Image retrieval based on fuzzy color histogram

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Abstract

Due to its simple, low computation complexity and invariant to geometric transform, color feature is widely used in Content-based image retrieval (CBIR). In this paper, a new fuzzy method of color histogram is proposed based on the Lab color space, which links the three histograms created by the three components of the color space and provides a histogram which contains only ten bins. The experimental results prove that the proposed method is more accurate and robust than other methods of histogram.

Keywords: *Image retrieval; Fuzzy systems; Color histograms*

1. Introduction

Nowadays and in the days to come, a large number of applications, including military, industrial and civilian generate, and will continue to generate, even more gigabytes of color images per day. As a result, there is a huge amount of information which cannot be accessed or made use of unless it is organized. The CBIR has been the hot research under this situation.

The extraction of meaningful features is critical in CBIR and therefore an open and active field of research. Among the methods that utilize color as a retrieval feature, the most popular one is probably that of color histograms[1]~[3]. The classic histogram is a global statistical feature, which describes the intensity distribution for a given image. Its main advantage is that it is fast to manipulate, store and compare and insensitive to rotation and scale. On the other hand, it is also quite unreliable as it is sensitive to even small changes in the scene of the image. A histogram is created by firstly dividing a color space into a number of bins and then by counting the number of pixels of the image that belongs to each bin. It is usually thought that in order for an image retrieval system to perform satisfyingly, the number of regions that the color space is divided into is quite large and thus the colors represented by neighboring regions have relatively small differences. As a result, the ‘‘perceptually similar colors’’ problem appears , ergo, images which are similar to each other but have small differences in scene or contain noise will produce histograms with dissimilar adjacent bins and vice versa due to the small distance that the regions are separated from each other[4].

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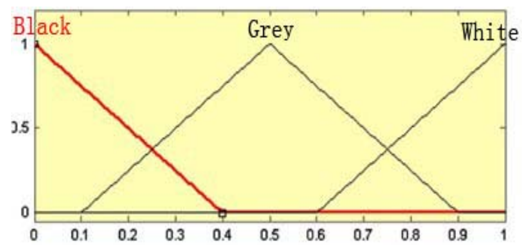
In order to present a solution to this problem, the method proposed uses a small number of bins produced by linking the triplet from the L*a*b* color space into a single histogram by means of a fuzzy expert system. The Mathworks_ Matlab fuzzy logic toolbox was used to assess a Mamdani style inference system and hence the fuzzy color histogram creation system in hand. The main reason why fuzzy logic [5] was selected is that since it was first introduced by Zadeh in 1965 it has proven effective in many applications such as automatic control and image understanding due to its flexibility and tolerance to imprecise data.

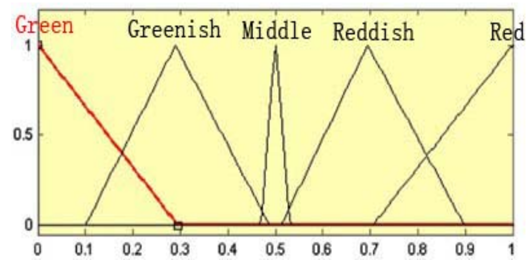
2. The fuzzy linking histogram creation method

One of the reasons why the L*a*b* color space was selected is that it is a perceptually uniform color space which approximates the way that humans perceive color. However, the main reason is that was found to perform better than other color spaces in various retrieval tests performed in the laboratory for this exact purpose [6]. In L*a*b*, L* stands for luminance, a* represents relative greenness-redness and b* represents relative blueness-yellowness. All colors and grey levels can be expressed throughout a combination of the three components.

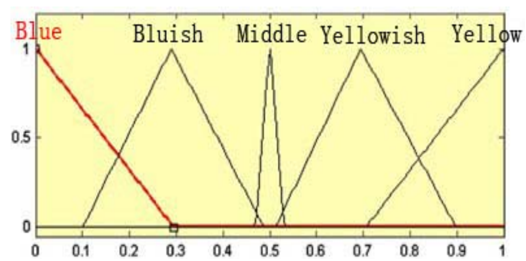
After a large number of tests performed on the regions of the L*a*b* color space, we reached to the conclusion that in order for the CBIR system to work effectively the a* and b* components should be subdivided into five regions representing green, greenish, the middle of the component, reddish and red for a*, blue, bluish, the middle of the component, yellowish and yellow for b*, whereas L* should be subdivided into only three regions: dark dim and bright areas. The fuzzification of the input is accomplished by using triangular shaped built-in membership functions (MF) for the three input components (L*, a*, b*) which represent the regions as shown in Fig. 1. The reason for which the middle MF exists both in a* and b*, is that in order to represent black, grey and white as seen in L*, then a* and b* must be very close to the middle of their regions; this is a well known fact about the L*a*b* space.



(a) input variable "L*"



(b) input variable "a*"



(c) input variable "b*"

Fig. 1. Membership functions of L*, a* and b*

The Mamdani type of fuzzy inference is used in which the fuzzy sets from the output MFs of each rule are combined through the aggregation operator which is set to max and the resulting fuzzy set is defuzzified to produce the output of the system. The implication factor which determines the process of shaping the fuzzy set in the output MFs based on the results of the input MFs is set to min and the OR and AND operators are set to max and min, respectively. The output of the system has only 10 equally divided MFs, as shown in Fig. 2. So, the final fuzzy histogram consists of only 10 bins approximately representing black, dark grey, red, brown, yellow, green, blue, cyan, magenta and white. The defuzzification phase is performed using the lom (largest of maximum) method along with the 10 trapezoidal MFs, thus producing 2500 clustered bin values (50×50) which lead to the 10 bin final fuzzy histogram.

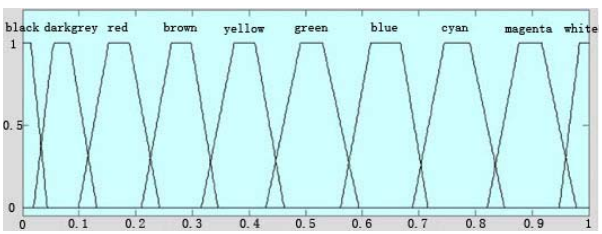


Fig. 2. Membership functions of the output of the fuzzy system

In Figs. 3 and 4, three query images and the respective resulting fuzzy histograms are presented. The histograms in the proposed scheme, though apparently rough, have proved to be an efficient tool for accurate image retrieval.

Fig. 3. Query image

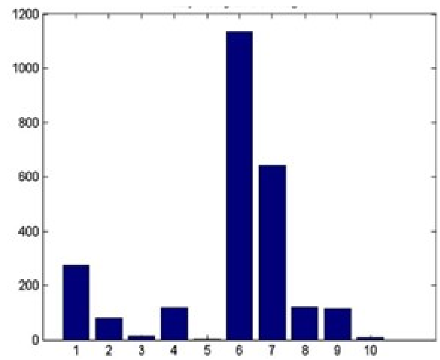


Fig. 4. fuzzy linked histogram

3. Experimental results

The proposed method of histogram creation was compared with Liang's et al, Swain's and Ballard's , Tico's et al and the straightforward histogram creation method. Their performance was compared through the color based retrieval of some query images from a collection of 1000 images. The range of topics present in the image database is quite wide and varies from several different landscapes to sports, concerts and other computer graphics which usually confuse image retrieval systems.

The similarity metric used is that of histogram intersection, introduced by Swain and Ballard[7] and which is very robust in respect to changes in image resolution, histogram size, occlusion, depth, and viewing point. The similarity ratio which belongs to the interval [0,1] can be expressed through the following equation:

$$H(H_Q,H_C)=\frac{\sum_{i=1}^{N}\min(H_Q,H_C)}{\min(\sum_{i=1}^{N}H_Q(i),\sum_{i=1}^{N}H_C(i))} \quad (1)$$

H_Q and H_C are the query and challenging histograms, respectively, and N is the number of bins. Despite the fact that their paper was published in 1991, Histogram Intersection still remains one of the best methods for comparing histograms in image retrieval applications.

The measure of the performance of the system is precision and recall. Precision is the proportion of relevant images retrieved R (similar to the query image)in respect to the total retrieved A, whereas recall is the proportion of similar images retrieved in respect to the similar images that exist. They can be expressed through the following equations:

$$Precision = (A \cap R)/A \quad (2)$$

$$Recall= (A \cap R)/R \quad (3)$$

We select three query images and every query session produces 20 images ranked in similarity according to the value produced by the metric. The retrieval performance measurement used in order to compare these five methods is the filtering performance percentage, which is the percentage of similar images produced in the 20 first most similar images retrieved by the system. On Table 1, one can see a synopsis of the comparisons of the five methods' performances for the three different image sets described above and notice the significant advantage which the proposed method holds above the rest.

Table 1 precision performance

Image set	Swain and Ballard	Classic L*a*b* histogram	Tico (HSI)	Liang (HSI)	Fuzzy linking (L*a*b*)
1	80%	75%	75%	90%	95%
2	70%	75%	70%	67%	85%
3	90%	90%	75%	80%	95%
Time (s)	511.8	226.95	303.52	318.99	525.54

Precision and recall are used together in graphs in order to point out the change of the precision in respect to recall. In most typical systems, the precision drops as recall increases, thus an image retrieval system is said to be effective if the precision values are higher at the same recall ones, which is the case in the proposed method.

4. Conclusions

A new histogram creation method has been proposed. The histogram is created based on the L*a*b* color space components which are considered to be fuzzy sets. The proposed histogram is acquired through the linking of these fuzzy sets according to some fuzzy rules. Very few bins are used to describe the color distribution of the image resulting in much faster comparison between the histograms and greater robustness of the algorithm. The method in hand was compared to other histogram creation methods proving to be much more accurate and robust through several image retrieval tests.

5. References

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