Non-linearly weighted fuzzy correlation for color-image retrieval

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An algorithm with non-linear weight factors in the summation process for fuzzy correlation of color histograms is presented, in which non-linear weights are assigned to some characteristic colors of interest. Experimental results show that this can improve the retrieval of color images with partial aberrations or with local color characters.

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Content-based image retrieval (CBIR) is a major topic of research for the last few years[1], of which color-based image retrieval is one of the most fundamental methods. For color histograms are invariant in size and orientation of images, color-based retrievals by means of color histograms are popularly employed in the retrieval of color images[2,3]. As an approximate treatment of CBIR, fuzzy correlation[4] of histograms can meet the criterion of human vision better than the conventional pure calculations of characteristic parameters matching.

In this paper, non-linear weights are introduced to the summation process of the fuzzy correlation[4], with which different terms have different contributions to the final summation result. Our experimental results show that the proposed algorithm can be employed to carry out an effective retrieval of color-images with partial color aberrations or with local color characters.

A color image can be described by a color histogram, of which the peak position in horizontal coordinate and the peak height in vertical coordinate express the pixel numbers (or the area proportion in a normalized histogram and the color in the color vector space) of the image, respectively[5]. Therefore, two normalized histograms can be considered respectively as two transformations of two color images, and the peak value of their correlation can be used to measure the similarity between the color contents of the two color images[4].

Analysis and experiments show that, except for the artificially designed patterns, the more complicated the color constructions of two nature images are, the stronger the correlation between the color contents and their color constructions of them. Therefore, as criteria, histograms can be employed to retrieve color images, with a very high correction rate[4−8].

In the fuzzy correlation[4], the color match of two color vectors respectively in the two histograms, $\vec{c}_i(r_i, g_i, b_i)$ and $\vec{c}_j(r_j, g_j, b_j)$, can be expressed as

$$\mu_{\widetilde{R}}(\vec{c}_i, \vec{c}_j) = \mathrm{e}^{-[(r_j-r_i)^2+(g_j-g_i)^2+(b_j-b_i)^2]}, \tag{1}$$

and the defuzzification of it is

$$\mu_{\widetilde{R}_{\alpha_1}}(\vec{c}_i, \vec{c}_j) = \begin{cases} 1, & \mu_{\widetilde{R}}(\vec{c}_i, \vec{c}_j) \geq \alpha_1 \\ 0, & \text{others} \end{cases} . \tag{2}$$

The match of their height, h_i and h_j, will be

$$\mu_{\widetilde{S}}(h_i, h_j) = \min(h_i, h_j)/\max(h_i, h_j), \tag{3}$$

of which the defuzzification is

$$\mu_{\widetilde{S}_{\alpha_2}}(h_i, h_j) = \begin{cases} 1, & \mu_{\widetilde{S}}(h_i, h_j) \geq \alpha_2 \\ 0, & \text{others} \end{cases} . \tag{4}$$

We introduce weight factors H_i into the summation process in the fuzzy correlation, in which special weights are assigned to the characteristic colors, as follows

$$R_h = \sum_{i,j=1}^{M} H_i \mu_{\widetilde{S}_{\alpha_2}}(h_i, h_j), \tag{5}$$

where M is the number of the character colors, and R_h is the peak correlation value of the two histograms. The weight H_i can be obtained by

$$H_i = \beta_i h_i, \tag{6}$$

where $\beta_i = 1$, for a linear weight algorithm, which means that the weight be the area proportion, and $\beta_i = 0 - \infty$, for a non-linear weight algorithm, which means that the weight be selected arbitrarily, and usually $\beta_i \neq \beta_j$ $(i \neq j)$, depending upon the character of the image and the propose of the retrieval.

After defuzzification of the Eq. (5), the peak value of the correlation result will be

$$R_h = \begin{cases} 1, & R_h \geq \alpha_3 \\ 0, & \text{others} \end{cases} , \tag{7}$$

where α_3 works as a defuzzification threshold value of the fuzzy correlation, with $R_h = 1$ for correlated or $R_h = 0$ for non-correlated histograms or images.

In the experiment, 900 pieces of color images are downloaded from a professional image web site, with which a data base is constructed for sampling, in which one of the images can be randomly selected as a query image for retrieving correlated images from the others as index images in the database.

During the non-linear weight algorithm of the fuzzy correlation, it is possible to carry out retrieval of images with partial color aberrations or local color characters by assigning some lower or higher weights to the correspondent term.

For example, Fig. 1(a) is a query image with local color character, namely four blocks with red (top left), green (top right), blue (bottom left) and yellow (bottom right) colors in the centre of the image, as shown in Fig. 1(b). Figures 1(c) and (d) are the correspondent histograms of Fig. 1(a), expressed respectively with 256 and 16 character colors. To retrieve images with above local color characters in the experiment, histogram in Fig. 1(d) with less character color is preferred for less time consuming, and the related smaller peaks 7, 8, 9 and 10 in Fig. 1(d) for red, green, blue, and yellow are signed to $\beta_i = 1$ and the others $\beta_i = 0$.

The retrieved images with above local color characters, as shown in Fig. 1, are given in Fig. 2. It can be seen that only the images with the same local color characters at the same proportion of area can be retrieved, and when the value of α_1 increases, which controls the precision of the color comparision, the color character of the retrieved image will be more identifiable.

Different from the screening algorithm[6] or linearly weighted correlation algorithm[4], this algorithm introduces selected non-linear weights to the summation process, which offers a possibility to concentrate the retrieval on the interesting color characters, regardless of their color proportion in the image.

In conclusion, we proposed a non-linear weight algorithm in the summation process of the fuzzy correlation calculation of color histograms for color-image retrieval. In this non-linear weight algorithm, each term in the summation can be assigned to a different weight value, which makes it possible for each character color to have different contribution to the summation process. Experimental results show that, by correspondently controlling the three difuzzication parameters α_1, α_2 and α_3, and the number of character colors M in this non-linear weight algorithm, retrievals of images with local color characters can be achieved. The result presented here is only a prime study, and further work has to be carried out, including an adaptive selection of all the parameters in the training process for different characteristic retrievals.

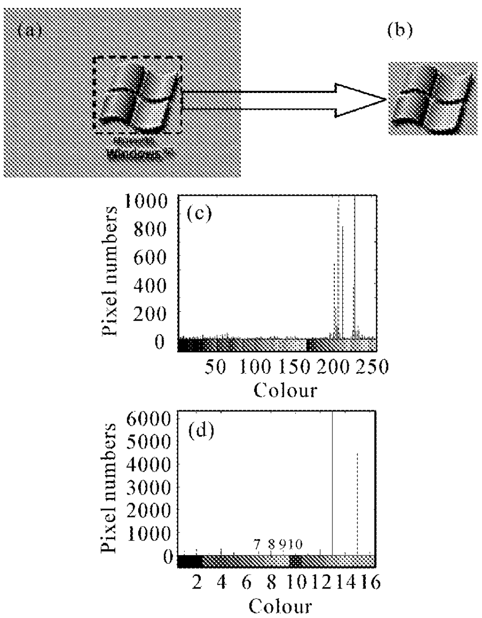

Fig. 1. Image with local color characters and its histograms. (a) Query image[9]; (b) local color character; (c) histogram of the query image expressed with 256 character colors; (d) histogram of the query image expressed with 16 character colors.

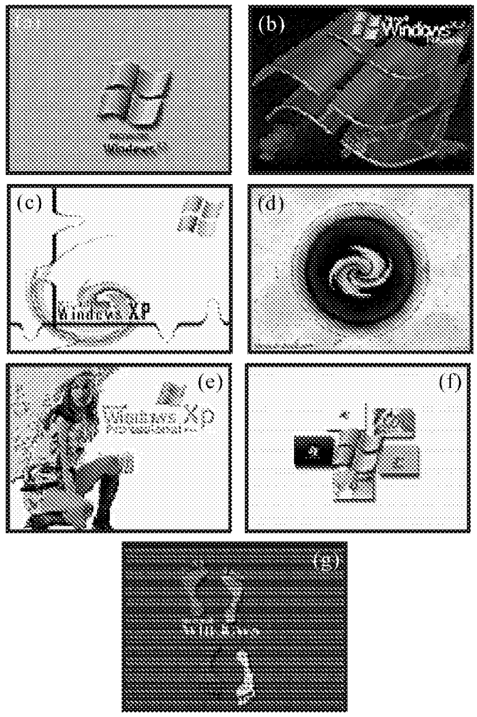

Fig. 2. Retrieval results by the non-linear weight algorithm[9] (M=16, α_2=0.95, α_3=0.9). (a) Retrieved image by α_1=0.97; (a)-(c) retrieved image by α_1 = 0.96; (a)-(g) retrieved image by α_1=0.95.

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References

1. A. Bimbo, *Visual Information Retrieval* (Morgan Kaufmann Inc., San Francisco, 1999).
2. M. J. Swain and D. H. Ballard, Internet J. Comput. Vision **7,** 11 (1991).
3. B. M. Mehtre, M. S. Kankanhalli, and A. D. Narasimhalu, Pattern Recognition Lett. **16,** 325 (1995).
4. Y. M. Liang, H. C. Zhai, and G. G. Mu, Science in China **33,** 8 (2003).
5. T. Syeda-Mahmood and D. Petkovic, Signal Processing: Image Communication **16,** 15 (2000).
6. Y. M. Liang, H. C. Zhai, and P. Chaval, Opt. Comm. **212,** 247 (2002).
7. H. C. Zhai, Y. M. Liang, and G. G. Mu, in *Proceedings of Optics for the Quality of Life* A. Consortini and G. C. Righini, ed. (SPIE, Bellingham, Washington, USA, 2002) p. 1049.
8. H. C. Zhai, Y. M. Liang, and G. G. Mu, Chin. Phys. **51,** 2671 (2002).
9. http://crc.deskcar.com.