The Impact of Image Structure on the Fractal Image Compression (FIC)

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***Abstract*— The paper proposed an algorithm to reduce the long time that has been taken in the Fractal image compression (FIC) technique using of the impact of the image structure. After partition the image into small parts (ranges), the algorithm use a variance factor as a criteria to exclude the homogenous or flat regions from the search and matching process. Excluding homogenous or flat will affect the encoding time, compression ratio and the reconstructed image quality. Several gray images (256x256) have been tested, the tested images are partitioned into fixed (4x4) blocks and then compressed using visual C++ 6.0 code. The result shows the proposed algorithm is faster about 70% with a higher compression ratio and high-quality images than the traditional FIC.**

Keywords-Fractal; range block; partition; image compression; encoding time.

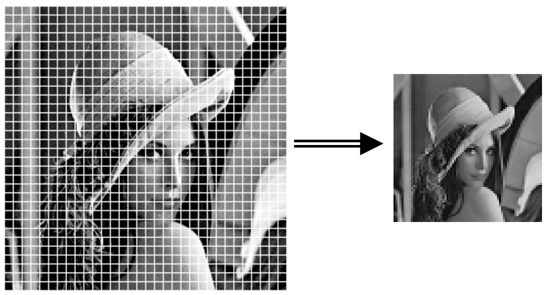
I. INTRODUCTION

The image compression is very important, it will lead to reduce the cost of storage and send data [1]. FIC is one of the techniques used for this purpose, This technique is based on the theory of Iterated Function System (IFS) and its performance relies on the presence of self-similarity between the regions of an image. Since most images possess high degree of self-similarity, fractal compression contributes an excellent tool for compressing them [3],[4]. FIC consists of finding a set of transformations that produces a fractal image which approximates the original image.

For encoding image, many main processes must be done. Firstly, range creating, the image must be partitioned into non-overlapping blocks (ranges) [2]. Secondly, domain creating, the domain is created through taking the average of every four (2 x 2) adjacent element in range to be one pixel in the domain, that means the size of domain image will be quarter size of the range [5]. Figure (1) shows an example of range and domain blocks size. Thirdly, matching process, for each range, the search process must be done to map each range and domain. For each domain block there are eight cases of the symmetries [6], affine transformation must be done on each domain blocks to find the best match (the error distance is minimized).

This method suffers from the length of time spent in the compression process because there are a huge number of mapping operations, as all over the range compared with all domains for each of eight cases of (8 symmetries) [7].

In decoder modules, the compressed image must be reconstructed from IFS-code, which is saved in codebook file. The reconstructed image starting from an arbitrary image and iterates these affine transformation parameters, according to the contractive mapping theory, the reconstructed image converges to attractor after some iteration.



Range pool Domain pool

Fig. 1 Construction domain block from the range block

II. IMAGE FEATURES

Any image has many different details regions, some of these regions may have some detailed information and some are have not (flat or homogenous) those regions where there is no gradation or that the gradation is not recognize with the naked eye, see Figure (2). Note facilitate homogeneous regions in the images that manufactured or installed by man, such as personal photos, which often contain areas of constant color, smooth as it is in the background. On the contrary, it is difficult to obtain a homogeneous 100% in natural images (landscape, etc.) such images may be reflected areas appear to the naked eye as a homogeneous or with a single color, but the arithmetic is not, the current research focuses on the exploitation of this principle , i.e., the exploitation of the regions that appear homogeneous to the naked eye and using them to speed up the process compression to the point FIC, so do not affect the quality of the image recovered after compression.

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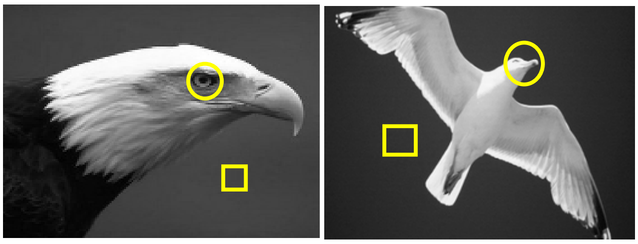


Fig. 2 Area inside the box is a homogenous region, while the region inside the circle contains different combinations

III. PROPOSED METHOD

In this work, many of ranges are excluding from process of matching with the 8 symmetries. A standard variance has been used to check the range area whether it is homogenous region or contains details. After the partitioning, the contents of each Range will be checked before starting the search operation to decide if it is a homogenous region or not using the variance criteria, in homogenous region the value of variance is about zero while it is increase in the areas with more details. The flat region means that all pixels of this region have the same value or are close to each other.

During the matching process of homogeneous ranges, cases of symmetries will be canceled and implemented it in other ranges (detail regions). There is no effect of symmetry operation on a flat region and this leads to reduce the huge amount of complex calculations, which lead to a quick completion of the compression process. In order to achieve the greatest benefit, the allowance of homogeneity is controlled by using several values of the variance; these values were named Homogenous Permittivity (HP) which represents the amount of homogeneity allowed. If the variance of any Range is zero, this means that all pixels of that Range is equal, then it will not enter in the search and matching operation and this range will be encoding only by saving it's mean value. Algorithm (1) utilized steps required to perform our Ranges Exclusion method.

Algorithm
Input: Image, HP
Output: IFS code (x, y, s, o, and symmetry)
Step1: Load the image into buffer
Step2: Partitioning the image into fixed blocks size with non-overleap (R1…Rn)
Step3: Generate the domain blocks (D1… Dm) from the original image by averaging method.
Step 4: Compute the mean for the current range block Ri according to equation:

$$Mr = \frac{1}{X_{size} \times Y_{size}} \sum_{i=0}^{X_{size}-1} \sum_{j=0}^{Y_{size}-1} X_{ij}$$

Step 5: Compute its variance according to equation:

$$Vr = \frac{1}{X_{size} \times Y_{size}} \sum_{i=0}^{X_{size}-1} \sum_{j=0}^{Y_{size}-1} \left[X_{ij} - Mr\right]^2$$

Step 6: If Vr = HP then save range's mean (Mr) and excluding this range from the mapping operation (jump to step 10) ,else jump to step 7.
Step 7:Do the mapping operation by:

- Compute the scale s and offset o coefficients according to equations:

$$S = \frac{\left[n\left(\sum_{i=1}^{n} d_i r_i\right) - \left(\sum_{i=1}^{n} d_i\right)\left(\sum_{i=1}^{n} r_i\right)\right]}{\left[n\sum_{i=1}^{n} d_i^2 - \left(\sum_{i=1}^{n} d_i\right)^2\right]} \text{ and}$$

$$O = \frac{\left[\sum_{i=1}^{n} r_i \sum_{i=1}^{n} d_i^2 - \sum_{i=1}^{n} d_i \sum_{i=1}^{n} d_i r_i\right]}{\left[n\sum_{i=1}^{n} d_i^2 - \left(\sum_{i=1}^{n} d_i\right)^2\right]}$$

- Quantize the s and o values
- Compute the approximation error E(Ri, Di; s, o) according to equation:

$$E(R,D) = \frac{1}{n}\left[\sum_{i=1}^{n} r_i^2 + S\left(S\sum_{i=1}^{n} d_i^2 - 2\sum_{i=1}^{n} d_i r_i + 2O\sum_{i=1}^{n} d_i\right) + O\left(nO - 2\sum_{i=1}^{n} r_i\right)\right]$$

- Compare the computed error with the minimum registered error (Emin): if E(Ri, Di; s, o)> Emin then jump to step 8, else
- Replace the Emin and store the current IFS code (i.e. x, y, s, o, and symmetry).

Step8: Repeat the step (7) for all symmetry versions of tested domain blocks.
Step9: Repeat step (7) to (9) for all domain blocks listed in the domain pool.
Step10: Get the next range.
Step11: Repeat step (4) to (9) for all range blocks listed in the range pool.

In order to get high speed FIC with more compression ratio and keep as much as possible the reconstructed image quality, different values of the variance are adopted in the present research

IV. RESULTS AND DISCUSSION

The program of FIC was applied to many images without check whether the image contains homogenous region or not (i.e. HP=0, the normal state), the results shown in figure (3-a). Then the modified FIC program was applied to the same images with HP=2, the compression ratio was increased to reach (5.534) and the time required has been reduced from (34 seconds) to (18 seconds).

The Original Image PEPPER image (File size: 64 kb)

The Reconstructed Image

(a) Traditional method

(HP=0)

Enco. time: 34 Sec.
PSNR 32.69 DB
C.R:5.12
File size: 12.5 kb

(b)

HP=4

Enco. time: 14 Sec.
PSNR 32.15 DB
C.R:5.65
File size: 11.33 kb

(c)

HP=30

Enco. time: 9 Sec.
PSNR 30.74 DB
C.R:5.82
File size: 10.99 kb

Fig. 3 Results of the impact of HP on the PEPPER image

The Original Image BIRD image (File size: 64 kb)

The Reconstructed Image

(a) Traditional method

(HP=0)

Enco. time: 34 Sec.
PSNR 30.30 DB
C.R:5.12
File size: 12.5 kb

(b)

HP=6

Enco. time: 13 Sec.
PSNR 29.92 DB
C.R:5.68
File size: 11.27 kb

(c)

HP=20

Enco. time: 9 Sec.
PSNR 28.69 DB
C.R:5.80
File size: 11.03 kb

Fig. 4 Results of the impact of HP on the BIRD image

The Original Image LENNA image (File size: 64 kb)

The Reconstructed Image

(a) Traditional method

(HP=0)

Enco. time: 35 Sec.
PSNR 32.22 DB
C.R:5.12
File size: 12.5 kb

(b)

HP=6

Enco. time: 12 Sec.
PSNR 31.51 DB
C.R:5.72
File size: 11.18 kb

(c)

HP=20

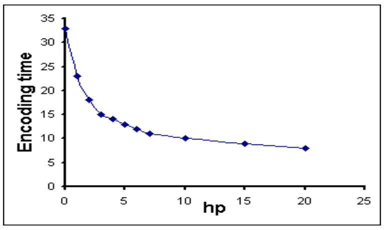
Enco. time: 9 Sec.
PSNR 28.69 DB
C.R:5.81
File size: 11.01 kb

Fig. 5 Results of the impact of HP on the LENNA image

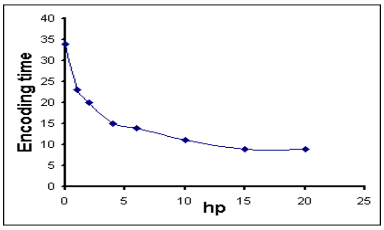
From the results shown in figure (3-b), when HP = 4 the compression ratio increase to (5.65) and the encoding time decrease to (14 seconds). When HP = 10 for the same image, the compression ratio increased to (5.747) and the time required for the compression has decreased to (11 seconds). When the value of HP = 30 the compression ratio increased to (5.82) with the loss in image quality recovered, but still high quality (30.74) and the time it takes to have decreased to (9 seconds) Figure(3-c). Compared to time-spent when HP = 0, a (34 seconds) we have obtained the proportion of speed about 70% of the compression process.

When performed the same steps for the rest of the images, Figures (4,5) shows some results obtained before and after using the HP and the values are different. Values used in the experiments ranged from 1 to 30 have been applied to all images.

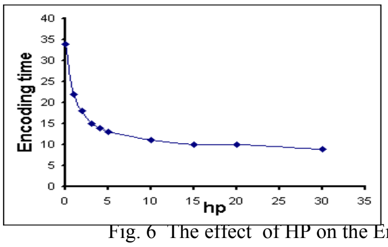
The data obtained from experiments, is plotted the relationship between the values of HP and time (Figure 6) as well as the relationship between HP and the quality of recovered image (Figure 7) and also the relationship between HP and the compression ratio (Figure 8).



LEENA image

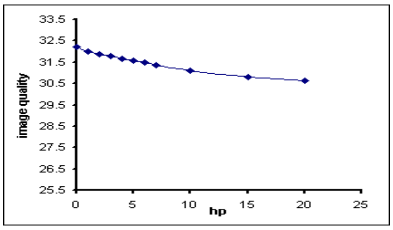


PEPPER image



BIRD image

Fig. 6 The effect of HP on the Encoding time



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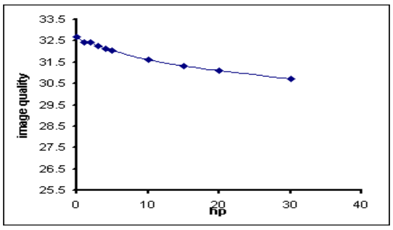
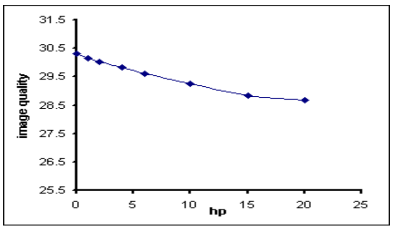
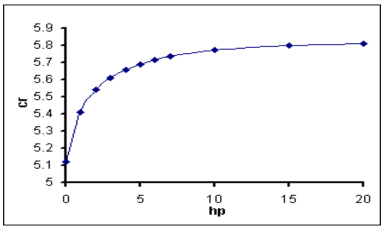


PEPPER image



BIRD image

Fig. 7 The effect of HP on the image quality



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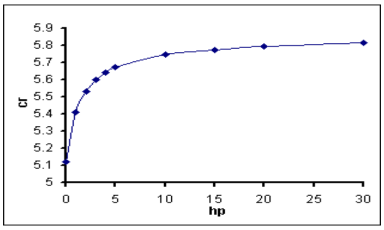
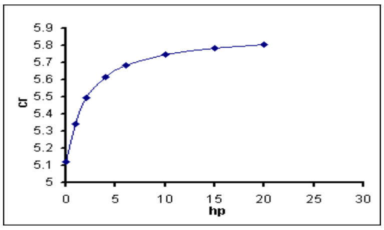


PEPPER image



BIRD image

Fig. 8 The effect of HP on the compression ratio

V. CONCLUSIONS

1. There was no fixed effect of the values of HP on the images, because each image's composition (different content), image of PEPPER have a number of homogeneous areas is different from the rest of the image regardless of the fact that the partitions are fixed for all images.
2. Experience has shown that before the use of an HP, the results represent the normal situation for the FIC process.
3. After you run the HP were excluded a number of range areas of the process of searching and matching in the compression algorithm.
4. The number of regions of the excluded area increases with increasing value of HP.
5. Experiments showed that an inverse relationship between HP and the time spent in the encryption process (Figure 4).
6. During the experiments show that there is an inverse relationship between HP and the quality of recovered image (Figure 5).
7. Experience has shown that the relationship direct correlation between HP and the compression ratio (Figure 6).

The use of a homogeneous permittivity HP has reduced the time spent in the encryption process by almost 70% with access to a higher compression ratio and image quality recovered.

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