initialized with 0;
(2) Create a temporary memory to save LBP coded values: LBPorder (int);
(3) for(int $i = r$; i <ImageGrayInfo.length- r; i++)
(4) {
(5) for(int $j = r$; j <ImageGrayInfo[i].length- r; j++)
(6) {
(7) for(int k =0; $k < P$; k++)
(8) {
(9) To calculate gray value V_k of k^{th} neighboring pixel using bilinear interpolation
(10) To calculate gray difference d between V_k and center ImageGrayInfo [i] [j];
(11) if($d \ge 0$)
(12) {
(13) LBPorder=LBPorder+ 2^k
(14) }
(15) }
(16) LBPHistogram[LBPorder]++;
(17) LBPorder=0;
(18) }

(19) }
(20) for(int i =0; i <LBPHistogram.length; i ++)
(21) {
(22) LBPStr = LBPStr + (int) ((float) LBPHistogram [i] / number of the centers of the image field) * 1000 + ",";
(23) }

Image texture feature extraction algorithm based on the rotation invariant LBP operator

A LBP coded value generated by the algorithm based on the rotation invariant LBP operator is cyclic shift a conventional pattern LBP coded value P (the total number of neighboring pixels) times. We take the minimum one from P coded values. So, we can design an image texture feature extraction algorithm based on the rotation invariant LBP operator by improving the algorithm mentioned above, namely doing cyclic shift and getting the minimum LBP coded value.

Algorithm 2: Image texture feature extraction algorithm based on the rotation invariant LBP operator

Function name: RotateLBPMinValue (int LBPorder, int P)

Input: LBP coded values obtained from algorithm 1: LBPorder, the number of neighboring pixels P .

Output: Find the minimum LBP coded value in LBPorder by running the rotate right P times.

Algorithm description:

(1) Create a RLBPorder (int) as a temporary storage to save the result of right shift 1 -bit of a LBP coded value.

(2) create LLBPorder (int) as a temporary storage to save the result that retaining the highest bit and other bits setting to 0 after left shift 7-bits of a LBP coded value.

(3) create Temporder (int) as a temporary storage to save the result of cyclic shift to the right, is initialized to LBPorder.

(4)for(int i =0; $i < P$; i ++)
(5){
(6) RLBPorder=Temporder>>1;
(7) LLBPorder=(Temporder<<7)&128;
(8) Temporder= RLBPorder| LLBPorder;
(9) if(LBPorder>Temporder)
(10) {
(11) LBPorder=Temporder;
(12) }
(13)}

Image texture feature extraction algorithm based on the uniform pattern LBP operator

The uniform pattern LBP operator is to examine whether the conventional pattern LBP operator can satisfy the measurement $U \leq 2$ or not. If it can, then add 1 to a corresponding a counter of LBP coded value, otherwise discard it. Finally, in the normalization process, the counter should be divided by the number of pixels that satisfying the measurement $U \leq 2$. Here is the algorithm for calculating U .

Algorithm 3: The algorithm for calculating U .

Function name: GetUValue (I , P)

Input: a set of pixels in the local domain I , the number of neighboring pixels P .

Output: The measurement U with regard to a LBP coded value.

(1) Create an *Uvalue* (int) standing for U , and is initialized with 0.
(2)for(int i =0; $i < P$; i ++)
(3){
(4) if(i ==0)
(5) {
(6) if (the gray value of pixel g_0 and g_{p-1} do satisfy the condition that are both bigger or smaller than or equal to the gray value of the center pixel)
(7) *Uvalue*++;
(8) }
(9) else
(10) {
(11) if (the gray values of pixel g_i and g_{i-1} do satisfy the condition that are both bigger or smaller than or equal to the gray value of the center pixel)
(12) *Uvalue*++;
(13) }
(14)}

Image texture feature extraction algorithm based on the rotation invariant uniform pattern LBP operator

An image texture feature extraction algorithm based on the rotation invariant uniform pattern LBP operator includes mainly two steps. First step, an uniform pattern LBP coded values is obtained based on algorithm 2. Next step, the LBP coded value is cyclic shifted P (the total number of neighboring pixels) times, and the minimum one from P coded values is taken as the rotation invariant uniform pattern LBP coded value.

FABRIC COLOR IMAGE RETRIEVAL ALGORITHM BASED ON LBP

Texture similarity calculation

Calculating the similarity of two images is the basis for image recognition and retrieval. Image similarity calculation of this paper is to calculate the similarity between texture features, and texture features are represented in histogram. In the paper, we use a measurement named Chi-square statistics based histogram commonly. Chi-square statistics is to calculate cumulative sum of the difference between two histograms in corresponding position. The formula is as follows [3] :

$$D_{x^2}(H,I)=\sum_{k=1}^{L}\frac{(H_k-I_k)^2}{H_k+I_k} \qquad (6)$$

In which L represents the total number of LBP patterns, H_k represents image H 's histogram data while the pattern is K, I_k represents image I 's histogram data while the pattern is I. The smaller the value of $D_{x^2}(H,I)$, the more similar of two images H and I which are characterized by histogram.

Fabric color image retrieval algorithm based on LBP

Image retrieval is to calculate the similarity between a tested image with images in an image database. Then first K -nearest neighbor images are sorted according to their similarity size by descent. We can record the ranking of these K images that belong to one class or the same with the tested image. An Image Retrieval Algorithm Based on LBP is described as follows.

Algorithm 4: Fabric color image retrieval algorithm based on LBP

Function name: GetTestPictureRank (*ds*, *tf*)

Input: Records *ds* (DataSet) in a texture feature library of fabric color images, texture feature value *tf* of the tested image, the parameter K representing the number of results you want to display.

Output: K -nearest neighborhood images of the tested image.

The algorithm is described as follows.

(1) Create a HashMap *hm* <Integer,Integer>;

(2) for (each record in *ds*)

(3){

(4) Calculate the difference(namely, similarity) of texture feature value between *i*-th record in *ds* and *tf.*

(5) Put the *id* of *i*-th record and similarity *d* into *hm*: *hm*.put (*id*, *d*);

(6)}

(7) Create a list to store *hm*: new ArrayList (*hm*.entrySet);

(8) Sort the list from small to large according to the value of *hm* using sorting function of collections;

(9) Take the top K images, observe the library record of image that belong to the same class or the same with test image, and record its sort value.

THE COMPARATIVE STUDY BETWEEN FOUR LBP OPERATORS IN FABRIC COLOR CARD IMAGE TEXTURE FEATURE EXTRACTION AND RETRIEVAL

Test environment

Experimental test platform: Windows Operating System (Windows XP or Window 7, Pentium (R) Dual-Core CPU T440, 2.20GHz, 2G Memory)

Experimental Programming Language: Java, Matlab IDE tool:Eclipse3.5.2 (Java project development), EMS (Database management)

DBS:MYSQL5.1

Introduction to datasets

In the paper, datasets for testing include Brodatz texture library,UIUC texture library, Outex texture library and Fabric color card image set.

Brodatz natural texture image library is collected by Brodatz during the study of texture images. All images in this library are grayscale images. Brodatz natural texture image library contains 112 texture images with different textures, and each image's pixel size is 640 * 640.

UIUC texture library contains texture data of real images with high resolution. UIUC texture library has 25 classes, 40 texture images per class, and each image's pixel size is 640 × 480.

Outex texture library contains 30 categories of texture images, each category contains one or more sub-category.In the texture library, the pixel size of an image is 746 × 538, there are "inca", "tl84", "horizon" three kinds of lighting conditions in each image, and each light conditions is divided into 100dpi, 120dpi, 300dpi, 360dpi, 500dpi, 600dpi six kinds of resolution. At each resolution shooting from 0 °, 5 °, 10 °, 15 °, 30 °, 45 °, 60 °, 75 °, 90 ° nine different rotation angle, so for a texture image there exists 3 × 6 × 9 = 162 different forms of pictures. These pictures simulate a variety of changes of images that might encounter in the practical application.

Fabric color card image set is an image set with 1344 images. Each image in this set is color photograph, which is obtained by scanning a variety of cloth and leather using EPSON PERFETION V10 full-color scanner. Those cloth and leather include oxford cloth, TC cotton faille, peach cloth, linen and a variety of high-grade bags' fabrics. These fabric color cards have rich colors and various textures. Fabric color card image set is a real and objective test set. Here are some images of the fabric color card image set(Figure 1).

Figure 1 : Fabric color card image set

Formation of image libraries of texture features and the image test set

- For Brodatz texture library: Each image is divided into nine sub-images of the same size, and each sub-image's pixel size is 213 * 213. Any three sub-images are used to extract their texture features using four different LBP operators, while the remaining six sub-images are used as the test images. The corresponding image texture features are obtained from and deposited in the database.
- For UIUC texture library: We take any 5 in 40 of each category to extract texture features using four different LBP operators, while the remaining 35 as a test set. The corresponding image texture features are obtained from and deposited in the database.
- For Outex texture library: We take those "horizon, 100dpi, 0°”images to extract texture features using four different LBP operators. The corresponding image texture features are obtained from and deposited in the database. And we use the "horizon, 100dpi, 90 °"image as a test set to test the recognition ability of LBP texture operator to rotational image, use "inca, 100dpi, 0 °" as a test of the recognition ability of the various modes of LBP texture operators to the change of light conditions.
- For fabric color card: We scan each fabric color card image by a scanner, then extract each image's texture features using four different LBP operators. The corresponding image texture features are obtained from and deposited in the database. While testing, take a sub-image of any fabric color card image as the test images.

Test evaluation

We take the recognition rate and the average ranking value as the evaluation standard in experiment. After comparing the tested image with images in the image texture database, we got matching results (namely, K --nearest neighboring images) from large to small order by similarity. If the first image of results belong to the same class or the same with the tested image, it shows correctly identified. Each tested image has image of the same class as it belongs to or has the same image in the database. After each testing with regard to each tested image, record this tested image's ranking value. The average value of all tested image's ranking values is called the average ranking value.

The recognition rate can show the proposed algorithm's ability to correctly identify the tested image, the bigger the stronger. The average ranking value can show ranking position of correct image in the retrieved result set, the smaller the better.

Testing and result analysis

We test 10 times for each image in a test set, then calculate each tested image's recognition rate and average ranking value. At last, we can get total recognition rate and average ranking value of all images in the test set. The test results are shown in TABLE 1 and TABLE 2 below.

TABLE 1: Experimental results in brodatz, UIUC and fabric color card image set

Data sets and evaluation standards	Brodatz		UIUC		Fabric Color Card Image Set	
LBP patterns	Recognition Rate	Average Ranking Value	Recognition Rate	Average Ranking Value	Recognition Rate	Average Ranking Value
Conventional LBP	91.82%	1.83	44.38%	6.58	96.28%	1.34
Rotation Invariant LBP	69.35%	2.11	47.93%	4.69	90.03%	1.93
Uniform Pattern LBP	91.07%	1.75	43.91%	6.31	93.82%	1.56
Rotation Invariant Uniform Pattern LBP	83.78%	2.32	46.27%	4.73	77.23%	3.49

TABLE 2: Experimental results in outex texture library

Light and Rotation	horizon, 100dpi, 90°		inca, 100dpi, 0°	
LBP patterns	Recognition Rate	Average Ranking Value	Recognition Rate	Average Ranking Value
Conventional LBP	19.69%	76.27	58.75%	3.21
Rotation Invariant LBP	80.63%	2.01	29.69%	10.23
Uniform Pattern LBP	17.81%	82.48	58.13%	3.25
Rotation Invariant Uniform Pattern LBP	76.56%	2.1	25.31%	12

The test results reported in Table 1 and table 2 show that the best results are obtained considering the conventional/uniform pattern LBP in Brodaze dataset and none of texture descriptors(LBP operators) across three databases do work well in performance. However, we can obtain a good performance in the Fabric Color Card Image Set when we use texture descriptors such as conventional LBP operator, rotation invariant LBP operator and uniform pattern LBP operator. The best approach to retrieving the tested images on the Fabric Color Card Image Set is the one based on the conventional LBP operator, it obtains a very good average recognition rate and a good average ranking of 1.34. But, experimental results show that none of the methods based on difference LBP modes work well in UIUC dataset.

Based on the experimental results, in this paper, we propose an approach to retrieving a fabric color card image based on conventional LBP technique and develop a retrieving system. In order to verify the effectiveness of the proposed retrieving approach, we compare the proposed approach with ALLGRA proposed in literature [7] on SCC and CCC datasets. Testing results are shown in Table 3 as follows.

TABLE 3: Performance comparing

Approaches	Proposed Method		ALLGRA	
Data sets	Recognition Rate	Average Ranking Value	Recognition Rate	Average Ranking Value
SCC	98.69%	1.21	94.12%	2.1
CCC	98.63%	1.26	78.61%	2.97

From TABLE 3, it shows that the proposed method has a performance higher than ALLGRA with performance recognition rate and average ranking value.

CONCLUSIONS

The LBP operator has a very strong ability of describing image texture feature. We have introduced four different LBP operators in detail, designed the algorithms of image texture feature extraction by using corresponding LBP operators, and design image retrieval and matching algorithms. We have made an intensive study of recognition effect of four different LBP operators in different texture image libraries. Through the results analysis, we get the advantages and disadvantages of different LBP texture methods towards to different data set, and propose an approach to retrieving the fabric color card images by using local binary pattern (LBP) that can retrieve fabric color card image effectively.

The future study includes the further optimization of algorithms and program, in addition, make an in-depth study of a more effective and practical method that combine image's color feature, and implement that program.

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