A Fast Image Retrieval System using Index Lookup Table on Mobile Device

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Abstract

The development of mobile-based image retrieval system is required for the efficient management about various image data with fast growth of mobile devices. The resource of mobile phone is a bit limited due to low memory capacity and low CPU performance. Hence, the system which is applicable on mobile phone should overcome the problem of limited resource. In this paper, we propose the fast feature extraction method which is applicable on mobile environment. The proposed algorithm is based on the lookup table which converts RGB color space to one of 36 indices on HSV color space. By the lookup table-based feature extraction, we extract three histograms which is about color distribution and the location of the distribution. Then, we load the proposed algorithm to mobile phone. Our system can query by three different quries: query-by-image, query-by-color, and query-by-blob. The experimental result shows that the proposed method is a fast and stable engine enough to utilize on mobile platform.

1. Introduction

Nowadays, the amount of digital image data is dramatically increasing with the rapid development of mobile devices. Thus, the researches for efficient content based image retrieval(CBIR) system on mobile devices became an essential part of computer science. Of course, there are several well-known CBIR systems which are developed by researchers and they are accepted as useful and efficient system. Examples of those CBIR systems can be founded in [5]. Some significant CBIR systems such as QBIC[4] and VisualSEEK[2] attempted to develop general CBIR system based on low-feature (such as color, shape and texture). QBIC[4] proposed to extract color, shape and texture features from images and users can query with these features, additionally, including sketches. In VisualSEEK[2], users can build queries combining color and spatial features of each region. Although these systems have offered diverse query methods for image retrieval systems, they are somewhat inconvenient and complicated to be useful in an image retrieval system on mobile devices. Unlike general PC's environment, many mobile devices have limited hardware resources, or, small memory capacity and low CPU power etc Thus, image retrieval systems based on mobile devices have to overcome those restrictions. Gavilan[1] proposed image categorization and image retrieval system on mobile devices. He used color blobs as features for image classification. A neural network is trained by using color blobs and each trained region is given its meaning. Thus, a blob corresponding to the region becomes a main feature of the region. However, it needs a complex prior efforts such as selection of representative blobs and classification of information manually in learning process.

In this paper, to overcome limited hardware resources and low performance of mobile devices, we propose a fast feature extraction algorithm using an indexed lookup table. First, we quantized each channel of RGB color space into k level. Then, we compute the index corresponding to all quantized colors where the index is one of 36 indices of HSV color space. We build the lookup table with a pair which is the quantized color and the index corresponding to the color in the learning phase. By the lookup table-based feature extraction, we extract three histograms. One is the histogram which represents color information about the given photo. The others are two histograms which represent x-coordinate and y-coordinate of color distribution. We propose the mobile-based image retrieval system by using the proposed algorithm. The proposed

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system can query by three different method: query-by-image, query-by-color, and query-by-blob.

2. Feature Extraction Method Using Index Lookup Table

The RGB color space has frequently been not utilized in the general image processing algorithm because of its high dependence between each channel. Hence, we consider a different color space. HSV color space is suitable color space to describe perceptual color relationships more accurately than RGB. So, we convert input RGB color space to HSV space, and divide HSV color space to 36 indices of HSV color space. This method is proposed in Zhang *et al*[3], and it is applied successfully to the image retrieval.

In this paper, we propose a lookup table method for a fast feature extraction. It computes the specific 36 indices of HSV corresponding to each RGB color value in the learning phase. These 36 indices reduce the dimension of color feature space efficiently, and well maintain the property of the dominant color on a picture. An input image $\mathbf{I}(\mathbf{x})$ is given where $\mathbf{x} = (x, y)^T \in \Re^2$ and $\mathbf{I}(\mathbf{x}) \in \Re^{m \times n}$. each pixel constitutes three dimensional feature vector of the combination of $r_{(\mathbf{x})}, g_{(\mathbf{x})}, b_{(\mathbf{x})}$. and each value of vector is within $0 \leq r_{(\mathbf{x})}, g_{(\mathbf{x})}, b_{(\mathbf{x})} \leq 255$. If we consider a lookup table for entire RGB color space, we should compute 256^3 indices. However, it is impossible to use on mobile platform having limited resource. We solve this problem by using the quantization of RGB color space. Each RGB color space is equally divided into k levels, then each quantized color space has the index from 0 to $k-1$. When $(r_{(\mathbf{x})}, g_{(\mathbf{x})}, b_{(\mathbf{x})})^{\mathbb{T}}$ of $\mathbf{x}$ on a photo are given, the propose quantization method is expressed as:

$$(\widetilde{r}_{(\mathbf{x})}, \widetilde{g}_{(\mathbf{x})}, \widetilde{b}_{(\mathbf{x})})^{\mathbb{T}} = (\lfloor r_{(\mathbf{x})}/q \rfloor, \lfloor g_{(\mathbf{x})}/q \rfloor, \lfloor b_{(\mathbf{x})}/q \rfloor)^{\mathbb{T}} \tag{1}$$

where $\lfloor \; \rfloor$ is the floor function, and $q = (255/k)$. A pixel r, g, b in an input image is first quantized to i_r, i_g, and i_b. Then, we compute the index, c, of HSV color space corresponding to the quantized color where index value, c, of quantized HSV space is from 0 to 35, and $0 \leq i_r, i_g, i_b \leq k-1$. If the quantization level k is low, only a few representative color indices will be generated. In this paper, we define k as 16 by the experiment. When k is 16, the clustering result is very good, and memory usage is applicable because just 16^3 indices are needed.

The pixels with same index value in input image are accumulated to each corresponding color histogram bin. The color histogram, $\mathbf{H}_c$, is the characteristic vector of $\Re^{36}$. The quantized color, $(\widetilde{r}_{(\mathbf{x})}, \widetilde{g}_{(\mathbf{x})}, \widetilde{b}_{(\mathbf{x})})^{\mathbb{T}}$, of one pixel, $\mathbf{x}$, is converted to color index, $c_{\mathbf{x}}$, by the lookup table. Each bin is computed as:

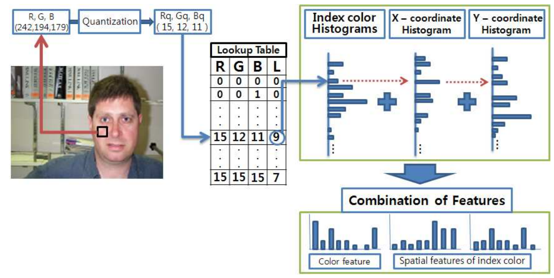


Figure 1. The conceptual diagram of the proposed feature extraction method

$$\mathbf{H}_c(i) = \sum_{\mathbf{x} \in \Re^{m \times n}} f(c_{\mathbf{x}}, i) \tag{2}$$

where $f(c_{\mathbf{x}}, i)$ is the delta function which the function value is 1 if $c_{\mathbf{x}} = i$, otherwise, 0. The histogram-based method has one drawback which it can not represent the spatial feature of color distribution. Hence, we extract the spatial feature of color distribution about each color index by the proposed method in [3]. The feature vector, $\mathbf{H}_x$, is the x-coordinate of color distribution, $c_{\mathbf{x}}$ where $\mathbf{H}_x \in \Re^{36}$. Each bin of $\mathbf{H}_x$ is given as:

$$\mathbf{H}_x(i) = \frac{\sum_{\mathbf{x} \in \Re^{m \times n}} x \cdot f(c_{\mathbf{x}}, i)}{n \cdot \sum_{\mathbf{x} \in \Re^{m \times n}} f(c_{\mathbf{x}}, i)} \tag{3}$$

The feature vector, $\mathbf{H}_y$, is y-coordinate of color distribution of color index, $c_{\mathbf{x}}$ where $\mathbf{H}_y \in \Re^{36}$. Each bin is computed as:

$$\mathbf{H}_y(i) = \frac{\sum_{\mathbf{x} \in \Re^{m \times n}} y \cdot f(c_{\mathbf{x}}, i)}{m \cdot \sum_{\mathbf{x} \in \Re^{m \times n}} f(c_{\mathbf{x}}, i)} \tag{4}$$

The feature vector, $\mathbf{H}$, is the vector formed by concatenating feature vectors which are $\mathbf{H}_c$, $\mathbf{H}_x$, and $\mathbf{H}_y$.

$$\mathbf{H} = (\mathbf{H}_c^{\mathbb{T}} \;\; \mathbf{H}_x^{\mathbb{T}} \;\; \mathbf{H}_y^{\mathbb{T}})^{\mathbb{T}} \in \Re^{108} \tag{5}$$

Figure 1 shows the conceptual diagram of the proposed method.

3. Proposed Image Retrieval System with Three Query Methods

Previous systems have the fault which need a bit complex control and query conditions. Query methods of the proposed system is simple and convenient. The proposed system can query by three different method: Query-by-image, Query-by-color, and Query-by-blob.

In Query-by-Image, we compute the distance between color histogram of a query image and color histograms of database. We define $\mathbf{H}^{(j)}$ as one of k histogram vectors in the database and define $\mathbf{H}$ as the color histogram vector of a query image. The distance is expressed as:

$$\|\mathbf{H}_c - \mathbf{H}_c^{(j)}\| < \mathbf{\Phi}_I \tag{6}$$

where $1 \leq j \leq k$ and $\mathbf{\Phi}_I$ is the threshold.

To query-by-color, we first select the one color among 36 colors. Assume that the selected color is c_d. Here, the distance of the focused color of two images is defined as:

$$\|\mathbf{H}_c(c_d) - \mathbf{H}_c^{(j)}(c_d)\| < \mathbf{\Phi}_c \tag{7}$$

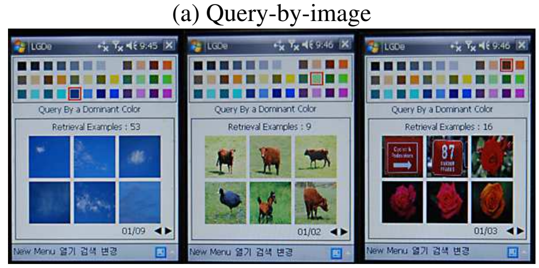
where $0 \leq c_d \leq 35$ and $\mathbf{\Phi}_c$ is the threshold.

Blob is defined as the combination of color and location. Our blob is expressed as the center coordinate of the specific color distribution. For query by blob, we should select the color and the location of it. Set the selected color index as c_d and the location of blob as $\mathbf{X}_b = (x_b, y_b) \in \Re^2$. Here, the distance between two images is given as:

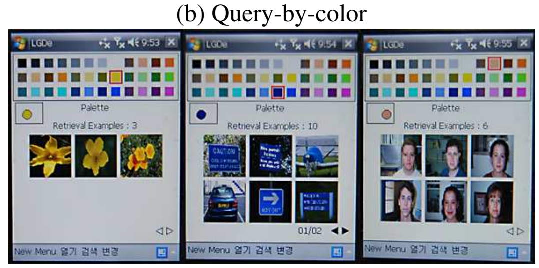
$$\sqrt{(x_b - \mathbf{H}_x(c_d))^2 + (y_b - \mathbf{H}_y(c_d))^2} < \mathbf{\Phi}_b \tag{8}$$

where $\mathbf{\Phi}_b$ is the threshold. Here, only a photo which satisfies the equation (7) is computed by the equation (8).

(a) Query-by-image



(b) Query-by-color



(c) Query-by-blob

Figure 2. Examples of the result about the proposed three different query

4. Experiment

In this paper, we loaded the proposed system on SPH-M4650 based on WM 6.0. For experiment, we first divided images of Corel DB, MSRC DB1.0, and CalTech DB as 10 category, and then we randomly chose 50 images about each category. 10 category is airplane, animal, building, car, chair, face, flow, sky, tree, and text. We interpolated each image as 160×120 image.

We evaluate its implementation on a mobile device. In order to make feature database, we extract feature histogram from 500 images in mobile device which is loaded proposed retrieval systems and various images, and the mean speed of feature extraction is summarized in Table 1. The result shows that the cost for feature extraction of whole image database takes total 25.72 seconds, and It takes approximately 0.05 seconds for each image. thus, proposed method is very fast to feature extraction. To test the retrieval system by different method of queries, we made three kind of test such as query by image, query by color, and query by blob. When we retrieve images using query by image,the system picks up one of images from database and use it as input image for the query. and it repeats this process with whole images. On the other hand, to retrieve using other methods, the system select one dominant color for query. and repeat the process with all 36 colors. The mean speed of similarity matching for image retrieval is demonstrated in Table 2, and compared with each query method. The retrieval performance is measured using average precision. Average precision measures the retrieval accuracy. and it is defined as ratio between the number of relevant images which is belonging to same category and the total number of retrieved images. Here, the average precision is given as:

$$Average\ \ precision = \frac{I_t \in I_r}{I_r} \tag{9}$$

where I_r is the number of retrieved images, and I_t is relevant images. Figure 3 illustrates that average precision of image retrieval by using query-by-image. The system

Table 1. Average time of feature extraction

average feature extraction time	$25.72(sec/500images)$ $0.05(sec/1image)$

Table 2. Average time of image retrieval

Retrieval Methods	feature matching time
Query by Image	0.014 (sec)
Query by Color	0.0054 (sec)
Query by Blob	0.098 (sec)

extract 36 index color features from input query image and compare similarity with this feature to images from the database. Figure 4 compares the average precision

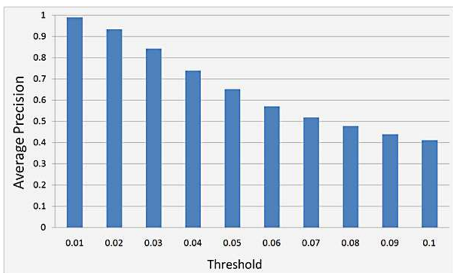


Figure 3. Average retrieval performance

before and after using combination of the spatial information of a index color. And it shows the better result. The blue lines show the retrieval precision result by using only color values of image, and the others illustrate combination of color and spatial information of dominant index color. This experimental result proves that our proposed method produces high quality retrieval results by using color values and spatial information of color together.

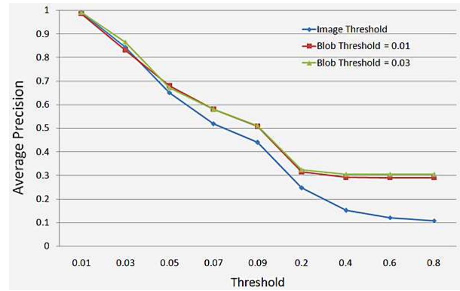


Figure 4. Average retrieval performance with combination of features

5. Conclusion

In this paper, in mobile system having a limited resource, we proposed the fast feature extraction method based on a lookup table to the efficient image retrieval. We can fast extract 36 indices on HSV color space by using the proposed lookup table about each pixel. We computed color and location histogram about each index extracted from the lookup table. In contrast to previous system, we made up for the fault of loss of location information in previous system from utilization of the center of the color distribution. We loaded the proposed system on mobile phone. The system can do a image retrieval from three different query: query by image, query by color, and query by blob. The experiment result shows that our system is fast algorithm enough to perform on mobile phone. The retrieval performance of the proposed algorithm is high also. The retrieval speed of our system outperforms other previous system.

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