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Perceptual Colour Features for Natural Scene Image Description and Retrieval

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***Abstract*—In this paper, we propose new image features called perceptual colour features. The features are based on twenty basic colours called emotional colours, which are used to describe the relationship between colours and emotions in psychological studies. We analyzed a colour image in L*a*b* and L*C*h colour spaces to link to emotions. Then, the perceptual colour features are derived from the histogram of the twenty emotional colours. We have demonstrated effectiveness of the perceptual colour features with an emotion based image retrieval application. Experiments were performed on a set of impressive natural scene images. The retrieval results were analyzed by both objective evaluation and subjective evaluation. The results revealed that the proposed perceptual colour features outperformed the conventional colour histogram features both in terms of precision and consistency with users' perception.**

Keywords-emotional colour; colour features; affective features; emotion based image retrieval

I. INTRODUCTION

Due to the increasing of computer storage capacity and the massive amount of information including images, available on the Internet, image retrieval becomes one of research areas that is widely studies. Content based image retrieval (CBIR) is a type of image retrieval that is used to search for images based on low-level features. Colour is one of the popular features used in many CBIR systems, for example, in QBIC system (1995) [1], Photobook (1996) [2], VisualSeek (1996) [3], SIMPLIcity (2001) [4], the search engine in [5] (2010), etc. However, there are some limitations such as low-level features cannot capture high-level semantics of an image that users require. After a few years later, there are some progresses in this research area, for example, Colombo et al. [6] proposed a method of art painting image retrieval by using rules to transform low-level information, e.g. colour, to emotional semantic phrases. Wang and Yu [7] introduced an emotional semantic query model with image segmentation technique to describe image region with emotional semantic words. Hun-Woo Yoo [8] proposed a technique of image retrieval based on colour, grey tone, and texture features with user's feedback to generate emotional descriptors. Later, the more sophisticate techniques have been applied to emotion based image retrieval research area [9-17]. However, this research area is at the beginning stage. We still need more studies and investigations to get the more satisfying results. In this paper, we proposed a new set of colour features by utilizing the models representing relationship between colours and emotions. The models are adopted from the psychological studies which support the idea that colour information in an image is a visual media that can express feeling and emotional semantic to the viewers.

This paper is organized as follows. Section I provides brief introduction. Section II introduces some background of colour-emotion relationships. Section III explains details of the perceptual colour feature extraction. Section IV explains details of an application to emotion based image retrieval. Section V discusses experimental results. Finally, Section VI concludes this work.

II. COLOUR-EMOTION RELATIONSHIP

Colours and emotions have been studied for a long time [18-20]. Colour information can affect our perceptions and emotional reactions, and can influence our attitude. Several studies have provided evidence of relationships between colours and emotions. The term "colour emotion" refers to relationships between colour and viewer's emotional response. Colour emotions can be described as emotional feeling or emotional words such as warm, cool, soft, hard, etc. On the other hand, the term "emotional colour" refers to the colour that related with human emotional feeling. Ou et. al. had investigated the relationship between colour emotion and colour preference based on twenty emotional colours [18]. The emotional colours were selected from the NCS colour Atlas. The specification of the twenty emotional colours in $L^*a^*b^*$ and L^*C^*h colour models is summarized in Table I. Note that the $L^*a^*b^*$, L^*c^*h, are the common colour models used in colour image analysis relating to human perception. In this paper, we investigate the possible usage of the twenty emotional colours to construct image features called perceptual colour features to use in emotion based image retrieval applications.

III. PERCEPTUAL COLOUR FEATURES

This section describes our proposed features. The procedure of the perceptual colour feature extraction consists of the following steps:

1) *Colour Transformation*
   An input image is converted from RGB colour representation to CIE $L^*a^*b^*$ and L^*C^*h colour representation.

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2) *Emotional Colour Categorization*
Each pixel in the resultant image from Step 1) is labeled with an emotional colour number (by using colour number: 1, 2, ..., 20 in Table I) that has the least value of CIE delta E measurement, Eq. (3), [21]. The delta E is the difference between colour of a pixel in an image and an emotional colour, which is measured in the $L^*a^*b^*$ and L^*C^*h colour spaces.

3) *Emotional Colour Histogram Construction*
An emotional colour histogram of the resultant image obtained from Step 2) is constructed by counting the number of each of emotional colours existing in the image, Eq.(1), i.e., all pixels in the image are grouped into 20 bins of histogram.

$$h_i = \textit{Number of pixels labeled with } i \tag{1}$$

where i is an emotional colour number, i=1, 2, ..., 20.

4) *Histogram Normalization*
The emotional colour histogram in Step 3) is normalized with image size to generate a perceptual colour feature vector which consists of 20 elements: $\mathbf{V} = [v_i]$, where v_i is the feature value of the emotional colour i as defined by Eq.(2).

$$v_i = h_i / (\textit{image width} \times \textit{image height}) \tag{2}$$

The CIE delta E, which is used for comparing similarity of two colours in $L^*a^*b^*$ and L^*C^*h colour spaces, is defined in terms of the differences of lightness, chroma, and hue as shown in Eq.(3).

$$\Delta E((L_i^*, a_i^*, b_i^*, C_i^*, h_i), (L_j^*, a_j^*, b_j^*, C_j^*, h_j)) = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right) \right]^{0.5} \tag{3}$$

where $(L_i^*, a_i^*, b_i^*, C_i^*, h_i)$, $(L_j^*, a_j^*, b_j^*, C_j^*, h_j)$ are colour data of a pixel in the considered image and an emotional colour respectively, represented in the $L^*a^*b^*$ and L^*C^*h colour spaces. $\Delta H'$, $\Delta C'$, $\Delta L'$ are CIELAB colour difference values in terms of hue, chroma, and lightness respectively. K_L, K_C, and K_H are constants (usually are ones).

The differences of lightness (L^*), chroma (C^*), and hue (a^*, b^*, h) can be calculated by Eq.(4), Eq.(5) and Eq.(6) respectively, which involve many factors (see details in [21]).

$$\Delta L' = L_j^* - L_i^* \tag{4}$$

$$\Delta C' = C_j' - C_i' \tag{5}$$

$$\Delta H^* = 2\sqrt{C_i' C_j'} \sin(0.5\Delta h') \tag{6}$$

TABLE I. THE EMOTIONAL COLOURS SPECIFICATION

Colour No.	NCS notation	(L^*, a^*, b^*, C^*, h)
1	R-1080	(45.9, 61.7, 29.1, 68.2, 25)
2	Y-1070	(84.8, 6.3, 82.0, 82.3, 86)
3	G-2060	(61.4, -49.7, 17.8, 52.8, 160)
4	R90B-3050	(49.6, -8.9, -33.2, 34.4, 255)
5	R70B-3060	(38.0, 13.8, -42.0, 44.2, 288)
6	Y60R-5040	(42.2, 25.9, 26.5, 37.0, 46)
7	G80Y-4040	(58.3, -3.2, 40.3, 40.4, 94)
8	B50G-5040	(39.3, -28.2, -5.8, 28.8, 192)
9	R70B-5030	(41.4, 5.0, -24.3, 24.8, 282)
10	R-1020	(84.7, 17.1, 5.6, 18.0, 18)
11	Y-1030	(89.0, 1.6, 38.4, 39.4, 88)
12	B30G-1040	(78.4, -26.7, -10.9, 28.8, 202)
13	R60B-1040	(74.0, 11.3, -23.7, 26.3, 296)
14	G50Y-4020	(64.2, -8.2, 19.0, 20.7, 113)
15	B50G-5030	(47.1, -22.0, -5.7, 22.7, 195)
16	R50B-5020	(49.8, 10.8, -11.9, 16.1, 312)
17	N-9000	(15.7, 0.3, -1.5, 1.6, 282)
18	N-7000	(43.2, 0.3, 0.2, 0.4, 37)
19	N-3500	(72.1, 0.4, 0.6, 0.7, 58)
20	B-0502	(97.8, -2.1, 0.4, 2.1, 168)

IV. APPLICATION TO EMOTION BASED IMAGE RETRIEVAL

To show effectiveness of the proposed perceptual colour features, we have applied them to an application to emotion based image retrieval by query image as detailed in the following sub-sections.

A. Image Data

Image retrieval experiments are performed on natural scene images (size: 256×256 pixels) which are classified into two groups: *Data Set 1 for objective evaluation,* and *Data Set 2 for subjective evaluation.* The images have a variety of colour tones which can express different feelings to the viewers. Some image samples are shown in Figure 1. The details are as follows:

1) Data Set 1: Image Samples for Objective Evaluation
The image samples used for objective evaluation are natural scene images that can be roughly classified by colour tones as follows:

(i) *Similar-tone:* a group of images that only one tone of colour is dominated, for example, green, red, blue, etc.
(ii) *Mixed-tone*: a group of images that more than one tone of colour are dominated, for example, red-green, yellow-green, orange-green-blue, etc.

We use 120 similar-tone images and 250 mixed-tone images to generate a set of similar images for objective evaluation. Each image is used as original image to create one relevant image set by using the following digital image processing techniques:

(1) Enlarge image size
(2) Reduce image size
(3) Convert from BMP to GIF format
(4) Segment an original image at top-left position
(5) Segment an original image at top-right position
(6) Segment an original image at bottom-left position

(7) Segment an original image at bottom-right position
(8) Segment an original image at the center of the image.

Therefore, one original image will have eight similar images called a set of relevant images. For the images that some important cues or part of objects in the images are deleted due to the techniques used, those images are not used in the experiments. Consequently, we obtain 960 similar-tone images, and 400 mixed-tone images, totaling 1,360 images for objective evaluation. Every image is used as a query image. Note that the case of perfect retrieval means all of eight relevant images are appeared as the top eight retrieval results.

2) Data Set 2: Image Samples for Subjective Evaluation

For subjective evaluation, we perform experiments on 2,000 natural images, and 110 images are used as query images. All images have size of 256 × 256 pixels. There are two scenarios of query images. Examples are shown in Figure 2.

Scenario-1: the same query image set is used for all participants to query the system.
Scenario-2: the different query image set is used for each participant to query the system.

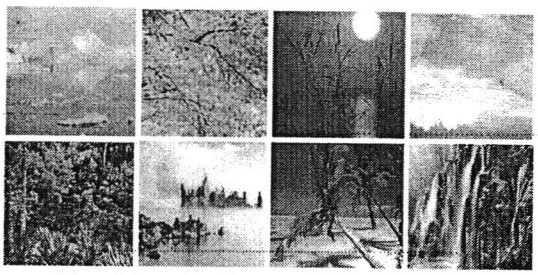
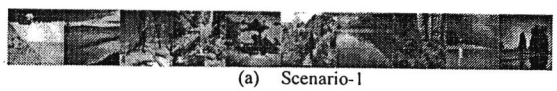
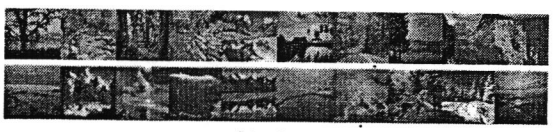


Figure1. Examples of images used in our experiments.



(a) Scenario-1



(b) Scenario-2

Figure 2. Example of Images Used to Query the System for Subjective Evaluation.

B. *Image Similarity Measure*

The similarity between the query image and each image in the database is computed. The retrieval image results are showed and ranked by similarity values in descending order. We have investigated on a number of similarity measures such as cosine similarity, Euclidean distance, histogram intersection distance, and quadratic distance. We found that the most effective one is the histogram intersection distance. It is defined by Eq. (7).

$$D_{\text{Intersection}}(Q,D) = 1 - \frac{\sum_{i=1}^{20} \min(C_Q[i], C_D[i])}{\min\left[\sum_{i=1}^{20} C_Q[i], \sum_{i=1}^{20} C_D[i]\right]} \quad (7)$$

where C_Q is the perceptual colour features of a query image (Q), and C_D is the perceptual colour features of an image in the database (D), i is an emotional colour number. The features are computed as explained in Section III.

C. *Evaluation*

We have used both subjective and objective methods to evaluate performance of the proposed features with an image retrieval application. An objective evaluation is rather difficult, however, we have adopted image processing techniques to generate a set of appropriate image samples for testing as detailed below.

(1) Objective Evaluation

Data Set 1 is used for objective evaluation. All 1,360 images are used to query the system. The retrieval performance is measured by using the average precision value of all query images. For each query image j, the precision (P_j) of the top eight retrieval results is calculated by Eq.(8).

$$P_j = N_j * 100 / 8 \quad (8)$$

where N_j is number of correct retrieval images (the relevant images of the query image j as explained in Section IV-A) from rank #1 to #8.

(2) Subjective Evaluation

Data Set 2 is used for subjective evaluation. There are 2,000 images stored in our database. Query images are arranged into two scenarios. *Scenario-1*: A set of ten query images is used by all ten participants. *Scenario-2*: ten different sets of ten query images are used by ten participants. There are totally 110 query images used in this experiment. The participants considered on the top ten image retrieval results, and then assessed the consistency scores between a query image and retrieval result images by using five levels of consistency score (5=Very good, 4=Good, 3=Average, 2=Minimal, and 1=Poor). The participants assessed the consistency of the retrieval results two times.

(i) At the first time, the participants assessed retrieval results by considering each of the retrieval images comparing with the query image, one by one image.
(ii) At the second time, the participants assessed retrieval results by considering overall top ten retrieval images comparing with a query image one

at a time.

The average consistency scores are calculated from the consistency scores obtained from all participants.

V. Results and Discussions

This section show results from objective evaluation and subjective evaluation with some discussions.

A. Objective Evaluation Results

The objective evaluation is performed by using precision as explained in Section IV. The average precision rate of retrieval results by using the proposed perceptual colour features were remarkably higher than those of the conventional colour histogram features both for similar-tones and mixed-tone images as summarized in Table II. Examples of retrieval results are shown in Figure 3 and Figure 4 for the proposed perceptual colour features and the conventional colour histogram features respectively. The proposed features can retrieve 7 correct images (#1 to #7) from 8 relevant images vs. 5 correct retrieval images by using the conventional features. Even there are some irrelevant retrieval results from the proposed method, for example, image rank #8 in Figure 3, but it looks much more similar to the query image than the three irrelevant retrieval results from the conventional method, (see image rank #5, #7, #8 in Figure 4). These results clearly demonstrate effectiveness of the proposed features.

B. Subjective Evaluation Results

For subjective evaluation by using *Data Set 2* (see Section IV), we obtained the average consistency scores of top ten image retrieval results as summarized in Table III for *Scenario-1*: using the same set of query images for all participants, and Table IV for *Scenario-2*: using the different query images for each of the participants. The average consistency scores of the proposed method were at a good level, more than 4 out of 5 points, while the average consistency scores of the conventional method were at a lower level, less than 4 out of 5 points. In addition, we can see that the average consistency scores from the consideration overall image retrieval results are higher than those of the consideration retrieval results image by image.

C. Retrieval Image Results

Examples of retrieval image results from the proposed method and the conventional method are shown in Figure 5 and Figure 6 respectively. It apparently shows that the proposed method can give the retrieval results that more agree with our visual perception than the ones from the conventional method. The top six retrieval results in Figure 5, in particular the retrieval image #4, 5, 6 look more similar to the query image than the ones in Figure 6. The average consistency scores of the top six retrieval results in Figure 5 vs. Figure 6 are significantly different, 4.10 vs. 3.73. Moreover, two scenarios of experiments give the same approximate value of average consistency scores (4.16 vs. 4.08) even though in the *Scenario-2*, we used the different query image set for each of participants. The experimental results indicated that the proposed perceptual colour features have robustness with query images of natural scenes to some degree.

TABLE II. Retrieval Results from Objective Evaluation

Method	Precision of retrieval result		
	Similar-tone	Mixed-tone	Average
Proposed method (using perceptual colour features)	78%	99%	88.5%
Conventional method using colour histogram	77%	96%	86.5%

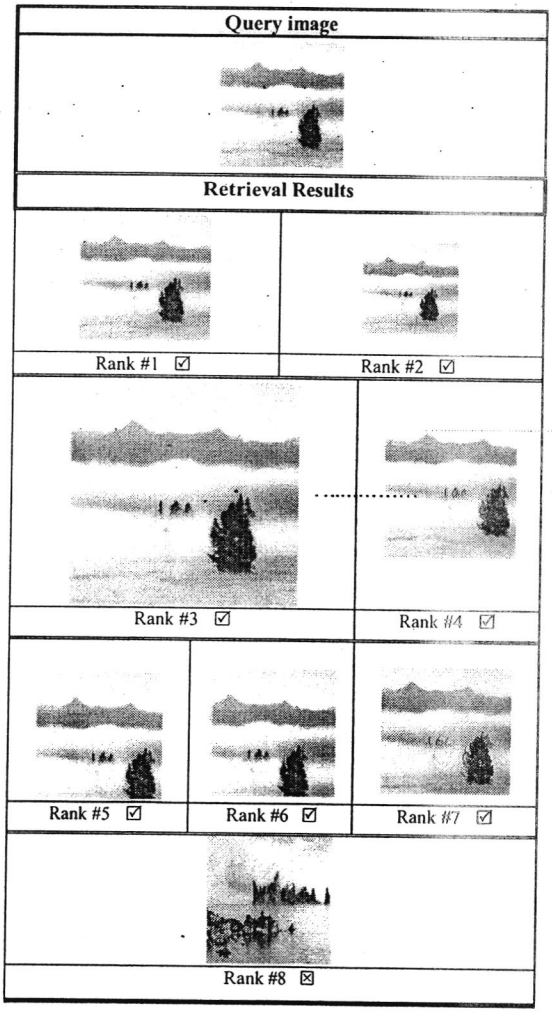


Figure 3. Example of Top Eight Image Retrieval Results from Data Set I by Using the Proposed Perceptual Colour Features

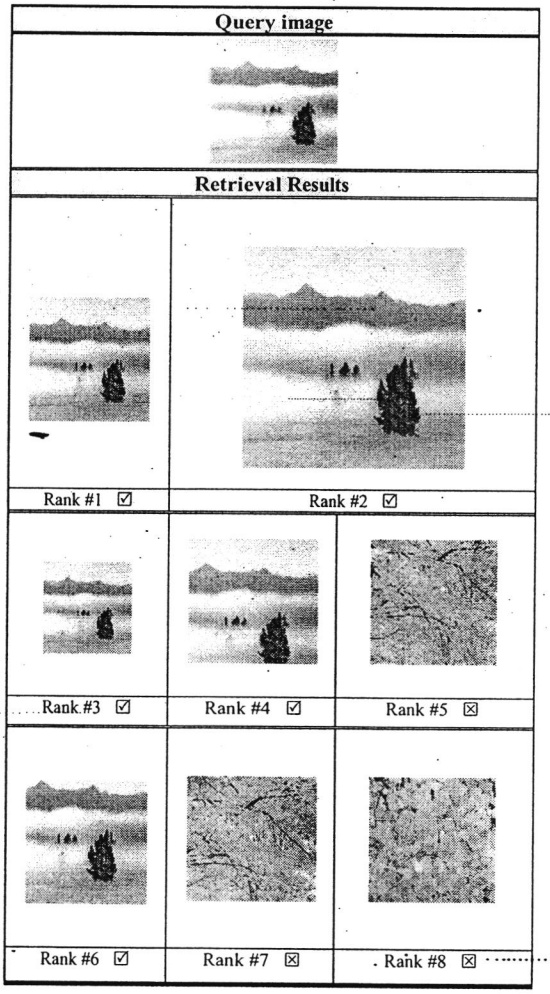


Figure 4. Example of Top Eight Image Retrieval Results from Data Set I by Using the HSI Colour Histogram Features.

TABLE III. RETRIEVAL RESULTS FROM SUBJECTIVE EVALUATION BY USING SENARIO-1 QUERY IMAGES.

Method	Average consistency score		
	Image by image	Overall	Average
Proposed method (using perceptual colour features)	4.09	4.22	4.16
Conventional method using colour histogram	3.87	3.98	3.93

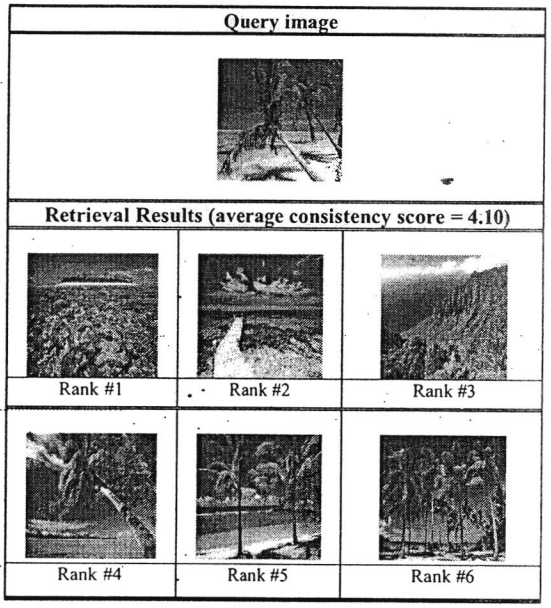


Figure 5. Example of Top Six Retrieval Results from Data Set 2 by Query Image Using the Proposed Perceptual Colour Features.

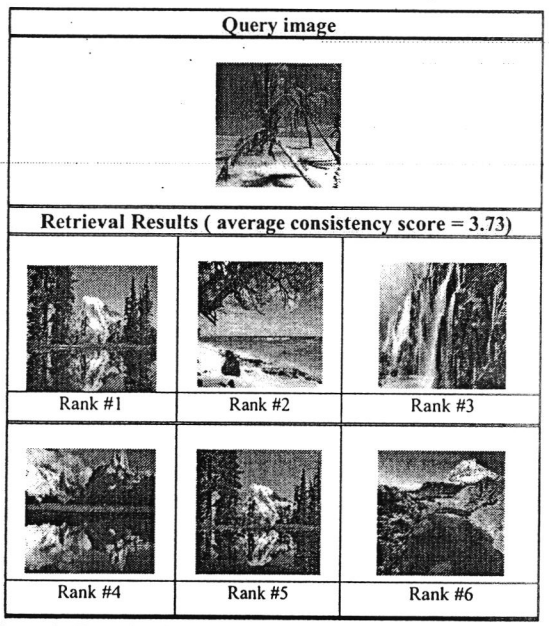


Figure 6. Example of Top Six Retrieval Results From Data Set 2 by Query Image Using the HSI Colour Histogram Features.

TABLE IV. RETRIEVAL RESULTS FROM SUBJECTIVE EVALUATION BY USING SENARIO-2 QUERY IMAGES.

Method	Average consistency score		
	Image by image	Overall	Average
Proposed method (using perceptual colour features)	4.04	4.11	4.08
Conventional method using colour histogram	3.78	3.95	3.87

VI. CONCLUSIONS

In this paper, we have proposed the perceptual colour features derived from the emotional colour of colour-emotion models. We had demonstrated their usefulness with an application to emotion based image retrieval on natural scene image domain. Results were evaluated by both objective and subjective evaluation methods. For objective evaluation, experiments were performed on 1,360 natural scene images. The average precision rate of the proposed method was 88.5% which was higher than that of the conventional method, 86.5%. In addition, even there were some irrelevant image retrieval results from the proposed method, but such images looked much more similar to the query image than the results from the conventional method.

For subjective evaluation, experiments were performed on 2,000 natural scene images with two scenarios of query images. The top ten image retrieval results were assessed by ten participants. The higher average consistency scores were obtained: 4.16 vs. 3.93 points out of 5 points for *Scenario-1* (using the same set of query images for all participants), and 4.08 vs. 3.87 points out of 5 points for *Scenario-2* (using different set of query images for each of participants) from the proposed method vs. the conventional method.

The results indicate that the proposed method performed significantly better than the conventional method, and yield the retrieval image results that are consistent with users' visual perception at a higher level.

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