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## NOVEL APPROACH TO COLOR TEXTURE RETRIEVAL BASED ON GLCM

*The color and texture are very important features in image analysis. In this paper, the combination of these features is presented. Several approaches for color texture features extraction are researched. The improvement of the one-dimensional version of GLCM (Gray Level Co-occurrence Matrix) for color textures was designed. We named this method as Color Level Co-occurrence Matrix (1D-CLCM). The experiments on database of 2600 color images are provided. Finally, the evaluation and comparison of image retrieval results for separate methods are presented.*

**Keywords:** Co-occurrence, color texture, GLCM, one-dimensional, texture extraction

### 1. Introduction

Texture has been one of the most popular representations in image retrieval [1]. Forasmuch as grayscale textures provide enough information to solve many tasks, the color information was not utilized. But in the last years, many researchers have begun to take color information into consideration [2-7].

However, the human eye perceives the image as combination of primary parts (color, texture, shape), our previous research was oriented to combination of these primary parts of image. Exactly, the combination of color and texture was researched and new possibilities of GLCM were researched [8].

Tou et al. [9], introduce the reduction of computations for the GLCM method by reducing the matrix dimension from two to one dimension. Based on these two approaches, the one-dimensional GLCM method for color-texture feature extraction is introduced.

In this paper, new and extended experiments of GLCM are described and new methods are proposed. Experiments are realized on database of 2600 color textures and 110 queries are used for evaluation.

The outline of the paper is as follows. In the next section, an overview of basic principles of GLCM and 1D-GLCM are introduced. Next, the color feature extractions based on 1D-GLCM are introduced in section 3. In this section, the 1D-GLCM is applied on separated color channels of RGB color image and new 1D-CLCM method is proposed. Finally, the experiments are described in 4 and brief summary is discussed in section 5.

### 2. Gray level methods

#### 2.1 GrayLevel Co-occurrence Matrix

The GLCM (Gray Level Co-occurrence Matrix) is a powerful method in statistical image analysis. This method is used to estimate image properties related to second-order statistics. GLCM considers the relation between two neighboring pixels in one offset, as the second order texture, where the first pixel is called reference and the second one the neighbor pixel. GLCM is the two dimensional matrix of joint probabilities between pairs of pixels, separated by a distance  $d$  in a given direction  $\theta$ .

For the scale invariant of texture pattern, the GLCM is standardized by total pairs of pixels as follows:

$$p(i,j) = \frac{Pd,\theta(i,j)}{\text{All\_pairs\_of\_pixel\_used}} \quad (1)$$

where  $Pd,\theta(i,j)$ , expresses joint probabilities between pairs in distance  $d$  and direction  $\theta$  and  $i,j$ , are luminance intensities of those pixels.

Haralick [10] defined 14 statistical features from gray-level co-occurrence matrix for texture classification. However, these features are strongly correlated [11], we decide to use only one feature descriptor for methods comparison. The feature Inverse Difference Moment also called "homogeneity" is used. The homogeneity is defined as follows:

$$\text{Homogeneity}_{d,\theta} = \sum_i \sum_j = \frac{Pd,\theta(\text{diff})}{1 + |i - j|^2} \quad (2)$$

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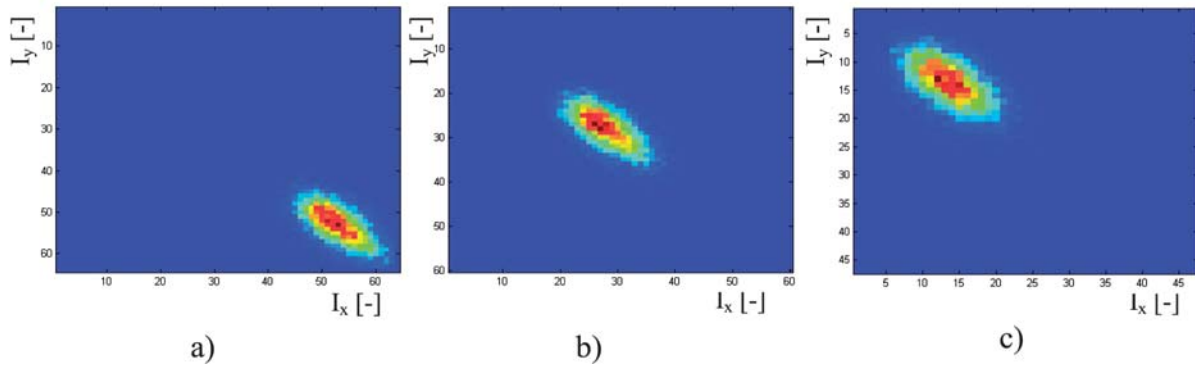


Fig. 1 Example of GLCM matrices plot for RGB color components ( $d = 1, \theta = 0^\circ$ ), a) GLCM in R channel, b) GLCM in G channel, c) GLCM in B channel

### 2.2 One-dimensional GLCM

Tou et al. [9] reduce computations of feature extraction vector. They reduce GLCM dimension from two to one dimension by combination of certain values of the matrix. In conventional two-dimensional GLCM, the matrix in size  $G \times G$  is used, where  $G$  represents the maximum gray level value in image. By focusing only on the differences of the gray level, a one-dimensional GLCM has a significantly smaller size, which is only  $2 \times G - 1$ . By reducing the dimension of the GLCM, the calculation of features is faster as fewer values are involved in the calculation.

Likewise in GLCM, the scale invariant of texture pattern is provided as follows [9]:

$$p(diff) = \frac{Pd, \theta(diff)}{All\_pairs\_of\_pixel\_used}, \quad (3)$$

where  $Pd, \theta(diff)$  expresses difference probabilities between pairs in distance  $d$  and direction  $\theta$  and  $diff$  shows the differences of gray value between the two pixels of the pixel pairs.

The textural feature homogeneity for one-dimensional GLCM is defined as follows [9]:

$$Homogeneity_{d,\theta} = \sum_i \sum_j = \frac{Pd, \theta(diff)}{1 + (diff)}. \quad (4)$$

### 3. Color level methods

However, the computations of texture features are reduced by one-dimensional GLCM, we used this advantage of computing time for next approach. Exactly, the input color image is not reduced to gray level for next methods. Thus, against previous methods, where only gray level value of pixels were considered, the color information is considered for texture feature extraction.

### 3.1 One-dimensional GLCM for separated color channels

The easiest way for using gray-level method for color image is applying method to each 2D matrix of three-dimensional color image representation.

Subsequently, the color feature extraction can be defined as follows:

$$FV = [FV(C_1), FV(C_2), FV(C_3)], \quad (5)$$

where,  $FV$  is feature vector and  $C_1, C_2, C_3$  are one-dimensional GLCM matrices of particular color channels. The example of difference of GLCM matrices for RGB color components is shown in Fig. 1. In our experiments, the color space RGB is used, thus, we named this method as RGB one-dimensional GLCM (RGB-1D-GLCM).

### 3.2 One-dimensional Color Level Co-occurrence Matrix

In our previous research [8], we used the 3D image interpretation directly for co-occurrence matrix computing. In this work, we applied this approach for one-dimensional GLCM and we called this method Color Level Co-occurrence Matrix (1D-CLCM).

The principle of CLCM method is shown in Fig. 2. For the distance and angles the cube of size  $3 \times 3 \times 3$  was created. In this case, three neighborhoods for every direction (#1-#12 in Fig. 2) was used. There are also neighborhoods on same position in image in different color components. Therefore, the direction #13 was also taken in consideration. The 13 directions neighborhood system was created. These 13 probability matrices express relations between component  $x_2$  and its neighbors in all channels of color space. In order to get information of all channels relations, it is necessary to use this procedure in three iterations, where  $x_1, x_2, x_3$  are changing the color space components (Table 1).

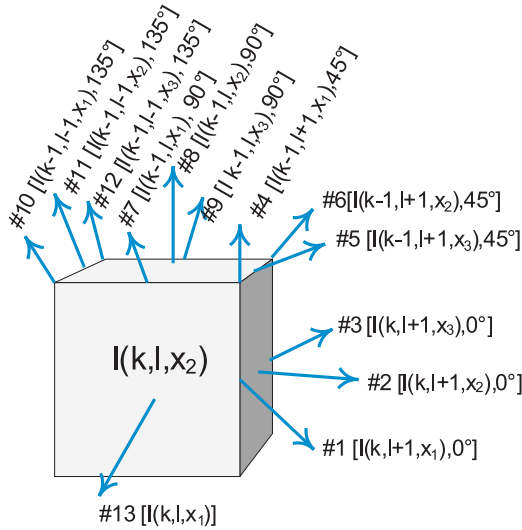


Fig. 2 Principle of 13 directions neighborhood system,  $x_1, x_2, x_3$  are color components of color image  $I$

The combination of color space components for GLCM Tab. 1

Colorcomponent	Iteration		
	1	2	3
$x_1$	$C_1$	$C_2$	$C_3$
$x_2$	$C_2$	$C_3$	$C_1$
$x_3$	$C_3$	$C_1$	$C_2$

For 1D-CLCM the differences for all neighbors by formula (3) are computed. Finally, feature vector consists of information of all three channels and their relations in 39coefficients (13x3).

#### 4. Experiments

For our experiments, the Matlab environment was used. For the extraction of standard GLCM features, the library functions were used. For the others, the own functions were developed. However, we wanted to test algorithms on big database, a dataset from several smaller datasets (e.g. Vistex [12], Outex [13]) was created. This dataset contains 130 types of textures in 2600 color images (20 images for each texture) in resolution  $128 \times 128$ . The example images from texture database are shown in Fig. 3. For all experiments, the parameters distance  $d = 1$  and angles  $\theta = 0^\circ, 45^\circ, 90^\circ, 135^\circ$  degrees are used. As was mentioned above, the only one feature “homogeneity” is used.

The scale invariant of texture pattern is provided by standardization of total pairs of pixels as was defined in (1) and (3).

For the rotation-invariant of texture pattern, the feature vector is rotated in stage of feature matching as follows:

$$VP_Q^{0^\circ} = [p(0^\circ), p(45^\circ), p(90^\circ), p(135^\circ)], \tag{6}$$

$$VP_Q^{45^\circ} = [p(45^\circ), p(90^\circ), p(135^\circ), p(0^\circ)], \tag{7}$$

$$VP_Q^{90^\circ} = [p(90^\circ), p(135^\circ), p(0^\circ), p(45^\circ)], \tag{8}$$

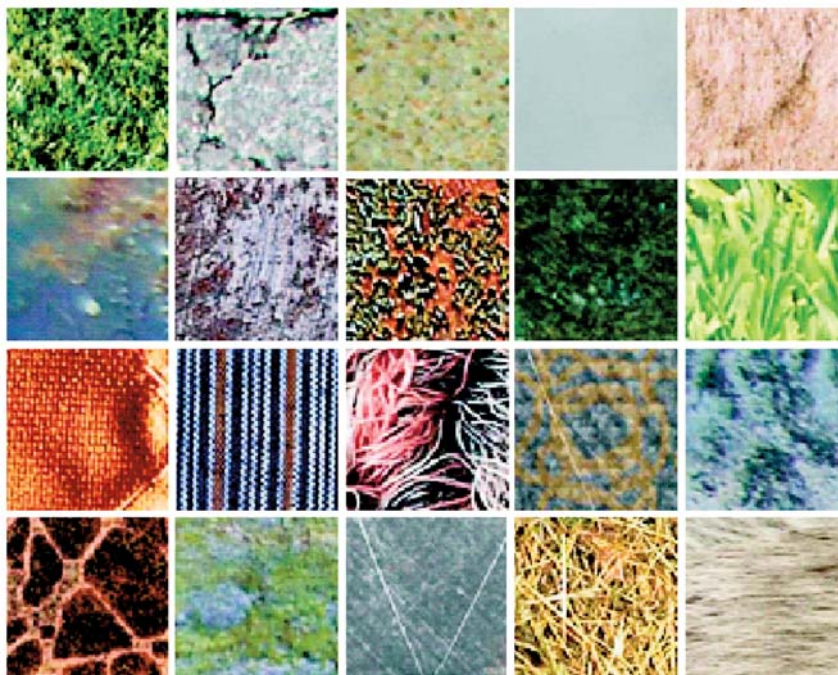


Fig. 3 Example images from texture database

$$VP_Q^{135^\circ} = [p(135^\circ), p(0^\circ), p(45^\circ), p(90^\circ)], \quad (9)$$

where  $VP_Q$  is feature vector of retrieved texture and  $p$  is feature value in rotation  $0^\circ, 45^\circ, 90^\circ$  or  $135^\circ$ .

The equation for computing the minimal vector's distance  $d$  is defined as [14]:

$$d = \min[\text{dist}(VP_Q^{(n-1)\theta_\Delta} | VP_{DB})], \quad (10)$$

where  $n = (1, 2, 3, 4)$  is iteration number for rotation of feature vector, and  $\theta_\Delta$  is rotation step in degrees. In our experiments, the rotation step  $45^\circ$  was used. The  $V$  and  $VP_{DB}$  are feature vectors of query image and database texture.

The percentage expression of image retrieval precision  $p$  is provided by a simple method defined as follows:

$$p = \frac{N_F - 1}{N_T - 1} * 100\%, \quad (11)$$

where  $N_F$  is number of truly found texture images and  $N$  is total number of relevant texture images. The subtraction of 1 is used, because there was a query image in database.

For a better view, the extra measure  $p^*$  was used for evaluation of image retrieval. The  $p^*$  expresses the precision of retrieval on first  $n = 2 * N_T$  positions. Thereby, it is possible to show if there are any images close to correct match. The principle of evaluation is shown in Fig. 4.

In our experiments where 20 images for each texture were used,  $n = N_T = 20$  for  $p^*$  and  $n = 2 * N_T = 40$  for  $p^*$ .

Two simple applications for annotation and retrieval were created. The first application is used for creating the annotated

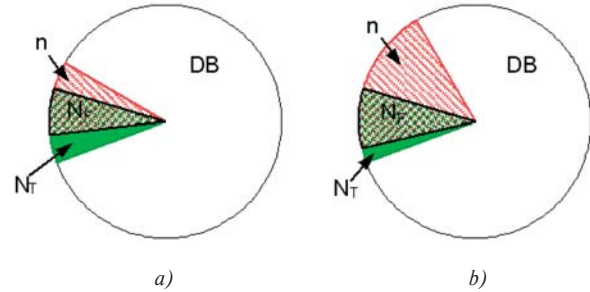


Fig. 4 Experiments evaluation, a) precision  $p$ , b) precision  $p^*$  (DB is image database,  $N_F$  is number of truly found texture images,  $N_T$  is total number of relevant texture images,  $n$  expresses first  $n$ -positions of sorted set of images for evaluation)

database where the database of images is the input and extracted feature vectors, exported into XML file, are the output. The query image and the annotated image database are inputs for a second application. Output of this application is a sorted set of images by minimal distance (10).

#### 4.1 Experimental results

The results of GLCM, 1D-GLCM, RGB-1D-GLCM and 1D-CLCM for 110 random query images are shown in Fig. 5. The average values of image retrieval precision are shown in Fig. 6. The conventional GLCM reached in our experiments precision  $p = 45.7\%$  and  $p' = 59.9\%$ . The 1D-GLCM reached only  $p = 38.0\%$  and  $p' = 51.6\%$ . After applying the 1D-GLCM on separated color channels, the better result were obtained. The RGB-1D-GLCM method reached  $p = 56.5\%$  and  $p' = 69.0\%$ . Finally, the 1D-CLCM

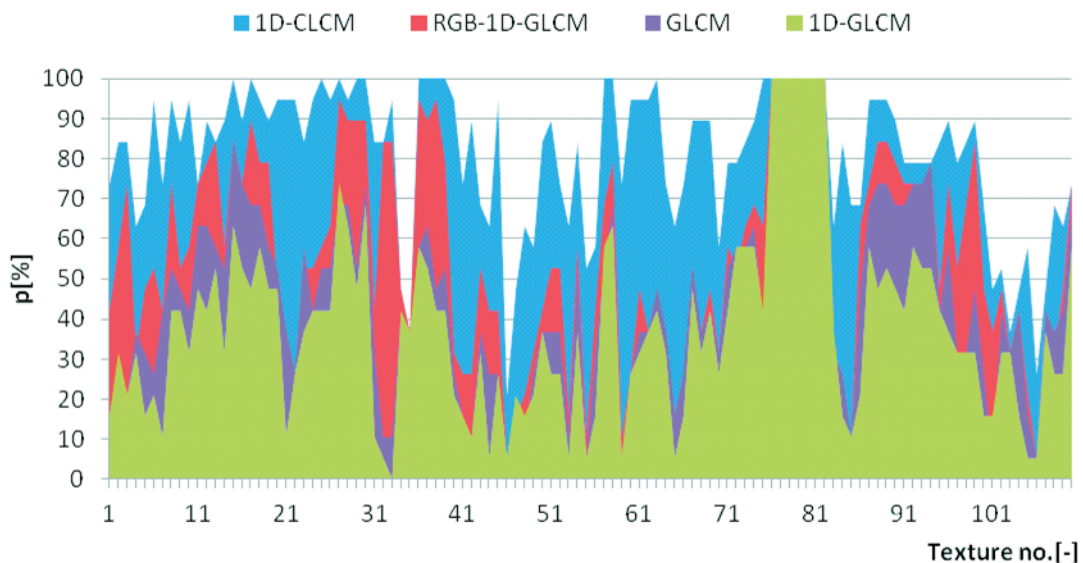


Fig. 5 The experimental results for 110 retrieved image textures

method reached  $p = 81.1\%$  and  $p' = 90.1\%$ . Thus, we reached improvement of 43.1% over basic 1D-GLCM and 35.4% over GLCM, after color information was applied. These results make 1D-CLCM fast and strong descriptor for color textures.

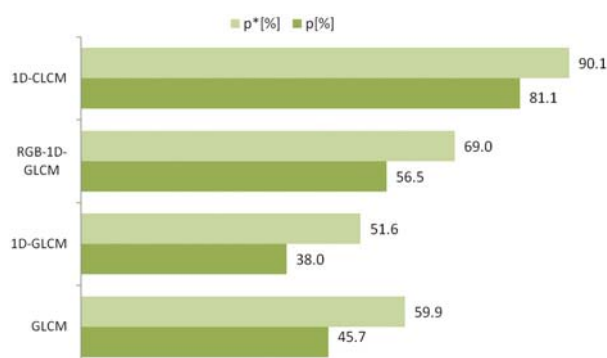


Fig. 6 The final experimental results for GLCM, 1D-GLCM, RGB-1D-GLCM and 1D-CLCM methods

## 5. Conclusion

In this paper, the methods for color texture feature extraction based on GLCM were proposed and tested. Exactly, we aimed our research to modification of one-dimensional GLCM and 1D-CLCM method was introduced. The experiments verified on the database of 2600 color images were provided. At first, the comparison of conventional GLCM, 1D-GLCM, applied on a separated channel of color image was presented. Next, we used our previous research on GLCM and modified this method for direct extraction from color image. The 1D-CLCM method was introduced and the precision of retrieval was rapidly increased. The designed 1D-CLCM method reached about 81% in texture retrieval with improvement of 43% over basic 1D-GLCM and 35% over GLCM were obtained.

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