International Journal of Computer Applications (0975 – 8887)
Volume 126 – No.5, September 2015

Content-based Image Retrieval using Conflation of Wavelet Transformation and CIECAM02 Color Histogram

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ABSTRACT
In this paper, a novel image retrieval technique based on the combination of Haar wavelet transformation and CIECAM02 color histogram (CH) have been proposed. In color based image retrieval, color histogram is one of the most repeatedly used image features and it is used at a great extent in content-based image retrieval (CBIR) systems as a significant color feature. The color histogram unchanged by translation and rotation. The local characteristics and texture features of an image are extracted by wavelet transformation. On conflation of wavelet transformation and color histogram new algorithm has been proposed. One may select a query image perceived to be similar to the visualized target image. A set of images similar to the query is then returned from the database. The final experimental results show that the proposed technique gives better performance than the other schemes, in terms of retrieval time.

General Terms
Image retrieval, color extraction methods and texture extraction methods.

Keywords
Color Histogram, Haar wavelet Transformation, Content-based image retrieval (CBIR), Color histogram, CIECAM02.

1. INTRODUCTION
The research on CBIR has gained remarkable drive both in frequency and spatial domains. The massive growth of digital image on Web is making it compulsory to develop efficient tools for retrieving this unconstrained imagery. Ancient CBIR systems are dependent on pre-defined image-to-image similarity measures. These types of computer-centric systems were easy to implement at the cost of inadequate performance [1]. Since 1990's a large number of methods are being purposed to overcome the drawbacks and enhance the performance in indexing, matching and retrieving the information from multimedia. The term CBIR was used by T.kato [1] [2] for the first time to describe the function of automatic retrieval of images basis on shapes and colors from a database. CBIR has been broadly used to discuss the process of retrieving relevant images from a large collection on the basis of image features. Image features can be automatically extracted from the images themselves, typically color, texture, and shape are the image features [1]. Only two types of features can be used for retrieval of images primitive or semantic but the extraction process must be substantially automatic. The noticeable step in CBIR is feature extraction technique because of its effectiveness. The resultant features of an image mainly depends upon the method used for extracting features for given images. The CBIR utilizes primitive features of an image such as shape, color, spatial layout texture etc., [3-7] to index and represent the image database. Color, texture and shape are not enough to represent an image semantically, so there has been novelty in semantic based image retrieval and it is still an open-ended problem. CBIR is one of the most significant, powerful and effectual image retrieval methods used in different applications such as medical diagnosis, remote sensing systems, military, geographical information, crime prevention, architectural engineering and face recognition.

The color feature is a considerable attribute of image retrieval, because of its simple and hasty computation. In image retrieval and matching algorithms color feature plays a significant role. The theory of digital image representation and method used for extraction of color feature gives color feature set of an image. Among the color feature extraction algorithms color histogram (CH) is one of the most frequently used color feature algorithm, this was proposed by Swain and Ballard [1] [8], to use the CH for retrieval. CH has low complexity of computation and it will not change on translation and rotation, as well as robust to scaling and occlusions [2] [9]. Two images can have similar color distribution but may look alike in the visual sense. The general idea behind using CH is to divide an image into sub-areas and calculate a histogram for each of these sub-areas. Increasing the number of sub-areas leads to increase the usage of memory and computational time. These problems will become worse for very large databases.

The texture is another influential primitive feature for image retrieval applications. Texture analysis and classification have been extensively used in pattern recognition and image segmentation, due to its powerful techniques in extracting the features [2]. A lot of potential research has been done in the last four decades. Many algorithms have been introduced the concept of wavelet and proposed different techniques for extracting texture features efficiently.

In this paper, CIECAM02 color histogram for extracting color features and haar wavelets for texture extraction have been used. The typical architecture of CBIR is as shown in figure1.

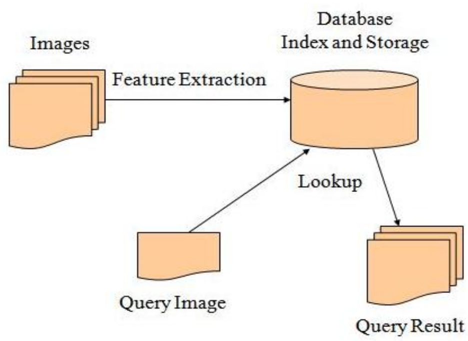

Fig.1: CBIR architecture

The organization of the paper is as follows: Section 2 describes texture feature concepts, Section 3 presents the CIECAM02 color histogram and the Section 4 describes the feature similarity matching using histogram intersection distance proposed by Swain and Ballard [1]. The proposed methods for color and texture features are described in Section 5 and finally the conclusion and future work is stated in Section 6.

2. TEXTURE EXTRACTION USING HAAR WAVELET

The main goal of using Haar wavelet is to achieve space frequency localization. Wavelet is a small wave which is used to analyze wavelet transformation [10-11]. It is a tool used for decomposition of an image and to compute frequency domain by using the spatial domain of an image. The spatial function *f(x)* is defined as

$$f(x) = \sum_k \alpha_k \phi_k(x) \qquad (1)$$

α_k : real-valued expansion coefficients

$\phi_k(x)$: real-valued expansion functions

This function can understand very clearly by scale and shifted versions of spatial function [15-16]. Scaling function is defined as

$$\phi_{j,k}(x) = 2^{j/2}\phi(2^j x - k), \quad \text{for } k \in \mathbf{Z} \text{ and } \phi(x) \in L^2(\mathbf{R}) \qquad (2)$$

Wavelet transformations are the fastest and simplest to compute image features. Haar wavelets allow speeding up the wavelet computation phase for thousands of sliding windows of varying sizes in an image, and also helping the development of efficient incremental algorithms for computing wavelet transforms for larger windows in terms of the one for smaller windows. The wavelet function is defined as follows

$$\Psi_{j,k}(x) = 2^{j/2}\Psi(2^j x - k) \qquad (3)$$

By using equation 2 and equation 3 wavelet series expansion is defined as

$$f(x) = \sum_k c_{j_0}(k)\phi_{j_0,k}(x) + \sum_{j=j_0}^{\infty}\sum_k d_j(k)\psi_{j,k}(x)$$

Where j_0 is an arbitrary starting scale

$$c_{j_0}(k) = \left\langle f(x), \tilde{\phi}_{j_0,k}(x) \right\rangle = \int f(x)\tilde{\phi}_{j_0,k}(x)dx$$

Called the scaling or approximation coefficients

$$d_j(k) = \left\langle f(x), \tilde{\psi}_{j,k}(x) \right\rangle = \int f(x)\tilde{\psi}_{j,k}(x)dx$$

Called the wavelet or detail coefficients

Fast Wavelet Transform (FWT) is computationally fruitful implementation of the Discrete Wavelet Transform (DWT). FWT is developed by Mallat's [1], it can broadly explained with analysis filter and synthesis filter bank [12-14] as shown in below figures Fig.2 and Fig.3 represent the analysis filter bank and synthesis filter bank respectively.

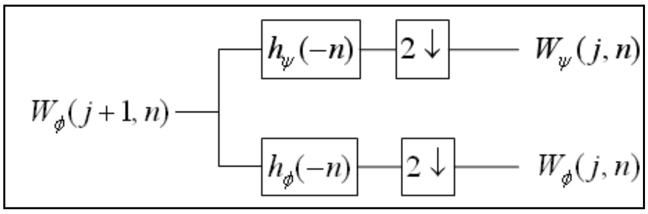

Fig.2: An FWT analysis filter bank.

Figure 2 shows the block diagram of decomposition of an image into one dimension. Discrete set of samples of an image is analyzed into high frequency and low frequency sets and then down sampled by factor of 2

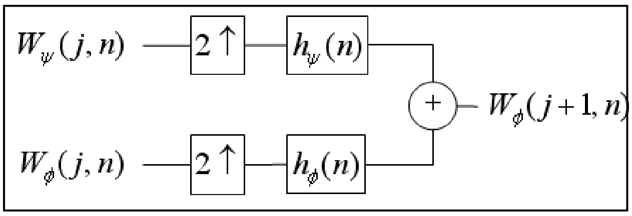

Fig.3: An FWT^{-1} synthesis filter bank.

Figure 3 is a mirror of FWT analysis filter bank. In particular the image is represented in two dimensions. So in this work two dimensional analysis filters using digital filters and down samplers have been applied [15]. The block diagram in Fig.4 represents 2D FWT. It gives the horizontal, vertical, diagonal coefficients of particular image that has been applied.

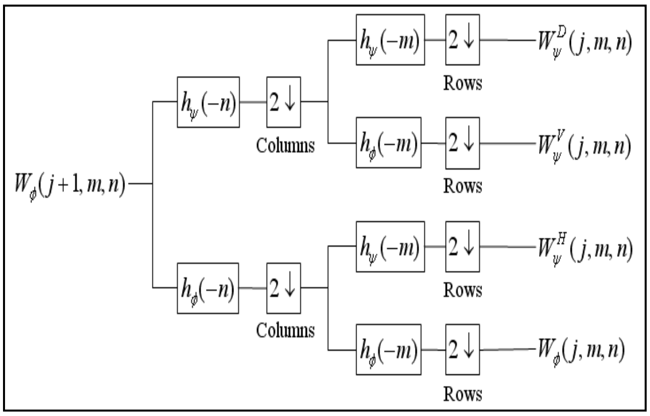

Fig.4: The two-dimensional FWT — the analysis filter.

The block diagram in Fig.5 depicts image decomposition using wavelet transformation. Two-level decomposition is explained in the following image followed by first level decomposition.

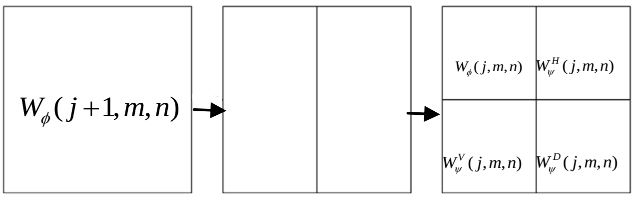

Fig 5: A two-level decomposition of the two dimensional FWT

The Block diagram in Fig.6 shows the two level decomposition of the two dimensional FWT by using an image

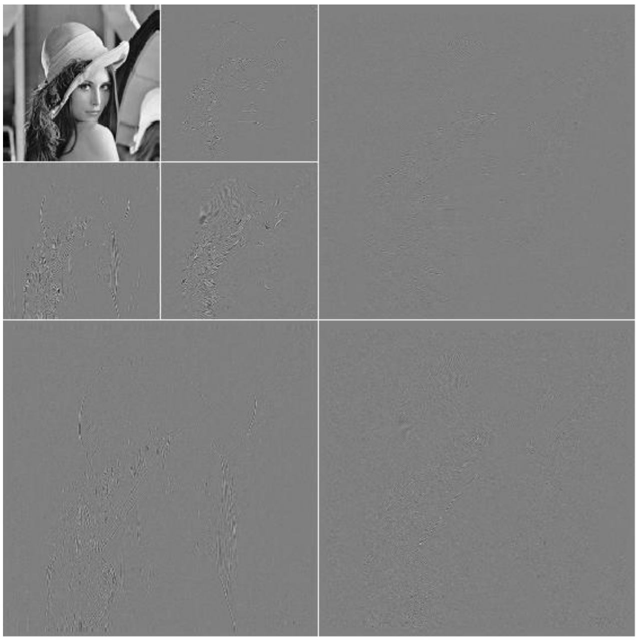

Fig 6: A two-level decomposition of the two dimensional FWT

3. COLOR FEATURE EXTRACTION USING CIECAM02

Color is the most repeatedly used primitive feature among color, shape, texture and layout features in CBIR because of it is invariant and robust nature with respect to orientation and image size. It changes slowly under change in scale, angle of view, rotation and depends on lightning condition [16] so it needs an effectual method for a color feature retrieval system. A color space must be intended before selecting a suitable color description. Frequently used color space are RGB, CIE L*a*b*, CIE L*u*v*, HSV, CIECAM02 and so on [1] [17]. Most of the defined color spaces are failing to retrieve desired images on different viewing conditions so powerful color space that can be invariant to viewing conditions [18-20] has to be required. CIECAM02 is a color appearance model competent of predicting color appearance under a vast range of viewing conditions for image applications recommended by CIE. Six technically defined dimensions of CIECAM02 model transforms the tri stimulus values of a stimulus under a specific set of viewing conditions to visual percepts [21]: colorfulness (*M*), brightness (*Q*), chroma (*C*), lightness (*J*), hue composition (*H*) and saturation (*s*). Brightness is the attribute of visual perception according to value of chromatic content in an area. Lightness is the brightness of an area illuminated reference white. Colorfulness is same as brightness but it deals with visual sensation. Colorfulness of an area illuminated reference white is chroma. Saturation is the colorfulness of its own brightness [22-23]. Sensation of an area seem to be similar to one, or two of the apparent colors red, green, blue and yellow is hue composition. CIECAM02 color space meets human visual sensation and does not depend on lightning conditions.

Color quantization is used to decrease the number of distinct colors in an image, generally with the intention to visualize retrieved image is similar to the query image [1]. Some typical color is extracted to depict the image in order to reduce the computation without a substantial reduction in image quality.

4. FEATURE SIMILARITY MATCHING

Intersection of histograms was first proposed by Swain and Ballard [24]. It was originally defined as

$$d = \frac{\sum min\ [Q[i]], D[i]]}{D[i]} \qquad (4)$$

The cardinalities of the two histograms are different then the denominator can be modified to:

$$d = \frac{\sum min\ [Q[i]], D[i]]}{min(\sum Q[i], \sum D[i])} \qquad (5)$$

Where Q = {Q[1], Q[2], . . . , Q[n]} and D = {D[1], D[2], . . . ,D[n]} are the query and target feature vectors, respectively[1].

5. ALGORITHM OF THE PROPOSED METHODS

In this section, the proposed CBIR algorithms have been described: the very first method is an image retrieval using CIECAMO2 CH. The second, third and fourth methods are haar wavelet based CH image retrieval. Color features are extracted by CH whereas texture features are extracted by decomposing the image into an approximate coefficient (A), horizontal (H), vertical (V) and diagonal (D) detail coefficients using haar wavelet transformation and their combinations give a efficient feature extraction process. Similarity matching between query image and the image in the database is calculated in all the proposed methods, as described in Section 4.The following subsections continues with the proposed algorithms method. Algorithm 5.1 describes image retrieval using color histogram, CIECAM02 histogram is proposed in this case.

Algorithm 5.1: CIECAM02 Color Histogram

AlG1: Image retrieval using CH in CIECAM02 color space
Step 1: Transform RGB image into CIECAM02 color space. Step 2: Color quantization is carried out using CH by assigning 8 levels to H,s,J to give a quantized CIECAM02 space with 8 × 8 × 8 = 512 for HSV and 8 × 8 × 8 = 512 for Q,C,M histogram bins. Step 3: Get a normalized histogram on dividing histogram bins with the total number of pixels. Step 4: Repeat steps 1–3 on each and every image in the database. Step 5: Intersection distance between the query image and the image present in the database gives similarity matrix. Step 6: Repeat the steps from 1 to 5 for all the images in the database. Step 7: Based on the similarity matrix retrieve the matching images from the image database. Images will retrieve on the basis of ranking (degree of matching).

Algorithm 5.2 describes image retrieval using wavelet based color histogram, CIECAM02 histogram and H component of haar wavelet is proposed in this case. Similarly image retrieval algorithm with V and D using CH can also be proposed.

Algorithm 5.2: Haar wavelet based Color Histogram

AlG2: Image retrieval using haar wavelet based CH
Step 1: Divide the image into three components red, green and blue.

Step 2: Attain approximate, horizontal, vertical and diagonal coefficients with respect to RGB color components by decomposing the image into red, green and blue component using Haar wavelet transformation to the first level
Step 3: intermix approximate coefficient of red, green and blue component.
Step 4: Similarly mix the horizontal coefficients of red, green and blue components respectively
Step 5: Add weight 0.003 (experimentally determined value) to approximate coefficient and horizontal coefficients
Step 6: Convert the approximate and horizontal coefficients into CIECAM02 plane by assigning 8 levels to H,s,J to give a quantized CIECAM02 space with 8 × 8 × 8 = 512 for HSV and 8
× 8 × 8 = 512 for Q,C,M histogram bins.
Step 7: Get a normalized histogram on dividing histogram bins with the total number of pixels.
Step 8: Repeat steps 1–7 on each and every image in the database.
Step 9: Intersection distance between the query image and the image present in the database gives similarity matrix.
Step 10: Repeat the steps from 1 to 9 for all the images in the database.
Step 11: Based on the similarity matrix retrieve the matching images from the image database. Images will retrieve on the basis of ranking (degree of matching).

Similarly the steps 1–11 are repeated for vertical (V) and diagonal (D) detail coefficient combinations for ALG3.

6. PERFORMANCE EVALUATION

Accuracy and relevance need to be obtained for the image retrieval technique. The relevance and accuracy is calculated on the basis of standard techniques. Two important metrics used are

- Recall
- Precision

Precision (P) and Recall (R) values are standard procedures to evaluate performance of retrieval systems [1]. Recall measures the relevant images in all retrieved models, while precision measures only the models that are relevant to query image. P and R are defined as follows:

Precision (P) = (Number of relevant images retrieved)/

(Total number of images retrieved)

Recall (R) = (Number of relevant images retrieved)/

(Total number of relevant images)

The number of relevant items retrieved = Number of the returned images that are similar to the query image

The number of relevant images = Number of images that are in the same particular category with the query image.

The total number of images retrieved = Number of images that are returned by the search engine.

The weighted Average Precision value is computed as follows (k retrieved images):

$$AP = 1/100 * \left(\sum_{K_1=1}^{100} nk/100 \right) \qquad (6)$$

Where
K =1, . . . , 100 and
nk = Number of matches within the first k retrieved images.

The Total Average Precision (TAP) is defined as follows

$$TAP = \sum_{q=1}^{10} AP/100 \qquad (7)$$

Here q represent category of an image.

Equation 6 and equation 7 are used to calculate precision of all images in the database.

7. RESULTS

Experiments are performed on the WANG [25] data set, consists of 10 different categories Evaluation methods. The primary goal of the proposed system is to design a content based image retrieval system that should be simple to use, easy to handle very large image databases with different image category models, and fastest to retrieve images using primitive features such as colour and texture, which are semantically related to the image. The proposed algorithm focused on the similarity between query image and database images rather than the exact match.

Table 1. Retrieval time of the proposed methods on WANG dataset

Category	ALG1	ALG2	ALG3
African People	60	56	55
Beach	57	58	55
Building	60	58	52
Buses	59	58	57
Dinosaurs	58	60	57
Elephants	62	58	53
Flowers	66	58	57
Horses	58	60	52
Mountains	59	60	53
Food	58	61	57
Total average time	59	58	56

For evaluation, WANG dataset is used and it is available in its official website. WANG had provided a collection of 1000 images, in JPEG format of size 384 × 256 and 256 × 386. These images are collection of 10 different set of images with each containing 100 images. Same category images are considered as similar images.

Fig 6: Query result of Proposed Technique.

The image retrieval has been evaluated by randomly selecting query image of the different category, as shown in figure 6. The relevant images retrieved from the database on the basis of query image. The results of proposed algorithms are discussed in Table1, The evaluation time taken in seconds. ALG1 deals with CIECAM02 color histogram whereas ALG2 and ALG3 deal with haar wavelet coefficients and color histogram. The transformation models are proposed with different coefficients such as H, V and D. These Coefficients used to calculate texture features and histogram gives color features. Equation 6 and equation 7 has been used to evaluate precision. On the basis of results, it has been proved combination of histogram and wavelet transformation gives a better result than other retrieval techniques. Existing color histogram methods evaluated by using the basic RGB components but the proposed algorithm is the combination of CIECAM02 color histogram and haar wavelet transformation. This allows increasing the efficiency of the proposed model. The results have been evaluated by different evaluation metrics as discussed in the section 4 and section 6.

8. CONCLUSION

In this paper, proposed image retrieval techniques to extract color features and texture features. Color Histogram mainly concentrates on color features where as wavelet based color histogram focus on texture features. The proposed algorithms are giving better results than previously proposed methods in terms of retrieval time. Implementing next generation wavelets like curvlets and bundlets may give better results on texture extraction process and also implementing these concepts with different color space like HSV, CIE, and CIECAM02 may give best results in image retrieval technique. The proposed idea can be extended by using conflation of different wavelet transformation and color spaces. Wavelet transformation gives precise texture features and color spaces are good at retrieving color feature.

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