REGION-BASED FRACTAL IMAGE COMPRESSION WITH QUADTREE SEGMENTATION

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ABSTRACT

Fractal image coding is a novel technique for still image compression. In this paper, a low bit rate region-based fractal image compression algorithm is proposed, several techniques are included as follows. First, we improve the performance of quadtree segmentation by adaptive threshold. Then, a merging scheme is employed to the resulting quadtree segmentation that combines several similar blocks into a small number of regions. We also provide a quadtree-based segmented chain code to efficiently record the contours of the regions. The experimental results show that the proposed scheme has the lowest bit rate among the existing schemes at the same level of image quality.

1. INTRODUCTION

Fractal image compression, which is based on the IFS (iterated function system) proposed by Barnsley [1], is a novel approach to image coding. Its performance relies on the presence of self-similarity between the regions of an image. Since most images process a high degree of self-similarity, fractal compression contributes an excellent tool for compressing then.

Recently, there are several methods [2-5] subsequently proposed to improve the performance of fractal image compression. In the range and domain block mapping, several other functions have been proposed in the literatures. Besides, various approaches were also proposed to reduce the searching within the domain pool. Among all fractal block coding schemes, the technique of variable-size blocking is included to compromise the compression ratio and the level of quality.

Range block segmentation is important to coding image for saving bit rate. Quadtree segmentation is a common method to partition image, since its flexibility and less overhead. Region-based segmentation is a more effective alternative then quadtree segmentation, however, we have to encode the shapes of all the regions located. In this paper, a low bit rate region-based fractal image compression algorithm is presented. It has low bit rate because the rate-distortion tradeoff is carefully considered, especially, the redundant coefficients are removed by the region-based technique. First, we improve the performance of quadtree segmentation by adapting the threshold values among each level of the quadtree. Then, an merging algorithm is designated to the resulting quadtree segmentation that combines several similar blocks into a small number of regions. To coding the shapes of the regions, we provide a quadtree-based segmented chain code to efficiently record the boundary of the regions. The details are in the following sections.

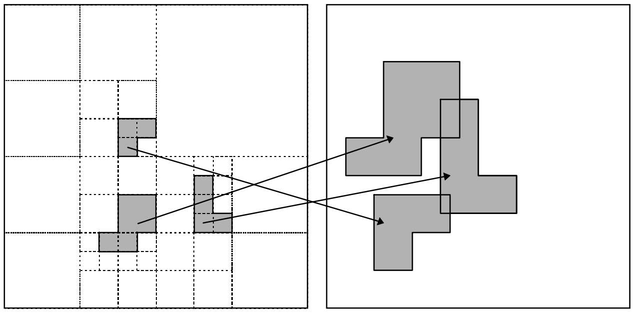
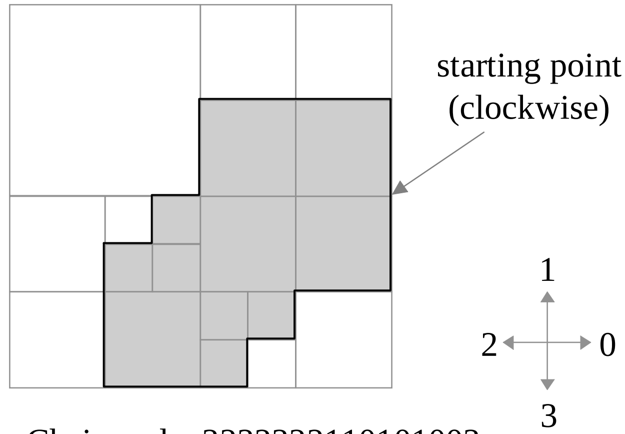


Figure 1: The mapping of region-based affine transformations.



Chain code: 3232322110101003

Figure 2: Quadtree-based chain code.

2. THE ADAPTIVE THRESHOLD QUADTREE SEGMENTATION

The first step of the compression makes use of quadtree segmentation to split image into variable-size blocks. Shusterman and Feder [6] proposed a scheme of compressing image via quadtree segmentation. They proved that if we use adaptive threshold on each quadtree level, the coding quality will be better than that with the fixed threshold, at the same bit rate. Suppose that the quadtree threshold is of the form

$$e_i = k \cdot e_{i-1}.$$

When k = 1, the threshold is fixed; when k = 2, it is the case proposed by Shusterman and Feder. We applied the same technique in quadtree-based fractal coding. From the experimental results, the result of k = 2 is always better than the results of the other cases at various bit rates. The consequence is not surprising because such thresholding has the close correlation with the coding area on the same quality level.

3. THE REGION-BASED FRACTAL IMAGE COMPRESSION

After the quadtree segmentation, a merging scheme is employed to the resulting quadtree segmentation that will combine several analogous surrounding blocks into a region. The mapping between the domain and range of each affine transformation is illustrated in Figure 1.

The merging procedure is as follows. Initially each block is a region. For each region-pair (R_i, R_j), if R_i and R_j are adjacent, merge R_i and R_j geometrically, denoted the result as $R_M = (R_i, R_j)$. We then calculate the coefficients of iteration function system and the corresponding error for R_M. The region-pair with the lowest error will be truly merged. And the merging process continues until the error is greater than a selected threshold T. This threshold T can be used to predict the resulting quality of the decoded image after merging. In our experience, if we set $T = N$ dB, the quality of decoded image is usually within the range [N, N-1] dB.

4. THE REPRESENTATION OF CONTOURS OF REGIONS

On common approach to represent the shape of a region is by using the *chain code*. The *segmented chain code* proposed by Kaneko and Okudaris [7] is an efficient encoding scheme. It can compress the standard chain code up to 50%.

Image	quadtree code	QBSCC	coefficients	total bits	bit rate (bit/pixel)	PSNR
Lena	2220	7034	14246	23500	0.0896	29.08
Peppers	2936	10306	20559	33801	0.128	28.67

Table 1: Results of 512×512 Lena and Peppers.

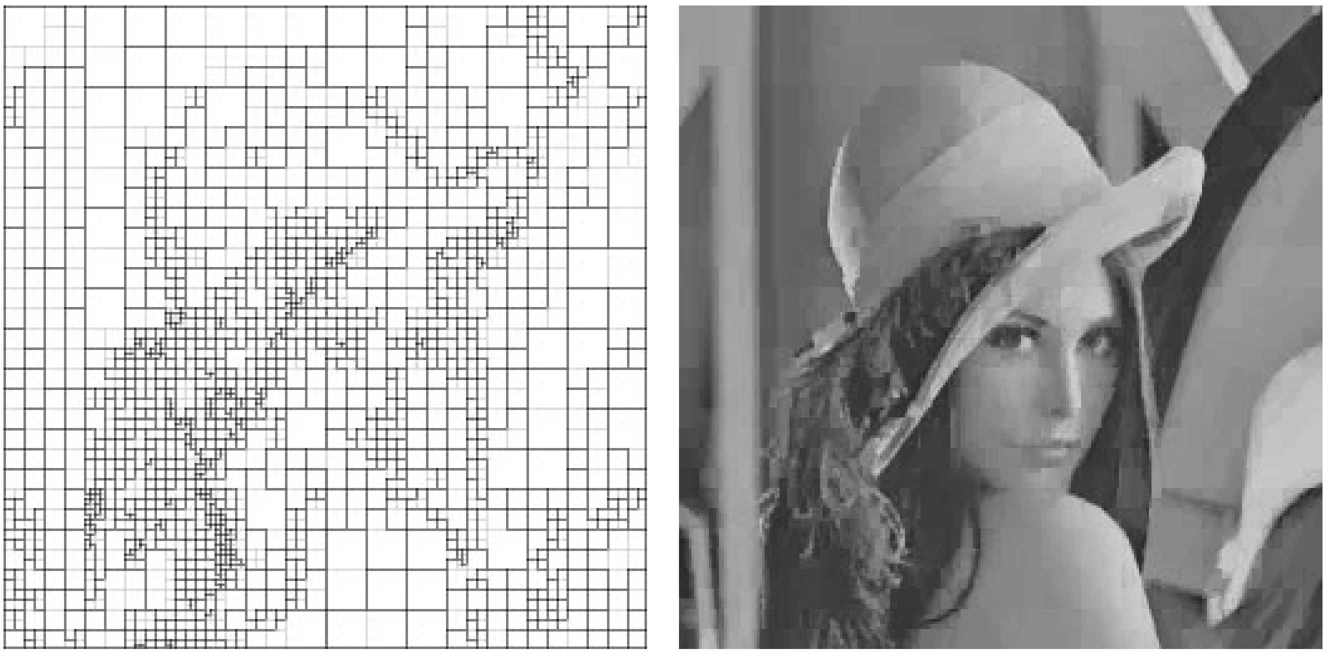


Figure 3: The region-based segmentation and the reconstructed image for the 512×512 Lena image at bit rate = 0.09 with PSNR 29.08 dB.

In traditional 4-directional chain code, a rectangular grid is superimposed on the contour. In this paper, we use quadtree block instead, see the illustration in Figure 2. Unlike 4-directional standard chain code, the length of a link is variable, depending on the distance between two end points on quadtree segmentation. To efficiently code the quadtree-based segmented regions, the tracing method proposed in [8] is thereupon applied to traverse region contours. Besides, the resulting chain codes are further compressed by entropy coding. This coding method is denoted as quadtree-based segmented chain code (QBSCC). The method QBSCC is more effective, it can compress the standard chain code up to 70%.

5. EXPERIMENTAL RESULTS

We conducted several experiments on 8-bit gray level 512×512 images. First, follows the method in Section 2, the image is segmented into several variable-size blocks. The threshold parameter of quadtree k is set as 2. The largest block size is limited to 32×32 and the smallest block size is at least 4×4. Then, we regard every resulting block as a region and apply the merging procedure on these regions until the resulting merged image with the predicted PSNR less than 29.5.

Name	PSNR (dB)	Bit rate (bit/pixel)	Bibliography
Thomas	27.7	0.29	[1]
Lu	28.7	0.29	[2]
Fisher	29.2	0.21	[3]
Chang	29.2	0.19	[4]
Ours	29.0	0.09	

Table 2: The comparisons of various fractal image coding schemes for Lena image.

The initial threshold of quadtree e_1 is less sensitive with the coding quality, except e_1 is set too large such that the total error of the initial segmentation is great than the merging threshold. The experimental results for Lena and Peppers are listed in Table 1.

Figure 3 illustrates the segmentation and reconstruct image for Lena. Each dash line in the segmentation image means a merging region. Since Peppers has more complicated background details, thus has more 300 resulting regions than Lena, so the bit rate can not decline too much. Table 2 summaries the results of existing methods and our proposed method. In the case of PSNR = 29, our scheme has significant improvement. In other cases, we always have the lowest bit rate.

6. CONCLUSIONS

In this paper, a low bit rate region-based fractal image compression method is proposed, several techniques are included Along with our proposed quadtree-based segmented chain code to record the contours of regions, the bit rate is reduced to 0.09 bits/pixel at PSNR 29.0 dB for Lena. The experimental results show that the proposed scheme has the lowest bit rate among the existing schemes at the same level of image quality.

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