

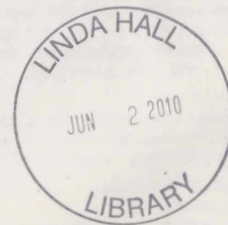
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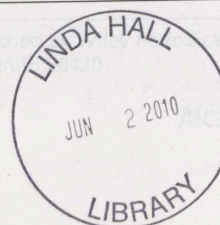
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◆ Facial Image Recognition Based on Fractal Image Encoding

Xiutao Tang and Cuilu Qu

Fractal image encoding uses self-similarity to encode an image. Utilizing this feature, a new method of facial image recognition based on fractal image encoding is examined. Fractal image encoding can approximate any given image by capturing intrinsic self-similarity within the image. This method has some invariance to rotation, scaling, translation, and luminance. The method encodes an image of record through the use of an encoding dictionary composed of images in a face image database. The fractal codes are then placed in a file, and the fractal codes are iterated multiple times to obtain decoding images. By comparing the peak signal-to-noise ratio of the image of record to all the decoding images, the image in the image database whose decoding image minimizes this norm is the recognized image. By experiment, the recognition performance achieved by this new method posted an average recognition rate of 94.54 percent on the publicly available database of faces hosted by the Cambridge University Computer Laboratory Digital Technology Group, when facial images at a side profile orientation are within 15 degrees of a full frontal image. © 2010 Alcatel-Lucent.

Introduction

Facial image recognition relies significantly on the application and development of pattern recognition algorithms. At present, most of the research work in this area is only at the beginning stage. Facial image recognition presents many difficulties, as described in [2]. For example, the face is not a rigid entity; it contains complicated and abundant expression, so strict feature matching is ineffective. In addition, the data associated with a facial image is usually quite substantial, so storage requirements for input data can be considerable. In fact, if the face pattern is unrestricted, input data may assume exponential proportions.

There are two methods by which a computer can recognize a facial image: first, via local features and relationships such as eyes, nose, and mouth [8, 9], and second, by a statistical analysis of facial features as

a whole [3, 5]. To date, the global facial expression has proven to be of only limited use in facial image recognition.

Teewoon Tan developed a face image recognition method based on fractal image encoding [4]. He first proposed that an "image of record" could be matched with another facial image in a face image database. All facial images in the face image database were then encoded, and the fractal codes were saved within the database. For the process of recognition, fractal codes were iterated a single time to obtain decoding images, and the decoding images were then compared to the neighbor distance of the image of record to obtain image recognition. The main idea was to filter high frequency information such as changes of expression through fractal encoding and a single iterative decoding,

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and then to compare the difference between the two facial images. Although this method filters high frequency information by fractal transformation, the recognition rate is not significantly improved.

Utilizing the feature of self-similarity, a new method of facial image recognition based on fractal image encoding is studied. This method encodes an image of a face for the purposes of recognition through the use of an encoding dictionary composed of all images in the facial image database. Fractal codes for the image are placed in a file, and the codes are iterated multiple times to obtain decoding images. By comparing the peak signal-to-noise ratio (PSNR) of the image of record to all the decoding images, the image in the image database whose decoding image minimizes this norm is the recognized image. By experiment, the recognition performance of this new method achieved an average recognition rate of 94.54 percent using the publicly available Cambridge University database of faces [1], when the face's side profile image was within 15 degrees of a full frontal image.

Principle of Fractal Image Encoding

Through research and analysis of a large number of images, Wei, Shen, and Li have shown in [6] that there is self-similarity between a local image and an image as a whole, as well as self-similarity in different parts of an image. Fractal image encoding develops an iterative function system (IFS) [7] by focusing on the self-similarity in the image. The process of developing an IFS for the image begins by creating a sub-block self-affine contraction to approximate another sub-block in the image. The decoding process utilizes the collage theorem to enable the IFS that can capture the image to iterate the initial image multiple times to reconstruct an approximate image.

To obtain the IFS of an image, we divide the image into non-overlapping range blocks. For each range block, we then search the domain block that is most similar to the range block by affine transform and gray transform.

Basic Algorithm of Fractal Image Encoding

The fractal image encoding algorithm is as follows:

1. The image is divided into non-overlapping blocks of size $B_{\max} \times B_{\max}$, named range blocks.

Panel 1. Abbreviations, Acronyms, and Terms

IFS—Iterative function system

PSNR—Peak-signal-to-noise ratio

rms—Root mean square

2. The image is divided into non-overlapping blocks of size $D_{\max} \times D_{\max}$, named domain blocks, usually $D_{\max} = 2B_{\max}$.
3. Block D_i , of size $D_{\max} \times D_{\max}$ is transformed and classified into three major categories and 24 sub-categories by the gray value and the variance of block D_i .
4. Each range block R_i is classified into three major categories and 24 subcategories by the gray value and the variance of block R_i . Next, search for the block D_j which can match block R_i best (usually there are many D_j blocks in the same class) from the same class of block R_i and compute the *rms* between the best matching block D_j and block R_i . If the *rms* is smaller than the given value, record the related parameters.
5. Otherwise, divide block R_i by a quad tree, and return to step 3.
6. End.

As shown in **Figure 1**, Image A is the image of record. Image B and Image C are other images in the facial image database. Image B is the same person as Image A with a different posture. Image C is a different person from Image A.

1. Image A uses itself as the encoding dictionary and generates fractal codes.
 - Image (a-1) is the decoding image that iterates fractal codes one time,
 - Image (a-2) is the decoding image that iterates fractal codes two times,
 - Image (a-3) is the decoding image that iterates fractal codes three times,
 - Image (a-4) is the decoding image that iterates fractal codes five times.
2. Image A uses Image B as the encoding dictionary and generates fractal codes.
 - Image (b-1) is the decoding image that iterates fractal codes one time,

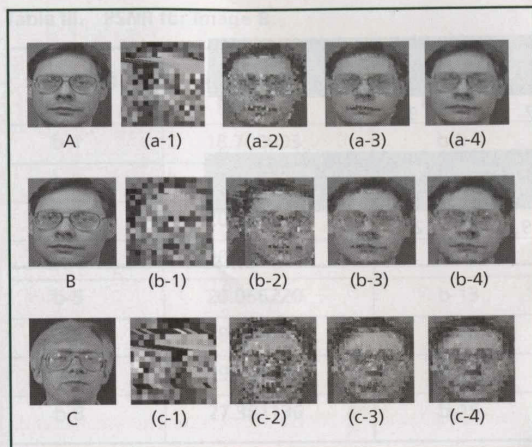


Figure 1.
Facial image recognition based on fractal image encoding.

- Image (b-2) is the decoding image that iterates fractal codes two times,
 - Image (b-3) is the decoding image that iterates fractal codes three times,
 - Image (b-4) is the decoding image that iterates fractal codes five times.
3. Image A uses Image C as the encoding dictionary and generates fractal codes.
- Image (c-1) is the decoding image that iterates fractal codes one time,
 - Image (c-2) is the decoding image that iterates fractal codes two times,
 - Image (c-3) is the decoding image that iterates fractal codes three times,
 - Image (c-4) is the decoding image that iterates fractal codes five times.

After five iterations of the same person with different facial images—detailed in step 2 above, where Image A uses Image B as the encoding dictionary—the decoding image, image b-4, is very similar to Image A, which is the image of record. However, given the images of two different persons—where Image A uses Image C as the encoding dictionary—the decoding image, image c-4, is unclear, and there are many small blocks in the image.

Table I. PSNR calculations.

	Image (a-4)/ Image A	Image (b-4)/ Image A	Image (c-4)/ Image A
PSNR	34.215244	25.437908	17.738887

PSNR—Peak signal-to-noise ratio

We then compute the PSNR, as shown in **Table I**. The PSNR between image (a-4) and Image A is 28.76, while the PSNR between image (b-4) and Image A is 23.73. Meanwhile, the PSNR between image (c-4) and Image A is 17.59. Image A is the image of record in the image database, while Image B is obviously the “recognized” image. By using the PSNR, we can recognize images of the same person with different expressions and different postures.

Face Image Recognition: Experiment Steps

Cambridge University maintains a database of faces containing a set of facial images captured between April 1992 and April 1994 [1], which was used in the experiment. There are 400 facial images of 40 persons with different expressions and different postures. **Figure 2** provides a representative sample of images.

Steps:

1. The image of record is the input image, and the images in the image database are the encoding dictionary (assuming there are n images in the database). The image of record is encoded by an encoding dictionary composed of images in the image database, which then provides n “.dat” files.
2. The n “.dat” files are iterated five times by the fractal image decoding program, which provides n decoding images.
3. The method of image recognition:

The PSNR—the peak signal-to-noise ratio between the image of record and the decoding image—is the quantitative measurement. The images whose PSNR is higher than the threshold value are the recognized images. If all PSNR values are lower than the threshold value, then there is no image of the same person with an image of record in the face image database.

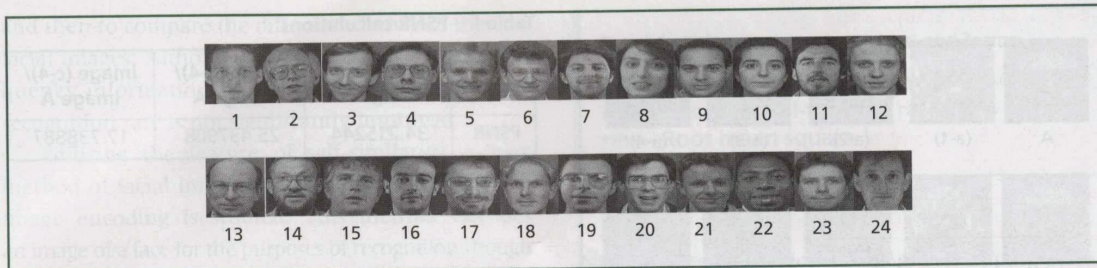


Figure 2.
Images in the image database.

$$PSNR = 10 \log_{10} \frac{M \times N \times 255^2}{\sum_{m,n} (s_{m,n} - \bar{s}_{m,n})^2} \quad (1)$$

$s_{m,n}$ is the gray value of the (m, n) pixel of the image of record, $\bar{s}_{m,n}$ is the gray value of the (m, n) pixel of the decoding image in the database, M is the height of the image, N is the width of the image.

Experiment Results

As shown in **Table II**, since the PSNR between image (a-24) and Image A is the highest, image (a-24) is obviously the recognized image of Image A. That is, image (a-24) is the same person who appears in

Image A with a different expression and different posture. As shown in **Table III**, since the PSNR between image (b-8) and Image B is the highest, image (b-8) is the recognized image of Image B. That is, image (b-8) is the same person who appears in Image B, with a different expression and different posture.

The time necessary for recognition is shown in **Table IV**.

Facial image recognition based on fractal image encoding compares favorably to the 94.54 percent recognition rate for images within the Cambridge University database of faces, with a side profile facial orientation within 15 degrees of a full frontal image.

Table II. PSNR for Image A.

Decoding image	PSNR with Image A	Decoding image	PSNR with Image A	Decoding image	PSNR with Image A
a-1	19.816535	a-9	19.970701	a-17	20.264797
a-2	22.508474	a-10	19.452519	a-18	17.744489
a-3	20.482979	a-11	21.286626	a-19	20.531052
a-4	20.190718	a-12	19.818913	a-20	21.079812
a-5	18.050826	a-13	17.211404	a-21	19.391354
a-6	16.788616	a-14	19.881216	a-22	20.618953
a-7	21.518394	a-15	21.392740	a-23	19.515317
a-8	18.573199	a-16	22.135498	a-24	23.953833

PSNR—Peak signal-to-noise ratio

Table III. PSNR for Image B.

Decoding image	PSNR with Image B	Decoding image	PSNR with Image B	Decoding image	PSNR with Image B
b-1	18.700903	b-9	21.834658	b-17	20.410737
b-2	20.115239	b-10	19.723254	b-18	19.514059
b-3	20.556330	b-11	21.773027	b-19	19.224120
b-4	20.683712	b-12	20.226770	b-20	19.582266
b-5	20.066220	b-13	15.855981	b-21	19.715886
b-6	19.420714	b-14	19.583121	b-22	19.370194
b-7	19.739001	b-15	20.158694	b-23	20.067946
b-8	27.381136	b-16	19.386892	b-24	20.486557

PSNR—Peak signal-to-noise ratio

Table IV. Time required for recognition.

Number of images in the image database	Time required for recognition (seconds)
50	9.64
100	16.905
200	33.421
300	45.515
400	66.468

Conclusions

This paper studies a new method of facial image recognition based on fractal image encoding. The method takes an image of record and encodes it via an encoding dictionary composed of images in a face image database to obtain fractal codes, which are then placed in a file. We iterate the fractal codes multiple times to obtain a decoding image, and then compare the PSNR between the image of record and the decoding images. The experiment shows that the method provides a favorable rate of recognition since it uses self-similarity within the facial image to eliminate the effects of expression and posture.

Acknowledgements

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Table II. PSNR for Image 2

Image	PSNR
Image 1	18.70093
Image 2	20.50346
Image 3	20.66520
Image 4	19.43016
Image 5	19.73901
Image 6	22.98116

Table III. PSNR for Image 3

Image	PSNR
Image 1	18.70093
Image 2	20.50346
Image 3	20.66520
Image 4	19.43016
Image 5	19.73901
Image 6	22.98116

Conclusions

This paper studies a new method of facial image recognition based on fractal image encoding. The method takes an image of a face and converts it to an image of a fractal. The fractal image is then encoded using a fractal image encoding algorithm. The encoded image is then compared with a database of encoded images to find a match. The method is shown to be effective in recognizing faces.

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