CEDD: Color and Edge Directivity Descriptor: A Compact Descriptor for Image Indexing and Retrieval

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Abstract. This paper deals with a new low level feature that is extracted from the images and can be used for indexing and retrieval. This feature is called "Color and Edge Directivity Descriptor" and incorporates color and texture information in a histogram. CEDD size is limited to 54 bytes per image, rendering this descriptor suitable for use in large image databases. One of the most important attribute of the CEDD is the low computational power needed for its extraction, in comparison with the needs of the most MPEG-7 descriptors. The objective measure called ANMRR is used to evaluate the performance of the proposed feature. An online demo that implements the proposed feature in an image retrieval system is available at: http://orpheus.ee.duth.gr/image_retrieval.

Keywords: Image Retrieval, Image Indexing, Compact Descriptors, Low Level Features, Color and Texture Histogram.

1 Introduction

The enormous growth observed in the multimedia applications, has led in the creation of large image databases. A characteristic example is the enormous number of images that "submerge" the internet after the growth of the Hyper Text Markup Language (HTML). In the past years a lot of systems were developed, which automatically are indexing and retrieving images, based on the low level features exported from them. This is widely known as content based image retrieval. CBIR undertakes the extraction of several features from each image, which, consequently, are used for the retrieval and the indexing procedure. These sorts of features are describing the content of the image and that is why they must be appropriately selected according to the occasion. The visual content of the images is mapped into a new space named feature space. The features have to be discriminative and sufficient for the description of the objects. Basically, the key to attain a successful retrieval system is to choose the right features that represent the images as "strong" and unique as possible. Regarding their type, CBIR systems can be classified in systems that use color features, those that use texture features and finally in systems that use shape features. It is very difficult to achieve satisfactory retrieval results by using only one of these feature categories. Many of the so far proposed retrieval techniques adopt methods, in which more than

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one feature types are involved. For example, color and texture features are used in the QBIC [1], SIMPLIcity [2] and MIRROR [3] image retrieval systems. A question however, that emerged in the past years is how these features could become more compact. The characterization of an image with a high dimensional vector may have very good retrieval scores but it delays significantly the retrieval procedure.

The descriptors that were proposed by MPEG-7 [4] [5], for indexing and retrieval, maintain a balance between the size of the feature and the quality of the results. These descriptors appear to be able to describe satisfactorily the visual content of the image [3].

This paper deals with the extraction of a new low level feature that combines, in one histogram, color and texture information and its length does not exceed 54 bytes.

Firstly, the image is separated in a preset number of blocks.

In order to extract the color information, a set of fuzzy rules undertake the extraction of a Fuzzy-Linking histogram that was proposed in [6]. This histogram stems from the HSV color space. Twenty rules are applied to a three-input fuzzy system in order to generate eventually a 10-bin quantized histogram. Each bin corresponds to a preset color. The number of blocks assigned to each bin is stored in a feature vector. Then, 4 extra rules are applied to a two input fuzzy system, in order to change the 10-bins histogram into 24-bins histogram, importing thus information related to the hue of each color that is presented. The process is described in section 2.

Next, the 5 digital filters that were proposed in the MPEG-7 Edge Histogram Descriptor [7] are also used for exporting the information which is related to the texture of the image, classifying each image block in one or more of the 6 texture regions that has been fixed, shaping thus the 144 bins histogram. The process is described in section 3.

Section 4 describes the entire proposed method implementation.

With the use of the Gustafson Kessel fuzzy classifier [8] 8 regions are shaped, which are then used in order to quantize the values of the 144 CEDD factors in the interval {0-7}, limiting thus the length of the descriptor in 432 bits. The process is described in section 5.

Section 6 comprises the experimental results of an image retrieval system that uses the proposed feature and the MPEG-7 features. The objective measure called ANMRR (Averaged Normalized Modified Retrieval Rank) [5] is used in order to evaluate the system performance. Finally the conclusions are given in section 7.

2 Color Information

In [6], a fuzzy system was proposed to produce a fuzzy linking histogram, which takes the three channels of HSV as inputs, and forms a 10 bins histogram as an output. Each bin represents a preset color as follows: (0) Black, (1) Gray, (2) White, (3) Red, (4) Orange, (5) Yellow, (6) Green, (7) Cyan, (8) Blue and (9) Magenta. These colors were selected based on works that were presented in the past [9].

The method presented in [6] is further improved, by recalculating the input membership value limits and resulting in a better mapping on the 10 preset colors.

These new limit calculations are based on the position of the vertical edges of images that represent the channels H (Hue), S (Saturation) and V (Value). Figure 1 shows the vertical edges of the channel H, which were used for determining the position of

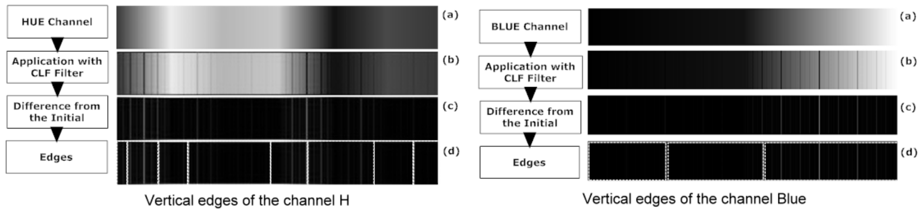

Fig. 1. Edges Extraction with CLF-AND Filter

membership values of Figure 2(a). The selected hue regions are stressed by dotted lines in figure 1(d). The membership limit values of S and V are identified with the same process.

The use of coordinate logic filters (CLF) [10] was found to be the most appropriate among other edge detection techniques for determining the fine differences and finally extracting these vertical edges. In the procedure followed, each pixel is replaced by the result of the coordinate logic filter "AND" operation on its 3x3 neighborhood. The result of this action, stresses the edges of the image. The total edges are exported by calculating the difference between the initial and the filtered image.

Based on these edges, the inputs of the system are analyzed as follows:

Hue is divided into 8 fuzzy areas. Their borders are shown in figure 2(a) and are defined as: (0) Red to Orange, (1) Orange, (2) Yellow, (3) Green, (4) Cyan, (5) Blue, (6) Magenta and (7) Blue to Red.

S is divided into 2 fuzzy regions as they appear in figure 2(b). This channel defines the shade of a color based on white. The first area, in combination with the position of the pixel in channel V, is used to define if the color is clear enough to be ranked in one of the categories which are described in H histogram, or if it is a shade of white or gray color.

The third input, channel V, is divided into 3 areas (Figure 2(c)). The first one is actually defining substantially when the pixel (block) will be black, independently from the values that the other inputs have. The second fuzzy area, in combination with the value of channel S gives the gray color.

A set of 20 TSK-like rules [11] with fuzzy antecedents and crisp consequents was used. The consequent part contains the variables that count the number of the original image pixels, which are mapped to each specific bin of the 10 bin histogram. Four of the rules depend on two only inputs (S and V). For these rules the decision is independent from the value of H. For the evaluation of the consequent variables two methods have been used. Initially LOM (Largest of Maximum) algorithm was used. This method assigns the input to the output bin which is defined from the rule that gives the greater value of activation. Next, Multi Participate algorithm was tried. This defuzzyfication method assigns the input to the output bins which are defined from all the rules that are being activated. More details about this algorithm are available in [6]. The experimental results show that the second algorithm performs better.

Next, a second system undertakes the task to separate each color in 3 hues. This system forms a 24 bins histogram as an output. Each bin represents a preset color as follows: (0) Black, (1) Grey, (2) White, (3) Dark Red, (4) Red, (5) Light Red, (6) Dark Orange, (7) Orange, (8) Light Orange, (9) Dark Yellow, (10) Yellow, (11) Light

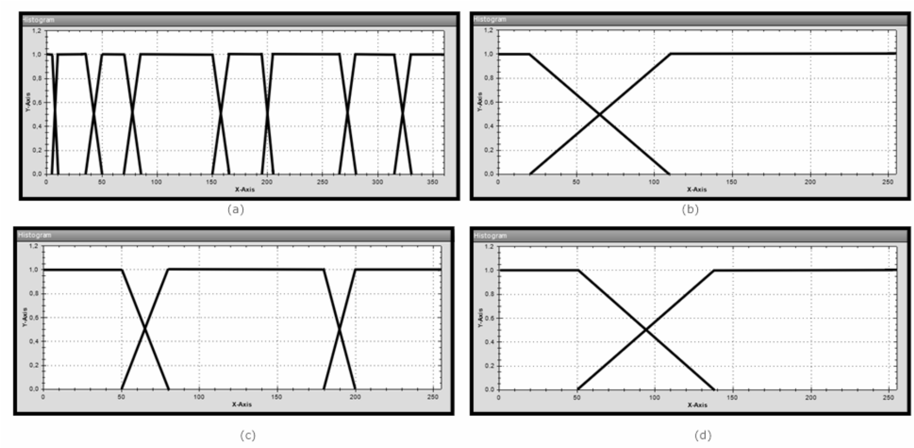

Fig. 2. Membership Functions for (a) Hue, (b) Saturation, (c) Value, (d) Saturation and Value for the expansion at 24-bins

Yellow, (12) Dark Green, (13) Green, (14) Light Green, (15) Dark Cyan, (16) Cyan, (17) Light Cyan, (18) Dark Blue, (19) Blue, (20) Light Blue, (21) Dark Magenta, (22) Magenta, (23) Light Magenta.

The design of a system that approaches these shades is based on the determinations of the subtle vertical edges appearing in images with smooth transition from the absolute white to the absolute black through a color. The use of the coordinate logic filter "AND" was found to be appropriate for determining these vertical edges too.

The values of S and V from each pixel as well as the value of the bin (or the bins) resulting from the fuzzy 10-bins unit constitute entries in the 24-bins Fuzzy Linking system.

So much the channels S as well as channel V are separated into 2 regions as they appear in figure 2(d).

This system actually undertakes to classify the input block in one (or more) from the 3 hue areas derived after the vertical edge extraction procedure described above. These hues are labeled as follows: Dark Color (as Color is used the color that attributed by the first 10-Bins system) - Color and Light Color.

In this system a set of 4 TSK-like rules [11] with fuzzy antecedents and crisp consequents were used. The Multi Participate algorithm was also employed for the evaluation of the consequent variables.

3 Texture Information

The 5 digital filters that were proposed by the MPEG-7 Edge Histogram Descriptor - EHD [7] [12], are shown in figure 3(A) [7]. These filters are used for the extraction of the texture's information. They are able to characterize the edges being present in their application region as one of the following types: vertical, horizontal, 45-degree diagonal, 135-degree diagonal and non-directional edges. The size of their application region will be described in section 4 and it is called henceforth *Image Block*.

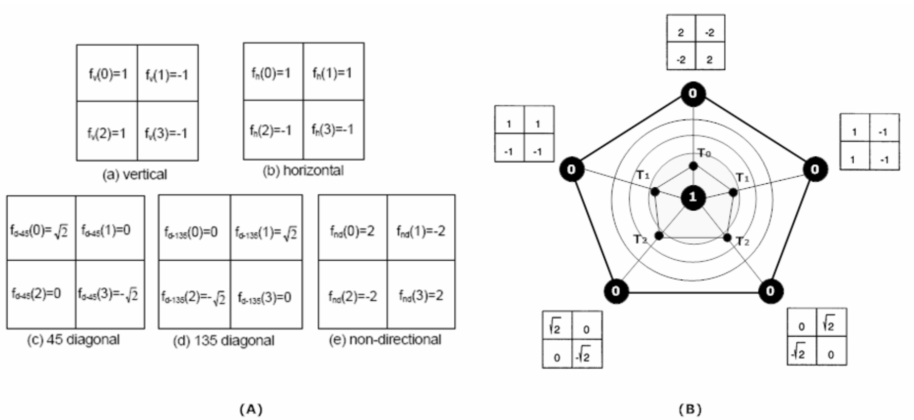

Fig. 3. (A) Filter coefficients for edge detection [7], (B) Edge Type Diagram

Each *Image Block* is constituted by 4 Sub Blocks. The average gray level of each Sub-Block at (i,j)th Image-Block is defined as $a_0(i,j)$, $a_1(i,j)$, $a_2(i,j)$, and $a_3(i,j)$. The filter coefficients for vertical, horizontal, 45-degree diagonal, 135-degree diagonal, and non-directional edges are labeled as $f_v(k)$, $f_h(k)$, $f_{d-45}(k)$, $f_{d-135}(k)$, and $f_{nd}(k)$, respectively, where $k=0,\dots,3$ represents the location of the Sub Block. The respective edge magnitudes $m_v(i,j)$, $m_h(i,j)$, $m_{d-45}(i,j)$, $m_{d-135}(i,j)$, and $m_{nd}(i,j)$ for the (i,j)th Image Block can be obtained as follows:

$$m_v(i,j) = \left| \sum_{k=0}^{3} a_k(i,j) \times f_v(k) \right| \tag{1}$$

$$m_h(i,j) = \left| \sum_{k=0}^{3} a_k(i,j) \times f_h(k) \right| \tag{2}$$

$$m_{d-45}(i,j) = \left| \sum_{k=0}^{3} a_k(i,j) \times f_{d-45}(k) \right| \tag{3}$$

$$m_{d-135}(i,j) = \left| \sum_{k=0}^{3} a_k(i,j) \times f_{d-135}(k) \right| \tag{4}$$

$$m_{nd}(i,j) = \left| \sum_{k=0}^{3} a_k(i,j) \times f_{nd}(k) \right| \tag{5}$$

Then the max is calculated:

$$\max = MAX(m_v, m_h, m_{d-45}, m_{d-135}, m_{nd}) \tag{6}$$

and normalize all ***m.***

$$m_v^{'} = \frac{m_v}{\max}, m_h^{'} = \frac{m_h}{\max}, m_{d-45}^{'} = \frac{m_{d-45}}{\max}, m_{d-135}^{'} = \frac{m_{d-135}}{\max}, m_{nd}^{'} = \frac{m_{nd}}{\max} \tag{7}$$

The output of the unit that exports texture's information from each Image Block is a 6 area histogram. Each area corresponds to a region as follows: EdgeHisto(0) Non Edge, EdgeHisto(1) Non Directional Edge, EdgeHisto(2) Horizontal Edge, EdgeHisto(3) Vertical Edge, EdgeHisto(4) 45-Degree Diagonal and EdgeHisto(5) 135-Degree Diagonal. The way that the system classifies the Image Block in an area is the following: Initially, the system checks if the *max* value is greater than a given threshold. This threshold defines when the Image Block can be classified as Texture Block or Non Texture Block (Linear).

If the Image Block is classified as Texture Block, all the m' values are placed in the heuristic pentagon diagram of figure 3(B). Each m' value is placed in the line that determines the digital filter from which it was emanated. The diagram centre corresponds in value 1 while the utmost corresponds in value 0. If m' value is greater than the threshold in the line in which it participates, the Image Block is classified in the particular type of edge. Thus the Image Block can participate in more than one type of edges. The source code that follows describes the process.

```
program SetEdgeType(max, m_nd, m_h, m_v, m_d_45, m_d_135)
{
       if (max < TEdge) then EdgeHisto(0)++
       else
            {
            if  (m_nd  >  T0)        then  EdgeHisto(1)++
            if  (m_h  >  T1)         then  EdgeHisto(2)++
            if  (m_v  >  T1)         then  EdgeHisto(3)++
            if   (m_d_45   >   T2)      then  EdgeHisto(4)++
            if   (m_d_135   >   T2)    then  EdgeHisto(5)++
            }
      endif
return(EdgeHisto)
}
```

Threshold values were selected to be: T_{Edge}=14, T_0=0.68, T_1=T_2=0.98.

4 CEDD Implementation

The configuration of CEDD is resolved as follows:

The unit associated with the extraction of color information is called Color Unit. Similarly, the Texture Unit is the unit associated with the extraction of texture information. The CEDD histogram is constituted by 6 regions, determined by the Texture Unit. Each region is constituted by 24 individual regions, emanating from the Color

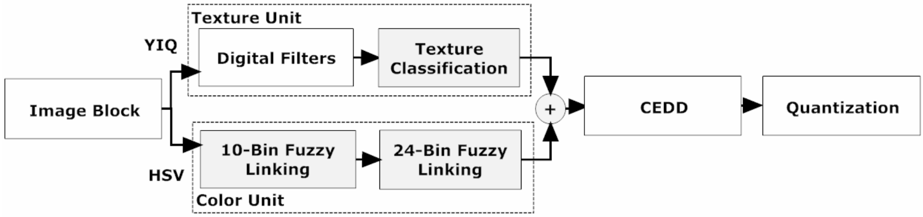

Fig. 4. CEDD Flowchart

Unit. Overall, the final histogram includes 6 × 24 = 144 regions. In order to shape the histogram, firstly we separate the image in 1600 Image Blocks. This number was chosen in order to compromise between the image detail and the computational power. Each Image Block feeds successively all the units. If we define the bin that results from the Texture Unit as N and as M the bin that results from the Color Unit, then the Image Block is placed in the output histogram position: N × 24 + M.

In the Texture Unit, the Image Block is separated into 4 regions, the Sub Blocks. The value of each Sub Block is the mean value of the luminosity of the pixels that participate in it. The luminosity values are derived from the transformation througth the YIQ color space. Each Image Block is then filtered with the 5 digital filters that were described in section 3, and with the use of the pentagon's diagram it is classified in one or more texture catogories. Assume that the classification resulted in the second bin, which defines NDE (Non Directional Edge).

In the Color Unit, every Image Block is transported in the HSV color space. The mean values of H, S and V are calculated and they constitute the inputs of the fuzzy system that shapes the fuzzy 10-bins histogram. Assume that the classification resulted in the fourth bin, which dictates that the color is red. Then, the second fuzzy system (24- Bin Fuzzy Linking), using the mean values of S and V as well as the value of the bin (or bins) expense from the previous system, calculates the hue of the color and shapes the fuzzy 24-bins histogram. Assume again that the system classifies this block in the fourth bin which dictates that color is the dark red. The combination of the 3 fuzzy systems finally will classify the block in the 27 bin (1 × 24 + 3). The process is repeated for all the blocks of the image. At the completion of the process, the histogram is normalized in the interval {0-1}. Each histogram value is then quantized in 3 bits. The quantization process is described in section 5.

5 CEDD Quantization

For the restriction of the CEDD length, a 3bits/bin quantization was used, limiting thus its total length in 144 × 3=432 bits. A sample of 10000 images was used to calculate the quantization table. Initially, CEDD vectors were calculated for the total of images. The crowd of 10000 × 144 elements constitutes the entry of the fuzzy Gustafson Kessel classifier [8], which separates the volume of the samples in 8 regions. Basically this classification maps the bin values from the decimal area {0-1} to the integer area {0-7}.

Table 1. Quantization Table

Bin: 0-23							
0.00018	0.02373	0.06145	0.11391	0.17912	0.26098	0.34179	0.55472
Bin: 24-47							
0.00020	0.02249	0.06025	0.12070	0.18112	0.23413	0.32566	0.52070
Bin: 48-95							
0.00040	0.00487	0.01088	0.01816	0.02704	0.03812	0.05267	0.07955
Bin: 96-143							
0.00096	0.01075	0.02416	0.04155	0.06289	0.09306	0.13697	0.26289

Gustafson Kessel parameters were selected to be: Clusters: 8, Repetitions: 2000, e=0.002, m=2. The resulting quantization is given in Table 1. The entries of the table have the following meaning: The values of the histogram appearing in bins 0-23 are assigned to one of the values {0-7} according to the minimum distance of each bin value from one of the eight entries in the first row of the table. The same procedure is followed for the entries of bins 24-47, 48-95 and 96-143 where in this case the eight entries of the second, the third and the fourth row respectively are used.

6 Experimental Results

The proposed low level feature has been integrated in the retrieval software system img(Rummager), which has been developed in the "Automatic Control Systems & Robotics" laboratory of "Democritus University of Thrace - Greece". Initially, experiments were performed in the database of 1000 images that was used by James Wang [2] [13]. CEDD was used in the retrieval procedure and the results are compared with the corresponding results of the following MPEG-7 [4] [5] descriptors:

Color Descriptors: Dominant Color Descriptor (DCD), Scalable Color Descriptor (SCD), Color Layout Descriptor (CLD), Color Structure Descriptor (CSD).

Texture Descriptors: Edge Histogram Descriptor (EHD), Homogeneous Texture Descriptor (HTD).

For the measurement of the distance of CEDD between the images, Tanimoto coefficient [14] was used.

$$T_{ij} = t(x_i, x_j) = \frac{x_i^T x_j}{x_i^T x_i + x_j^T x_j - x_i^T x_j} \tag{8}$$

Where x^T is the transpose vector of x. In the absolute congruence of the vectors the Tanimoto coefficient takes the value 1, while in the maximum deviation the coefficient tends to zero.

The objective measure called ANMRR (Averaged Normalized Modified Retrieval Rank) [5] is used in order to evaluate the performance of the image retrieval system. The average rank *AVR (q)* for query *q* is:

$$AVR(q) = \sum_{k=1}^{NG(q)} \frac{Rank(k)}{NG(q)} \tag{9}$$

Where

- *NG (q)* is the number of ground truth images for query *q*. As ground truth we define a set of visually similar images.
- *K = min (2 × NG (q), 2 × GMT) where GTM = max {NG (q)}.*
- Consider a query . Assume that as a result of the retrieval, the k^{th} ground truth image for this query *q* is found at a position *R*. If this image is in the first *K* retrievals then *Rank (k)=R* else *Rank (k) = (K+1).*
- *Rank (k)* is the retrieval rank of the ground truth image.

The modified retrieval rank is:

$$MRR(q) = AVR(q) + 0.5 - 0.5 * NG(q) \tag{10}$$

Note that *MRR* is 0 in case of perfect retrieval.

The normalized modified retrieval rank is computed as follows:

$$NMRR(q) = \frac{MRR(q)}{K + 0.5 - 0.5 * NG(q)} \tag{11}$$

Finally average of *NMRR* over all queries defined as:

$$ANMRR(q) = \frac{1}{Q} \sum_{q=1}^{Q} NMRR(q) \tag{12}$$

The ANMRR is always in range of 0 to 1 and the smaller the value of this measure is, the better the matching quality of the query is. ANMRR is the evaluation criterion used in all of the MPEG-7 color core experiments. Evidence was shown that the ANMRR measure approximately coincides linearly, with the results of subjective evaluation about retrieval accuracy of search engines. A set of ground truth images that are most relevant to query were identified.

In particular experiments we used as ground truth, the groups of images proposed in the MIRROR image retrieval system [3]. MIRROR separates the Wang's database in 20 queries. In table 2 that follows certain indicative results appear, while in table 3 the values of ANMRR for the total of the 20 queries have been calculated. An online demo of the application is available at [15] and the NMRR values for the MPEG-7 descriptors in Wang's database are available at [16].

For every query, the average NMRR value of the MPEG-7 descriptors is calculated. Figure 5(a) illustrates these values in juxtaposition with the CEDD results.

Table 2. Query (Image Number) / NMRR Values for the Descriptors

	DCD	SCD	CLD	CSD	EHD	HTD	CEDD
600	0.5273	0.0828	0.4543	0.0658	0.2771	0.4451	**0.04798**
327	0.3363	0.4063	0.5419	0.3477	0.3172	0.5944	**0.12015**
102	0.3893	0.5668	0.3697	0.4923	0.4684	0.9355	**0.27547**
204	0.4039	0.4417	0.6164	0.3228	0.7817	0.8867	**0.29035**
522	0.6018	0.5077	0.4544	0.5263	0.6904	0.7343	**0.34489**

Table 3. ANMRR Results for the Descriptors (Wang's Database)

	DCD	SCD	CLD	CSD	EHD	HTD	CEDD
ANMRR	0.4959	0.3566	0.3999	0.3162	0.5088	0.7054	**0.2431**

Table 4. Descriptors Results in img(Rummager) Database

	DCD	SCD	EHD	CLD	CEDD
ANMRR	0.5111	0.3214	0.5987	0.3645	**0.2333**

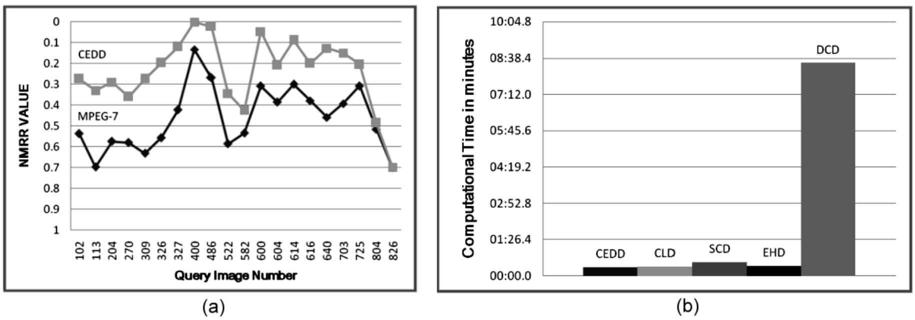

Fig. 5. **(a)** CEDD and MPEG-7 Average NMRR Values in Wang's Database, **(b)** Descriptor Extraction Computational Time in Wang's Image Database

Experiments have also been performed on the database that is incorporated in the application img(Rummager). This database has 15000+ images, coming from several retrieval systems and images from private collection. Table 4 presents the descriptors' results in the Img (Rummager) database. The experiments concern 102 queries.

Note that DCD, SCD, EHD and CLD implementation in img(Rummager) application match the XM implementation [18].

One of the most important attribute of the proposed feature is the low computational power needed for its extraction, in comparison with the needs of the most MPEG-7 descriptors. Figure 5(b) illustrates the CEDD computational time in the Wang's database (1000 images) in juxtaposition with the CLD, SCD, EHD and DCD descriptors. Extraction time was measured in the img(Rummager) application.

7 Conclusions

This paper presents the extraction of a new low level feature that contains, in one histogram, color and texture information. This element is intended for use in image retrieval and image indexing systems. Experimental results show that the proposed feature can contribute in accurate image retrieval. Its main functionality is image-to-image matching and its intended use is for still-image retrieval, where an image may consist of either a single rectangular frame or arbitrarily shaped, possibly disconnected, regions.

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