Advanced Fractal Image Coding Based on the Quadtrees

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Abstract

Fractal image coding simply based on quad tree is a unique technique for still image compression. Compared with other image compression methods, fractal image coding has the advantage of higher compression ratio, higher decoding speed and decoded image having nothing to do with the resolution of image. It spends too much time to look for the best matching R block on encoding. To improve the encoding speed, we must narrow the search range and improve the search skills to ensure the best match block falls within our range. In this paper, an advanced fractal image compression algorithm based on quad tree is proposed. First, we can improve the construction method of search attractor by constructing directly from the big D block, so it can save a lot of searching time in encoding. Second, the attractors can be self-constructed, so it is not happened that the attractor is not found in the traditional methods. Experimental result shows that the algorithm makes image coding faster and more efficiency.

Keywords: Image compression; Fractal; Quad tree; Coding

I. Introduction

The setting of the paper is given below. Section II shall introduce the basic fractal image coding based on quad tree. Section III shall describe our improvement. Then the experimental results of the proposed method shall be shown and compared with that of the traditional one in Section IV. Finally, Section V shall serve to present the conclusions.

II. Review of the Quad tree Approach

Quad tree segmentation is a unique technique that divides a gray level image into a set of homogenous regions. The segmentation represents into a tree, and each tree node has four children. When we decompose an image following this quad tree technique, we first assign the whole image to the root of the tree and test its uniformity. If the uniformity condition is not met, it is then quartered into four sub-images. These four sub-images have the same size and are associated with the four child nodes of the root. The uniformity of each sub-image will be tested next, and the sub-image will be subdivided repeatedly until the uniformity criterion is met or some minimum sub-image size has been reached and it has been proposed in Distasi R, Nappi M,(2006). A demonstration of the process is shown in Figure 1.

(a) The segmentation process

(b) The corresponding quadtree

Figure 1: Example of quadtree segmentation

Before division, we first set maximal and minimal depth of the quad tree and maximal allowable error to decide the number of ranges. Then, we continuously split a range into four square ranges of the same size by the quad tree method until minimal depth is met. An optimum matching block will be searched for each range on the level. If it is found, it can be marked as $R_i$ and the range corresponding with it can be marked as $D_i$ and the split is not done again. Otherwise they are further split into four ranges. This process continues until we get the maximal depth is met. It has been proposed in Erjun Zhao, Dan Liu, (2005), Tong Chong (2001).

III. The Proposed Method

A. The Proposed Algorithm

As mentioned above, the traditional method of fractal coding generally divides the original image into larger blocks $D_i$ and also divides the original image into smaller blocks $R_i$. Then classifies the blocks $D_i$ by the defined standard and searches the similar $D_i$ in the divided classes. It takes too much time in searching, and it is also the main reason of the long time in fractal coding. The algorithm of the paper
used is different from the traditional method. It divides the original image directly into larger blocks $D_i$, then classifies the blocks $R_i$ by the defined standard and searches the similar $R_i$ in the divided classes. Then it searches the attractor in the corresponding classes, if it does not find out the right $R_i$, searches the most similar $R_i$, and calculates the correctional value to construct the fictitious $\bar{R}_i$ and saves the correctional value, instead of searching the $R_i$ from the huge database. So it boosts the speed of the encoding. And the algorithm begins searching $R_i$ from the biggest block, and the traditional algorithm begins searching $R_i$ from the least block. Main step of the improved encoding algorithm is as follows:

Step I. First of all, the original image is segmented to determine $D_i$.
Step II. Then, directly split to locks to find the correct $R_i$ for each block.
Step III. Exchange and distribute the $D_i$ sub-blocks according to the block mean, and note the information of exchange. The block mean and exchange information are added as part of its code.
Step IV. Interchange $R_i$ according to the same method as step 3, and the exchange information is added as part of the it’s code.
Step V. Search the same block of $D_i$ in $R_i$ if find, continue next, if not find, look for the most similar block $R_i$, and calculates the correctional value to construct the fictitious $\bar{R}_i$, add the correctional value as part of its code.
Step VI. Repeat step 4 and 5 until it reaches the set of conditions.
Step VII. Encoding with the traditional fractal encoding method based on quad tree.

Main step of the improved decoding algorithm is as follows:
Step I. Read the encoding file by sequences. First, read the block mean of $D_i$ and its exchange information. According to the exchange information, we can get the sub-block mean with the original order.
Step II. Then read the correctional value and Interchange information of $R_i$ to calculate the mean of $R_i$.
Step III. Repeat step 2 until reaching the smallest block size.
Step IV. According to exchange information and the original mean, decoding with the traditional fractal decoding method based on quad tree.

B. Encode file format

Encode file format is shown as figure 2, which consists of 5 parts

![Figure 2: encode file format](image)

Part 1 is block classification information, which occupies 2 bytes.
Part 2 is judging information of initial $D_i$ block mean. Its each bit shows that the mean error of initial block is less than the given error or not. If 0, it is less than and indicates that the block pixel value equal the block pixel mean multiply by the size of block. If 1, it is larger than and indicates that the block...
should be further split into four small blocks. So the second part byte size is not fixed, its equal line number multiply by column number, and divided by 8.

Part 3 is judging information of square $R_i$ block mean. Its each bit shows that the mean error of $R_i$ block is less than the given error or not. Its value represents the same meaning as Part 2. Its byte size is not fixed too, which equal line number multiply by column number, and divided by 8.

Part 4 is the basic information of Original Square $R_i$ block, occupying 6 bytes. The first 4 bytes represent the mean of initial block, and following 1 byte represents position exchange information of initial block, the last 1 byte represents judging information of quad tree mean.

Part 5 is the cycle information of quad tree, occupying 4 bytes which represent the judging, correctional and exchange information of quartered squares individually. Correctional value is computed as follows:

$$C_i = E_{R_i} - \overline{E_{R_i}}$$

(1)

Where $E_{R_i}$ is the block mean of $R_i$ and $\overline{E_{R_i}}$ is computed as follows:

$$\overline{E_{R_i}} = 4 \times E_i \times \frac{E_i}{E_1 + E_2 + E_3 + E_4}$$

(2)

Where $E_1$, $E_2$, $E_3$, $E_4$ are mean of the original four sub-blocks mean.

So when decoding, the corresponding $E_{R_i}$ can be computed as follows:

$$E_{R_i} = 4 \times E_i \times \frac{E_i}{E_1 + E_2 + E_3 + E_4} + C_i$$

(3)

C. Exchange information format

There are eight special classification transformation methods known as the "reflection-rotation" transformation, shown in table 1. With the transformation methods, we can classify the blocks $R_i$ and reduce the searching time in encoding.

Table 1 eight "reflection-rotation" transformations

<table>
<thead>
<tr>
<th>ID</th>
<th>transformation matrix</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$\begin{pmatrix} 1 &amp; 0 \ 0 &amp; 1 \end{pmatrix}$</td>
<td>Rotation $0^\circ$</td>
</tr>
<tr>
<td>1</td>
<td>$\begin{pmatrix} 0 &amp; 1 \ -1 &amp; 0 \end{pmatrix}$</td>
<td>Rotation $90^\circ$</td>
</tr>
<tr>
<td>2</td>
<td>$\begin{pmatrix} -1 &amp; 0 \ 0 &amp; -1 \end{pmatrix}$</td>
<td>Rotation $180^\circ$</td>
</tr>
<tr>
<td>3</td>
<td>$\begin{pmatrix} 0 &amp; -1 \ 1 &amp; 0 \end{pmatrix}$</td>
<td>Rotation $270^\circ$</td>
</tr>
</tbody>
</table>
But in our methods, the encoding time is mainly used in calculating the correctional value, not in searching the similar block, so we don’t use the eight special classification transformation methods. To get the exchange information, first we divide the original image directly into four smaller blocks, shown in figure 3.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>X reflection</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-1</td>
<td>0</td>
<td>Y reflection</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>Y = X reflection</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>-1</td>
<td>Y = X reflection</td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3 the sequence of blocks

And then we define an array named as $A_1, A_2, A_3, A_4$, the value of $A_1, A_2, A_3, A_4$ are assigned with the corresponding mean value of block.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4 block exchange information

As shown in figure 4, the block exchange bit value is all set “0” first. We compare the $A_1$ value with the $A_2, A_3, A_4$, and set the exchange information in corresponding $6^{th}$, $5^{th}$, $4^{th}$ bit in figure 4. For example, if $A_1$ is smaller than $A_2$, then exchange the mean value of $A_1$ and $A_2$, and set “1” in the $6^{th}$ bit in figure 4, if $A_1$ is smaller than $A_3$, then exchange the mean value of $A_1$ and $A_3$, and set “1” in the $5^{th}$ bit, and so on. We compare the $A_2$ value with the $A_3, A_4$, and set the exchange information in corresponding $3^{rd}$, $2^{nd}$ bit in figure 4, and the exchange information of $A_3$ compared with $A_4$ is set in $1^{st}$ bit.
IV. Experimental results

We have made several experiments in MatLAB to code and to decode the original image “Lena” (256 x 256) by the traditional fractal and the advanced method on a microcomputer(PIV 2.4G,256MB). Experimental parameters and demands are listed as follows: Maximal size of a range: 32x 32; Minimal size of a range: 4x4. Under the same experimental conditions, the two methods can both reconstruct the original image well. Figure 5 is the image processing results. From Table 2, we can see that the advanced method provides significant improvement in encoding time, but the compression ratio decreased.

(a) Original image

(b) Reconstructed image with traditional method

(c) Reconstructed image with the improved method
V. Conclusions

In this paper, we have proposed an advanced fractal image compression algorithm based on quadtree, which construct search attractor directly from the big $D_i$ block. And if $D_i$ can not search the similar $R_i$, we searches the most similar $R_i$, and calculates the correctional value to construct the fictitious $\overline{R}_i$. Experimental results show that if the correctional value is reasonable, it could reduce the image distortion degree, and the algorithm makes image coding faster and more efficiency. Disadvantage of the advanced algorithm is that image compression ratio decreased Compared with the traditional method, and it is the direction of further research.

References

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