EXTRACTING DOMINANT COLOR TEMPERATURES

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ABSTRACT

The paper presents a new algorithm for extraction of dominant color temperatures description. Dominant color temperatures were previously proposed by the authors as a descriptor for image indexing/retrieval. They can be used in two general search scenarios: query by color temperature value and query by example. The originally proposed extraction algorithm uses an approach derived from dominant colors. The new algorithm, presented in this paper, is based on scalar quantization in color temperature domain. This algorithm is simpler, and requires significantly less computations.

1. INTRODUCTION

Huge amount of available multimedia data has introduced increasing demand for efficient multimedia retrieval and browsing tools, which will support fast and convenient access to required data. In the case of images, there are two general approaches to image indexing. The first is based on textual descriptions of image data and the other is based on visual features of image content. The advantage of content-based image indexing is that it can be performed using automatic image analysis algorithms, the user assistance is not required. On the other hand, the drawback of content-based indexing techniques is, that they hardly express semantical meanings, associated to the indexed images. They are primary designed for describing low-level features of images.

A number of features and extraction algorithms may be used in content-based image indexing. They could represent color, texture, shape, motion (in moving pictures), and their spatial relationships. A set of descriptors representing visual features are included into the Visual part of MPEG-7 standard [1]. The set of descriptors was chosen from submitted propositions (and refined by core experiments), in such a way that the chosen ones cover a broad range of meaningful, distinct aspects of visual content.

One of the significant visual features is color. MPEG-7 has a set of descriptors designed for representing image color. Each of them covers a different aspect of color content characteristics: color histogram, dominant colors, color structure, color layout. The Amendment to the Visual part of the MPEG-7 standard also defines Color Temperature descriptor, which represents the overall color temperature characteristics of images.

Color temperature is a feature of light, associated with color, and is derived from light perception by the human visual system. Because of this, color temperature seems to be a promising feature in image indexing, as perceptual similarity of images is important. In [2] the Dominant Color Temperatures descriptor has been proposed, which would allow new functionalities to be introduced for color temperature searching: query by example and query by value. Dominant Color Temperatures describe a few representative color temperatures in an image, and are extracted in a similar way as Dominant Colors in the MPEG-7 Dominant Color descriptor. But that algorithm is not optimally suited for Dominant Color Temperatures extraction, and is also computationally costly (vector quantization of pixel values in 3D color space). To avoid these drawbacks, a new algorithm for Dominant Color Temperatures extraction is presented in this paper, based on scalar quantization in one-dimensional color temperature domain. The syntax of the Dominant Color Temperatures descriptor remains the same as the originally proposed one in [2].

The paper is structured as follows. In paragraph 2 the Dominant Color Temperature description is shortly outlined. In paragraph 3 the new algorithm is introduced, and in paragraph 4 some experiments are presented to compare the new algorithm and the old algorithm that originates from Dominant Colors.

2. DOMINANT COLOR TEMPERATURES

Color temperature is a significant perceptual feature that can be attributed to images and observed scenes according to its visual perception by viewers. An image usually has one or a few groups of colors which give dominant color temperature feeling to the observer. This observation was the basis for designing of Dominant Color Temperatures descriptor, which has been proposed as a new descriptor to the Amendment of Visual part of MPEG-7 standard, and accepted for core experiments [3].

Dominant Color Temperatures descriptor is intended for similarity searching of images. It consists of a few representative color temperatures and the percentages of their content in an image. Extraction of this description is done by first obtaining up to eight dominant colors and their percentages, and then computing color temperatures for these colors. The colors which do not meaningfully impact color temperature perception (e.g. black colors) are omitted from the calculations.

Dominant Color Temperatures can be used in two search scenarios, for which appropriate similarity functions are specified. One of them is query by value, in which the user inputs a value of color temperature, and next, the search application retrieves a list of images that have perceived color temperatures of (dominant) colors close to the user input. For this purpose a similarity function is defined, given by equation (1), as the sum of differences between the user input RT_{REF} and dominant color temperatures RT_i of the description, weighted by percentages p_i. RT denotes color temperature value in reciprocal megakelvin scale (mired, $1MK^{-1}$=1000000/K), which is usually used in color temperature calculations instead of Kelvin scale.

$$\Delta RT = \sum_{i=1}^{k} \left| RT_i - RT_{REF} \right| p_i \qquad (1)$$

The second searching scenario is query by example. It's a well known and important paradigm of content-based searching, in which images are searched according to their similarity to an example image given by the user. In this case the similarity function is based on the difference of color temperature percentage distributions for two compared images [4]. This similarity function is a generalization of the function given by formula (1) for two sets of dominant color temperatures (formula (1) represents the difference between a percentage distribution of dominant colors and a single color temperature value).

3. EXTRACTION OF DOMINANT COLOR TEMPERATURES

The originally proposed method for Dominant Color Temperatures extraction is based on the extraction algorithm for Dominant Colors [5]. This solution is justified by the fact that perceptually distinct dominant colors are obtained by averaging color values of similar pixels in an image. Color values averaging for pixels which influence color temperature perception is also used in extraction of Color Temperature descriptor contained in Amendment to Visual part of MPEG-7 [6]. But the Dominant Color's based approach for Dominant Color Temperatures extraction has two significant drawbacks. The first is high computational cost caused by vector quantization of pixel values in 3D color space. The second drawback is that dominant colors do not always correspond to distinct color temperature values. For example two distinct dominant colors, light-red and dark-red, may have undistinguishable color temperature values. The better solution would be if the dominant color temperatures were well distinguishable. Such solution is the extraction method proposed in the following part of this section.

The new extraction algorithm is based on scalar quantization in one-dimensional color temperature domain. The algorithm can be outlined as follows:

1. Compute color temperature values, in reciprocal megakelvin scale, for all pixels in the image;
2. Mark pixels without significant color temperature values, that should be omitted (e.g. black colors);
3. Compute a histogram of color temperature values for the remaining pixels;
4. Perform scalar quantization of the histogram bins to obtain dominant color temperatures;
5. Merge similar dominant color temperature bins (by using a merging threshold).

The histogram is computed from pixel samples represented by color temperature values. Values of the samples are clipped to the range from 40 MK^{-1} (25000K) to 600 MK^{-1} (1667K), and quantized with step q. The resulting histogram has (600-40)/q bins. We used q=1, what gives 560 bins in the histogram. Scalar quantization is performed by modified Lloyd algorithm [7] in color temperature histogram domain. Te range of color temperature values is being split into K subranges, points in the middle between any two split points are considered to be representative points of the relevant subranges. The algorithm calculates (locally) optimal division of the color temperature range into K subranges having minimum distortion. The distortion is calculated as a sum of distances from the representative points of each subrange to the color temperature values represented by histogram bins contained within this subrange, weighted by histogram bin values. The K obtained centers of the subranges are candidates for dominant color temperature values. In the next step, the color temperature representative points that are closer to each other than a given merging threshold T_{merg} are merged to obtain perceptually distinct dominant color temperature values.

After computing up to K representative color temperature values, they are used for constructing Dominant Color Temperatures description. Percentages are obtained by summing histogram bin values in each color temperature subrange. The syntax of the descriptor is the same as originally proposed, the extraction algorithm is only changed.

4. COMPARISON OF THE EXTRACTION METHODS

The experiments were performed using subjective test data obtained during core experiments for MPEG-7 Color Temperature descriptor [8]. In this experiments test images were classified into 4 subjective color temperature categories according to voting by viewers participating in the experiment. The subjective categories are: hot (reddish colors dominate), warm (orange and yellowish colors), moderate (white, grey, green colors) and cool (bluish colors).

Figure 1 and 2 show graphs which depict query result rankings obtained for the test images for moderate color temperature category. The graphs depict relationships between the viewer's subjective color temperature perception of images (according to subjective category) and the ranking of query results for the two extraction methods of Dominant Color Temperatures descriptor. The vertical axes in both graphs represent percentage of viewer's votes assigning images to moderate color temperature category. The horizontal axes represent image positions on a ranked result list obtained for moderate category. Figure 1 shows result for the new extraction method, and Figure 2 shows result for the original extraction method. The query results were ranked according to formula (1), where RT_{REF}=181,92 MK^{-1} (middle of the moderate category subrange in reciprocal scale given in [6]). The user votes in the graphs were smoothed by averaging in a shifted window of 50 consecutive images. As it can be intuitively assumed, it is desirable that images positioned at the beginning of the result list had the percentages of viewer's votes close to 100%.

Additionally, the graphs contain lines which best fit the smoothed ranking curves for the two descriptions. The line parameters were obtained by linear regression of the data. An equation of the approximation line can be expressed by $y=a*x+b$, where x relates to an image position (horizontal axis of the graph), y relates to a smoothed percentage of votes value, a is the slope of the line, and b is the intersection of the line with the vertical axis of the graph (intercept, percentage of votes for the first positioned image on the retrieved list). Table 1 shows start points (b parameter values) of the lines for all of the four subjective color temperature categories, table 2 shows average deviations of the data points from the approximated lines. In table 1 the bigger value is the better. In table 2 the smaller value is the better.

The new method is significantly faster, as it utilizes scalar quantization of one dimensional color temperature histogram with fixed size instead of vector quantization in 3D color space with complexity depending on image size. In the case of vector quantization, the most time consuming task is an iterative process of clustering, which is performed by finding a nearest representative point for each pixel of the indexed image, until the change in distortion of quantization (quantization error) in two consecutive iterations comes down below an established threshold. For example, if we have an image of the size MxN and K representative color points, the number of distance calculations needed is MxNxK, The distance between two colors in 3D color space is given by: $(l_1 - l_2)^2 + (u_1 - u_2)^2 + (v_1 - v_2)^2$, where l, u, v are color components in LUV color space, which is used due to its perceptual homogeneity. It means that computation of single distance requires 3 subtractions, 3 multiplications and 2 additions. For M=256, N=256, K=8, the number of distance calculations in a single clustering step is: 356 x 256 x 8 = 524288. Quantization may need a few dozen iterations of clustering. In the case of color temperature histogram the quantization is performed in one dimensional space for data of fixed size. The clustering is done, by assigning subrange's cut points between neighboring representative color temperature values. The distortion of the clustering is computed by summing up the distances from the representative points to assigned to them color temperatures represented by histogram bins, weighted by histogram bin values. This task needs B distance calculations, involving two basic operations: subtraction and multiplication, where B is the number of histogram bins (e.g. B=560). Experiments showed that even for small images (384x256) the generation of indexes was more than two times faster when the new algorithm was used. For bigger images the difference was even greater.

Table 2. The first point of the regression line – b parameter

Color temperature category	New - scalar quant.	Dominant color
Hot	91,69	92.26
Warm	75,23	73.76
Moderate	87,12	86.5
Cool	87,91	87.46

Table 3. Average squared deviation of percentage of votes (regarding regression line)

Color temperature category	New - scalar quant.	Dominant color
Hot	5,36	5.47
Warm	13,03	15.7
Moderate	13,13	11.42
Cool	6,98	6.22

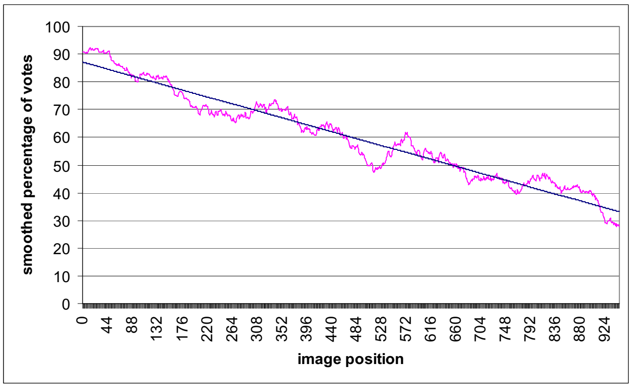

Figure 1. Ranking of query result for scalar quantization based extraction algorithm

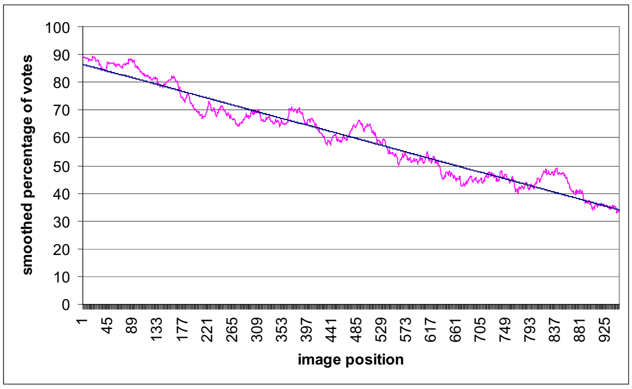

Figure 2. Ranking of query result for dominant color based extraction algorithm (original)

5. CONCLUSIONS

The results presented in the graphs and tables indicate that the new algorithm fits the subjective user judgment at least as good as the originally proposed algorithm in the query by value functionality. Further tuning parameters of the algorithm may improve the results (for example the merging threshold of dominant color temperatures). The main advantage of the new algorithm is considerably lesser computational cost, which significantly decreases the extraction time of the descriptor. The final conclusion of the presented work is that the new algorithm is a better solution for extraction of Dominant Color Temperatures description.

6. REFERENCES

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