Content-based Image Retrieval Using Entropy and Fractal Coding

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Abstract: - Describing and extracting image's feature is a key question in content-based image retrieval system, and this paper puts forward a novel image retrieval method using image information entropy and fractal coding. First, compared with a given threshold computed from the inquired image, each image in the database is classified by computing its image entropy. Second, the inquired image's fractal coding is got by Jacquin method, which is applied to the same kind of database images with fractal tenth iteration decoding. Finally, image retrieval result is obtained by matching the similar Euclidean distance between the inquired image and the iterated decoded image. Experimental results show that compared with the direct image pixels similar matching strategy, our scheme improves the retrieval time greatly and guarantees the retrieval accuracy, thus our proposed method is effective and feasible.

Key-Words: - Fractal coding; Image information entropy; Image retrieval; Similar

1 Introduction

In recent years, more and more applications such as digital libraries, geographical map and medical image management, require effective and efficient means to access images. Up and now, there are two main image retrieval methods: the text-based image retrieval and the content-based image retrieval. Text-based image retrieval is based on key words, and the image is expressed as a set of fixed attributes. It is easy to be implemented. However, the more the attributes are abstracted, the more information the users need to input. To overcome the limitation of the traditional text-based image retrieval, the inquiring retrieval is based on the content of an image, including color, shape, texture and the object's special relationship[1-2]. However, It is limited by the development of correlated subjects, such as image procession, pattern recognition and computer visualization. Furthermore, it has higher complexity.

A fractal code of an image is a compression code generated by exploiting the self-similarity of the image. The original image can be decoded with an arbitrary resolution from the fractal coded image. These advantages make fractal coding an extremely promising compression method that is suitable for the development of image retrieval systems in the compression data domain. The prospects of fractal coding in the content-based image retrieval was first discovered by A.D.Sloan[2]. He proposed a method that directly coded the patched up images in the image database. For any range block, there exists a corresponding domain block in any image of the image database and the similarity between two images, say A and B, could be measured by the total domain numbers in image B for all the range blocks in image A. Further research can be referenced in Ref[3-6]. Joint fractal coding based image retrieval [3] and the retrieval method combining the ninth furcated tree decomposition and the fractal coding [4] are proposed. A.X.Hong [5] extended the fractal coding matching strategy in the polar coordinates and S.Y.Yang[6] put forward a content-based image retrieval method in the fractal compression domain.

In this paper, we propose a novel image retrieval method based on image entropy and fractal coding. In our image retrieval scheme, compared with the inquired image, each image in the database is classified by computing formation entropy. And we apply the fractal coding of the inquired image to be iterative decoded from the same kind of database images. Then the similarity is measured between the decoded image and the inquired image. Finally the image retrieval result is obtained. Experimental results show that compared with the direct pixels similar matching strategy, our retrieval scheme improves the retrieval time greatly and guarantees the retrieval accuracy.

The balance of the paper is organized as follows. Theoretical foundations of the image information entropy and fractal coding are described in Section 2. Our retrieval method using image entropy and fractal coding is presented in Section 3. Experimental results and discussions are given in Section 4. Finally, concluding remarks are drawn in Section 5.

2 Image Information Entropy and Image Fractal Coding

2.1 Image Information Entropy

2.1.1 Information Entropy

Shannon was a key figure in the development of information science. He proposed a measure of information content for messages in a message system. A message system is a collection of tokens that can be sent or used to record information. The idea is that in constructing content of longer records, these messages will appear with different frequencies and according to patterns. These patterns govern how much information each message actually carries. Let X be a discrete random variable taking a finite number of possible value $X_1, X_2, \ldots, X_n$ with probabilities $P_1, P_2, \ldots P_n$ respectively such that $\sum_{i=1}^{N} P_i = 1, 0 \le p_i \le 1, i = 1, 2, \ldots, N$. We attempt to arrive at a number that will measure the amount of uncertainty. Let h be a function defined on the interval (0, 1] and $h(p)$ be interpreted as the uncertainty associated with the event $X = x_i, i = 1, 2, \ldots, n$ or the information conveyed by revealing that X has taken on the value x_i in a given performance of the experiment. For each n, we shall define a function H_n of the n variables $p_1, p_2, \ldots p_n$. The function $H_n(p_1, p_2, \ldots p_n)$ is to be interpreted as the average uncertainty associated with the event $\{X = x_i, i = 1, 2, \ldots n\}$. Shannon's entropy is defined as form (1)

$$H_n(p_1, p_2, \ldots, p_n) = -\sum_{i=1}^{N} p_i \log_2 p_i \qquad (1)$$

Shannon's entropy is considered as the measure of the information uncertainty[7].

2.1.2 Image Entropy

Digital image is composed of pixels. Given $f(i, j)$ is the grey level of pixel (x, y), clearly $f(x, y) > 0$, for an image of dimension $M \times M$,defining the relationships

$$H(f) = -\sum_{i=1}^{M}\sum_{j=1}^{M} p_{ij} \log_2 p_{ij}, \quad p_{ij} = \frac{f(i, j)}{\sum_{i=1}^{M}\sum_{j=1}^{M} f(i, j)} \qquad (2)$$

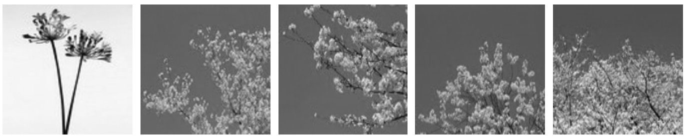
Where $H(f)$ is the image entropy, in which p_{ij} is the grey level probability distribution.

Because the entropy value corresponds to the distribution level of the image greyness, the greater the partial entropy, the better distribution the grey level. It does not influence its grey level itself, so we can make use of its partial entropy value to segment uniform objects. This segmentation method is not sensitive to a single pixel noise, because all its pixels contribute to the partial entropy in the window, which thus becomes a filter.

Equation (2) needs enormous calculation because it involves logarithm calculation, speed is low. From Equation (2) we can know, $P << 1$, therefore we can expand equation (2) using Taylor and rounding the higher terms to get an approximate equation as followers

$$H(f) \approx -\sum_{i=1}^{M}\sum_{j=1}^{M} p_{ij}(p_{ij} - 1) = 1 - \sum_{(i,j)\in(M,M)} P_{ij}^2 \qquad (3)$$

Equation (3) only includes $M \times M$ terms of multiplication addition and its calculation speed is faster than equation (2).



(a) (b) (C) (d) (e)

Figure.1 flowers images entropy

Computing with equation (3), we can easily get image entropy of five sequent flowers (Fig.1) as 2.2337，3.3162，3.4761，3.2481，3.5932. We can see that in vision the more similar two images are, in computing the closer image entropy two images have. Image entropy is represented image colorful statistics information, and it can also be describing and extracting image attribution feature [8].

2.2 Image fractal coding

Fractal image coding makes good uses of image self-similarity in space by ablating image geometric redundant. Fractal coding process is quite complicated but decoding process is very simple, which makes use of potentials in high compression ratio. The main theory of fractal image coding is based on iterated function system, attractor theorem, and collage theorem. Regard original compressible image as attractor, how to get LIFS parameters is main problem of fractal coding. We explain the basic procedure for the fractal image coding [9].

1.A given image I is divided into non-overlapping M range blocks of size $B \times B$ and into arbitrarily located N domain blocks of size $2B \times 2B$. The range blocks are numbered from 1 to M , and represented by $R_i(1 \le i \le M)$. Similarly, the domain blocks are from 1 to N, and represented by $D_j(1 \le j \le N)$.

2. For each range block R_i, the best matched domain $D_k(1 \le K \le N)$ and an appropriate contractive affine transformation τ_{ik} which satisfy the following equation are found as

$$d(R_i, \tau_{ik}(D_k)) = \min d(R_i, \tau_{ij}(D_j)) \quad (4)$$

Where τ_{ij} is an contractive affine transformation from the domain block D_j to the range block R_i; the distortion measure $d(R_i, \tau_{ij}(D_j))$ is the mean square error (MSE) between the range block R_i and the contractive domain block $\tau_{ij}(D_j)$. The contractive affine transformation τ_{ij} is composed of two mappings ϕ_j and θ_{ij} as follows:

$$\tau_{ij} = \theta_{ij} \circ \phi_j \quad (5)$$

The first mapping ϕ_j is the transformation of domain-block size to the same size as range blocks. This transformation can be described as follows: The domain block D_j is divided into non-overlapping unit blocks of size 2×2; and each pixel value of the transformed block $\phi_j(D_j)$ is an average value of four pixels in each unit block in D_j. The second mapping θ_{ij} consists of two steps: The first step transforms the block $\phi_j(D_j)$ by one of the following eight transformations: rotation around the center of the block $\phi_j(D_j)$, through 0^0,$+90^0$,$+180^0$, and $+270^0$ and each rotation after orthogonal reflection about mid-vertical axis of the block $\phi_j(D_j)$.Those eight transformations are called isometries. The second step is the transformation p_{ij} of pixel values of a block obtained by the first step. This transformation p_{ij} is defined as

$$p_{ij}(v) = s_{ij}v + h_{ij} \quad (6)$$

where v is a pixel value of the block obtained by the first step, and the parameters s_{ij} and h_{ij} are computed by the least square analysis of pixel values of the range block R_i and the block obtained by the first step. We call the parameters s_{ij} and h_{ij} a scaling coefficient and an offset, respectively.The LIFS parameters listed below are encoded:

- Parameters to indicate a location of the best matched domain block;
- A parameter to indicate an isometric on the best matched domain block;
- A scaling coefficient and an offset.

The proposed method quantizes these LIFS parameters [10].

3 Our Proposed Algorithm

Combined with image entropy and fractal coding, our proposed image retrieval algorithm is as follow.

Step1. the inquired image is encoded by Jacquin fractal coding with 4×4 fixed child block, and then IFS code of the inquired image's is obtained. Moreover, we use equation (3) to calculate the information entropy of the inquired image and the fixed setup threshold is got.

Step2. compared with the inquired image entropy, if current database image entropy computed by equation (3) exceeds the fixed setup threshold, they are not of the same kind and current database image does not satisfy with the retrieval require, thus we choose next image in the database. Otherwise goto Step 3 until the database image is ended.

Step3. current database image is as original image for the inquired image IFS code to be decoded with tenth fractal iteration, and fractal decoded image is obtained. The Euclidean distance computed between the decode image and the inquired image is measure of two image similar metric. We choose next image in the database then goto Step 2.

Here, consumed the inquired image is I_q with the fixed size $M \times M$, the decoded image is I_P with the same size, P is the number of the database images. Their image Euclidean distance is defined as

$$D(p,q) = \sum_{i=1}^{M}\sum_{j=1}^{M}\sqrt{(I_p(i,j) - I_q(i,j))^2} \quad (7)$$

Step4. These computed Euclidean distances are descending sorted and the smallest or the smaller distance of the first N number images are as the inquired image's same or the similar images. Retrieval process is done.

4 Experimental Results and Discussion

All the experiments are carried out on a computer with Intel 2.5Ghz and 1GB RAM in the Win2000 professional operating system and Matlab7.0 language is used. The inquired image is classical 128×128 grey-level flying eagle image coded with 8 bits per pixel. This image database has 500 images, classified into four categories including birds, insect, domestic animals and scene to verify our retrieval scheme credible and wide application. Each image in database is first tailored to the size for 128×128 for evaluating our retrieval approach. Estimation way of retrieval result is shown in Ref[11] as follows. Assume the total number of the image database is P, according to each image i in database, we list out $N_i(1 \le i \le P)$ images similar with the inquired image artificially. According to each input inquired image q, we retrieval out $N_q + t$ images which are similar to the image q, here t is setup retrieval allowance in advance. If there are n_q similar retrieval images, so retrieval efficiency N_r is defined as

$$N_r = \frac{\sum_{q=0}^{p} n_q}{\sum_{q=0}^{p} N_q} \qquad (8)$$

The value of N_r is directly represented image retrieval efficiency. Fig.2 shows that the inquired image is a flying eagle. Fig.3 shows that our retrieval output with the first twelve images.

Fig.2 the inquired image

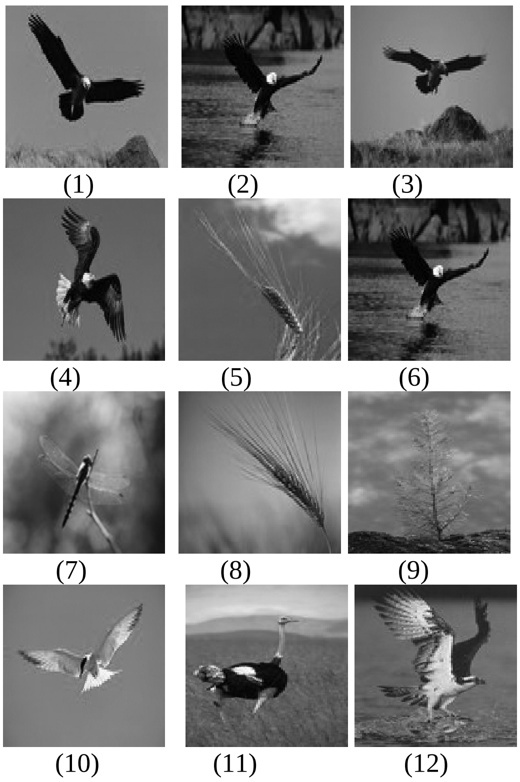


Fig.3 twelve similar retrieval images with our scheme

We can see from Fig.3 that the smaller Euclidean distance between the retrieval image and the inquired image, the more similar two images are. Among twelve retrieval images, there are seven images of the same bird kinds. With our retrieval method, we can retrieval out the same kind or the same contend-based image from the inquired image, thus our retrieval method is stabilized. Table.1 gives the experimental data our retrieval scheme comparison with the direct pixel similar matching strategy (directly standard deviation of the two original images is computed as their image Euclidean distance).

Table 1. Retrieval performance comparison with two methods

Method / performance	the direct pixel similar matching strategy	Our retrieval strategy
Retrieval time	**150 S**	**82 S**
Retrieval efficiency	**82%**	**75%**

Experimental results show that our retrieval scheme mainly guarantees the retrieval accuracy and can significantly reduce the computing retrieval time. The image database is classified in advance by matching the image entropy between the current database image and the inquired image. Moreover, the inquired image is encoded with fractal coding only once, matched parent block definition lies in the inquired image itself, and image tenth iteration decoding process is fast. Each image computing time is 2 seconds with the direct pixel similar matching strategy while in our scheme each image computing time is 1.2 seconds on average, which improves retrieval speed evidently.

5 Conclusion

In this paper, we proposed a novel image retrieval method using image entropy and fractal coding. Each image in database is classified by computing its image entropy compared with the inquired image entropy, and the same kind of images is as the original image to be fractal iteration decoded with the inquired image fractal IFS coding, and final similar matching lies in the decoded image and the inquired image. Compared with the direct pixel similar matching strategy, our retrieval scheme mainly guarantees the retrieval accuracy and reduces the computing retrieval time significantly. How to setup experimental matching image entropy threshold and how to choose effective similarly measure of two images combined with the fractal coding feature is our future research work.

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