# Effect Of Quantization Process On FIC For Gray Image by Using Zero-Mean Method

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**Abstract**: this work is show the effect of quantization on the reconstructed image in fractal image compression FIC method. it is based on zero-mean block matching method, at this method the mean of the range blocks is used instead of traditional offset parameter. This reduces and simplifies the computations of the affine parameters during the encoding process. This method is tested on 8 bits/pixel gray image. The test results conducted on Lena image indicated that the quantization increases compression ratio about (69.6%) and encoding time about (18.6%) but the decreases of PSNR around (0.3%), The quality of the reconstructed image is good either we use the quantization process or not used it.

***Key Words***: Image Compression, Quantization, fractal image compression, Zero-Mean

# دراسة تأثير عملية التكميم على الضغط الكسوري للصورة الرمادية باستخدام طريقة المعدل-الصفري

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**الخلاصة** تمت دراسة تأثير عملية التكميم على الصورة المسترجعة في ضغط الصور الكسوري FIC باستخدام طريقة المعدل الصفري ، في هذه الطريقة ( طريقة المعدل الصفري) تم استبدال معامل الاوفست التقليدي بمعامل جديد هو معامل معدل المدى .هذا يقلل من تعقيد البحث خلال عملية التشفير. تم استخدام الصورة لينا (8 بت) في الاختبارات التي تم إجراؤها، النتائج العملية أثبتت إن عملية التكميم تزيد في نسبة الضغط CR بمقدار(69.6%) وكذلك في زمن التشفيرET بمقدار (18.6%) ولكنها تؤدي إلى تناقص في قيمة الـ PSNR بحوالي (0.3 %)، ولكن على العموم فان جودة الصورة المسترجعة تكون تقريبا جيدة في الحالتين.

***كلمات مفتاحيه:***ضغط الصور،عملية التكميم ، ضغط الصور الكسوري، طريقة المعدل الصفري

## 1. INTRODUCTION

Quantization is the process of reducing the number of bits needed to store coefficient values by reducing its precision (i.e, rounding from float type to integer). The quantization process may be performed either by using uniform or non uniform method. at this research project, the uniform quantization was adopted, because it can be run faster than the other method. The IFS coefficients are real valued, so in order to increase the compression it must be quantized before storage. The quality of the reconstructed image depends on the quantization process. The change of numbers from real to integer leads to loss of more information. If this information loss is big, the quality of the reconstructed image will be worse. while, if the lost information is small ,the quality of the reconstructed image will be better and the compression ratio will be little.[Geor06]

## 2. IFS Coding for Zero-Mean Blocks

The traditional offset factor has wide dynamic range (-255,511). This may cause large errors in some image regions (or points), especially those which belong to high contrast areas. the analysis results is indicate the correlation between the offset coefficients of the adjacent blocks is week and it is not similar to that found between the average brightness of the adjacent blocks. Normally, the offset values of the block was correlated with average brightness values of blocks. So, to handle this disadvantage a change in IFS mapping equation was performed. For a range block with pixel values ($r_o,r_1,\ldots,r_{n-1}$), and the domain block ($d_o,d_1,\ldots,d_{n-1}$) the contractive affine approximation is [GeHi11]:-

$$\grave{r}_i = sd_i + o, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

$$\bar{r} = s\bar{d} + o, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

$$\bar{r} = \frac{1}{m}\sum_{i=0}^{m-1} r_i , \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

$$\bar{d} = \frac{1}{m}\sum_{i=0}^{m-1} d_i , \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

$$\acute{r}_i - \bar{r} = sd_i - s\bar{d}, \ldots \ldots \ldots \ldots \ldots (5)$$

So, this contractive affine transform could be rewritten to become in the form:-

$$\acute{r}_i = s\left(d_i - \bar{d}\right) + \bar{r}, \ldots \ldots \ldots \ldots (6)$$

From equation (6), the fractal parameters become ($s$) and ($\bar{r}$) instead of the conventional ($s$) and ($o$) coefficients in traditional IFS mapping equation. The scale ($s$) parameter could be determined by applying the least mean square difference ($\epsilon^2$) between the approximated ($\acute{r}_i$) and actual ($r_i$) values [Geor06]:

$$\epsilon^2 = \frac{1}{m}\sum_{i=0}^{m-1} (\acute{r}_i - r_i)^2, \ldots \ldots \ldots \ldots (7)$$

$$\frac{\partial \epsilon^2}{\partial s} = 0, \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

The straight forward manipulation for equations (7), (8) leads to:

$$s = \begin{cases} \dfrac{\frac{1}{m}\sum_{i=0}^{m-1} d_i r_i - \bar{r}\bar{d}}{\sigma_d^2} & if\ \sigma_d^2 > 0 \\ 0 & if \sigma_d^2 = 0 \end{cases} \ldots (9)$$

$$\epsilon^2 = \sigma_r^2 + s\left[s\sigma_d^2 + 2\bar{d}\bar{r} - \frac{2}{m}\sum_{i=0}^{m-1} d_i r_i\right], (10)$$

$$\sigma_d^2 = \frac{1}{m}\sum_{i=0}^{m-1} d_i^2 - \bar{d}^2 , \ldots \ldots \ldots \ldots (11)$$

$$\sigma_r^2 = \frac{1}{m}\sum_{i=0}^{m-1} r_i^2 , \ldots \ldots \ldots \ldots \ldots (12)$$

## 3. Quantization

The parameter ($\bar{r}$) has a smaller dynamic range [0,255] than the ($o$) parameter [-255,511]. So, in case of implementing quantization it is more cost effective (in terms of minimizing the quantization error) to code the quantization of ($\bar{r}$) than to encode the ($o$) parameter.

Before determination of the values of ($\epsilon^2$), the values of the scale ($s$) and range average ($\bar{r}$) coefficients should be limited and quantized as follows:

1. The value of the range average $\bar{r}$ should be bounded within the interval $\bar{r}_{\min} \le \bar{r} \le \bar{r}_{\max}$ , where $r_{\min}$ and $r_{\max}$ are the lower and upper boundaries of the permissible values of range average ; they should always be within the range [0,255].

2. Also, the values of scale ($s$) parameters should be bounded within the interval $s_{\min} \le s \le s_{\max}$ , where $s_{\max}$ and $s_{\min}$ are the lower and upper boundaries of the permissible values of the scale.
3. The coefficient $\bar{r}$ should be quantized by using the following equations [Geor06]:

$$Q_{\bar{r}} = \frac{(255)}{2^{b_{\bar{r}}} - 1}, \dots\dots\dots\dots\dots\dots\dots.\dots\dots (13)$$

$$i_{\bar{r}} = round\left(\frac{\bar{r}}{Q_{\bar{r}}}\right) \dots\dots\dots..\dots\dots\dots\dots\dots (14)$$

$$\bar{r}_q = i_{\bar{r}} Q_{\bar{r}}, \dots\dots\dots\dots\dots\dots..\dots\dots\dots\dots.\dots\dots (15)$$

where,
$b_{\bar{r}}$ is the number of allocated bits to represent the quantization index of the average brightness ($\bar{r}$) coefficient.
$Q_{\bar{r}}$ is the quantization step of the brightness ($\bar{r}$) coefficients.
$i_{\bar{r}}$ is the quantization index of the brightness ($\bar{r}$) coefficient.
$\bar{r}_q$ is the quantized value of the brightness ($\bar{r}$) coefficient.

4. The scale value should be quantized by using the following equations [Geor06]:-

$$Q_s = \begin{cases} \dfrac{s_{Max}}{2^{b_s - 1} - 1} & if\ \ s_{Max} = -s_{Min} \\ \dfrac{s_{Max} - s_{Min}}{2^{b_s} - 1} & if\ s_{Max} \neq -s_{Min} \end{cases} \dots (16)$$

$$i_s = round\left(\frac{s}{Q_s}\right), \dots\dots\dots\dots\dots\dots\dots.\dots. (17)$$

$$s_q = i_s Q_s, \dots\dots..\dots\dots\dots\dots\dots\dots\dots\dots\dots.... (18)$$

where,
$s_{Max}$ is the greatest permissible value of scale coefficient.
$s_{Min}$ is the lowest permissible value of scale coefficient.
$b_s$ is the number of allocated bits to represent the quantization index of the scale coefficient.
$Q_s$ is the quantization step of the scale coefficient.
$i_s$ is the quantization index of the scale coefficient.
$s_q$ is the quantized value of the scale coefficient.

## 4. Encoding in the Zero-Mean Method Process

Encoding in the zero-mean method could be summarized by the following steps [Hilo07] :-

A. *Loading image and put it in 2D array.*
B. *Establishing range image (array).*
C. *Down sampling range image to produce the domain array.*
D. *Partitioning*
   1. The range array must be partitioned into non-overlapping fixed blocks, for generate the range blocks ($r_1, \dots, r_n$).
   2. The domain must be partitioned into overlapping blocks, using specific step size, to generate the domain blocks ($d_1, \dots, d_n$), they should have the same size of range blocks.

E. *Searching*:-
   1. Calculating the range average $\bar{r}$ which is the average of each range block.
   2. Quantizing range average $\bar{r}$ according to equations (13-15).
   3. Picking up a domain block from the domain pool.
   4. Performing one of the isometric mappings.
   5. Calculating the scale ($s$) coefficient by using equation (9).
   6. Applying the following condition to bound the value of ($s$) coefficient:

*If $s < s_{min}$ then $s = s_{min}$*
*Else if $s > s_{max}$ then $s = s_{max}$*
*End if*

7. Quantizing the value ($s$) using equations (16-18).
8. Computing the approximate error ($\epsilon^2$) using equation (10).
9. After the computation of the IFS code and the sum of errors ($\epsilon^2$) of the matching between the range and the tested domain block that listed in the domain pool, the ($\epsilon^2$) is compared with registered minimum error ($\epsilon^2_{min}$); such that:

*If* $\epsilon^2 < \epsilon^2_{min}$ *then*
$s_{opt}=i_s$ ; $\epsilon^2_{min}=\epsilon^2$
*PosI=domain block index*
*Sym=symmetry index*
*End if*

10. If $\epsilon^2_{min} < \mathcal{E}$ then the search across the domain blocks is stopped, and the registered domain block is considered as the best matched block.
11. Repeating steps (4) to (10) for all symmetry states of the tested domain block.
12. Repeating steps (3) to (11) for all the domain blocks listed in the domain pool.
13. The output is the set of IFS parameters (*i.e.,* $i_s$ , $i_{\bar{r}}$, *posl, Sym*) which should be registered as a set of fractal coding parameters for the tested range block.
14. Repeating steps (1) to (12) for all range blocks listed in the range pool.
15. Storing all IFS mapping parameters as an array of record. The length of this array is equal to the number of range blocks in the range pool.

## 5. Decoding in the Zero-Mean Method Process

The decoding process by zero-mean method can be summarized in the following steps:-

1. Generating the first reconstructed domain pool, as a blank image or as a piece of any available image.
2. The values of the indices of ( $i_{\bar{r}}$) for the range blocks should be mapped (dequantized) to reconstruct the values of $\bar{r}$ by using the dequantization equations (13, 15).
3. The values of the indices of ($i_s$) for the range blocks should be mapped to reconstruct the values of ($s$) by using the dequantization equations (16, 18).
4. Choosing the value of the maximum possible iteration (m), and the value of the threshold of mean square error (TMSE), in our program used (m=20, TMSE=0.05). At each iteration do the following steps:

a. For each range block determine from its corresponding IFS parameter (*PosI*) the coordinates ($x_d$,$y_d$) of the best matched domain block in order to extract the domain block ($d$) from the arbitrary domain image.
b. Calculating $\bar{d}$ for the corresponding domain block.
c. For each range block, (its approximation $\acute{r}_i$) is obtained according to equation (4).
d. The generated $\acute{r}_i$ block is transformed (rotated or reflected or both) according to its corresponding IFS symmetry parameter value (*Sym*).
e. Putting the generated $\acute{r}_i$ block in its position in the decoded image plane (range image).
f. Checking whether there are other range blocks need to be reconstructed, If yes then repeat steps (c, d, e).
g. Down sampling the reconstructed image (range array) in order to produce a new domain array by using the averaging (or integer) sampling.

5. Calculating the mean square error (MSE) between the newly reconstructed range and the previous reconstructed range image. If the MSE is greater than the (TMSE) value then the iteration continues and the steps (a-g) should repeat; till reaching the attractor state (i.e., the reconstructed range image is very similar to the previous reconstructed image). Sometimes the iteration continues till reaching the predefined maximum number of iterations without the fulfilment of MSE stopping condition,
6. Calculating the quality measures for the reconstructed image.

## 6.Tests Results

This work is carried out in Visual Basic 6.0 version on Aser laptop with (2.20GHZ, RMA 956MB) Windows XP. To evaluate the performance of the established gray FIC system by Zero-Mean method, The proposed system has been tested using Lena image (256x256 pixel, 8bits) as test image. The value of the parameters MaxAvg ($\bar{r}_{max}$) and MinAvg ($\bar{r}_{min}$) were fixed in all these tests at (0) and (256) respectively. This set

of tests was conducted to study the effect of quantization on the reconstructed image. Quantization tests include the effect of the ScaleBits and AvgBits on the reconstructed image. In this set of tests the values of other coding parameters were taken as shown in table (1).

The listed results are show that quantization increases the compression ratio while causing an increase in PSNR. Table (2) shows the effects of the ScaleBits parameter on the compression performance parameters. Figure (1) shows the reconstructed images for the cases of using and not using quantization. Figures (2-8) show the effect of the AvgBits parameter on ET, MAD, MSE , BitRate, PSNR, CR, and CF, respectively.

In these tests the value of compression parameters are set: MinScale=-1, MaxScale =1, BlockSize =4x4, DomSize=(128x128), StepSize=2, $\varepsilon_o$=1, TMSE=0.05.

**Table (1) Effects of the ScaleBits parameter on compression performance parameters**

| ScaleBit | AvgBit | BitRate | MAD | MSE | CF | PSNR | CR | ET |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 3.75 | 12.66 | 244.09 | 0.16 | 24.255 | 6.4 | 66.9 |
| 2 | 4 | 3.94 | 6.86 | 79.103 | 0.16 | 29.148 | 6.1 | 65. 48 |
| 2 | 5 | 4.13 | 4.315 | 38.392 | 0.17 | 32.288 | 5.82 | 63.34 |
| 2 | 6 | 4.31 | 3.385 | 29.531 | 0.18 | 33.427 | 5.57 | 60.55 |
| **2** | **7** | 4.5 | 2.983 | 26.865 | 0.19 | **33.838** | **5.33** | **53.81** |
| 3 | 3 | 3.94 | 12.66 | 244.09 | 0.16 | 24.255 | 6.1 | 66.89 |
| 3 | 4 | 4.13 | 6.86 | 79.104 | 0.17 | 29.148 | 5.82 | 66.44 |
| 3 | 5 | 4.31 | 4.316 | 38.393 | 0.18 | 32.288 | 5.57 | 64.11 |
| 3 | 6 | 4.5 | 3.39 | 29.581 | 0.19 | 33.42 | 5.33 | 61.58 |
| 3 | 7 | 4.69 | 2.984 | 26.878 | 0.2 | 33.836 | 5.12 | 54.55 |
| 4 | 3 | 4.13 | 12.66 | 244.09 | 0.17 | 24.255 | 5.82 | 67.56 |
| 4 | 4 | 4.31 | 6.86 | 79.103 | 0.18 | 29.148 | 5.57 | 66.7 |
| 4 | 5 | 4.5 | 4.312 | 38.396 | 0.19 | 32.29 | 5.33 | 64.45 |
| 4 | 6 | 4.69 | 3.396 | 29.614 | 0.2 | 33.415 | 5.12 | 61.92 |
| 4 | 7 | 4.88 | 2.984 | 26.897 | 0.2 | 33.833 | 4.92 | 54.84 |
| 5 | 3 | 4.31 | 12.66 | 244.09 | 0.18 | 24.255 | 5.57 | 67.62 |
| 5 | 4 | 4.5 | 6.86 | 79.104 | 0.19 | 29.148 | 5.33 | 66.25 |
| 5 | 5 | 4.69 | 4.318 | 38.396 | 0.2 | 32.287 | 5.12 | 64.44 |
| 5 | 6 | 4.88 | 3.399 | 29.643 | 0.2 | 33.411 | 4.92 | 61.44 |
| 5 | 7 | 5.06 | 2.978 | 26.841 | 0.21 | 33.842 | 4.74 | 54.75 |
| 6 | 3 | 4.5 | 12.66 | 244.09 | 0.19 | 24.255 | 5.33 | 67.58 |
| 6 | 4 | 4.69 | 6.68 | 79.103 | 0.2 | 29.148 | 5.12 | 66.41 |
| 6 | 5 | 4.88 | 4.312 | 38.365 | 0.2 | 32.29 | 4.92 | 65.08 |
| 6 | 6 | 5.06 | 3.398 | 29.632 | 0.21 | 33.413 | 4.74 | 61.83 |
| 6 | 7 | 5.25 | 2.979 | 26.836 | 0.22 | 33.843 | 4.57 | 54.58 |
| 7 | 3 | 4.69 | 12.66 | 244.09 | 0.2 | 24.255 | 5.12 | 67.45 |
| 7 | 4 | 4.88 | 6.86 | 79.104 | 0.2 | 29.148 | 4.92 | 66.22 |
| 7 | 5 | 5.06 | 4.316 | 38.377 | 0.21 | 32.29 | 4.74 | 64.2 |
| 7 | 6 | 5.25 | 3.397 | 29.618 | 0.22 | 33.415 | 4.57 | 61.42 |
| 7 | 7 | 5.44 | 2.979 | 26.864 | 0.23 | 33.838 | 4.41 | 54.81 |
| **No Quantization** | | 14.81 | 2.845 | 26.214 | 0.62 | 33.945 | 1.62 | 43.8 |

| No quantization | Original Image | With quantization ScaleBits=2 , AvgBits =7 |
|---|---|---|
|  |  |  |
| PSNR =33.945 | ( 8 bits/pixel ) | PSNR =33.838 |
| CR =1.62 | | CR =5.33 |
| ET=43.8 | | ET=53.81 |

Fig (1) The reconstructed images for the cases of no quantization and quantization

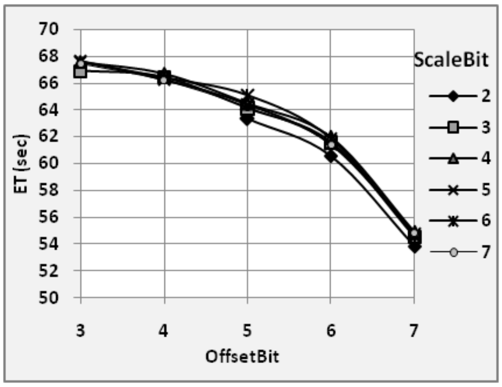


Fig (2) The effect of AvgBits on ET

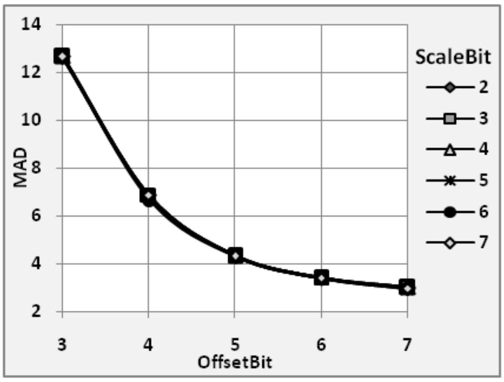


Fig (3) The effect of AvgBits on MAD

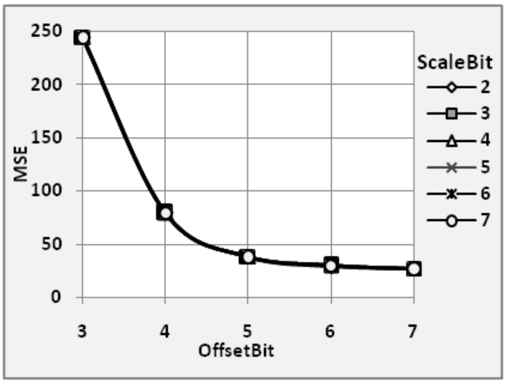


Fig (4) The effect of AvgBits on MSE

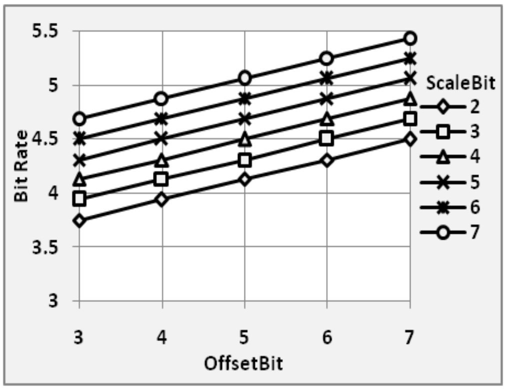


Fig (5) The effect of AvgBits on BitRate

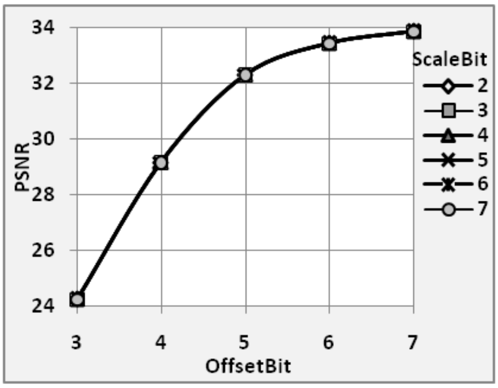


Fig (6) The effect of AvgBits on PSNR

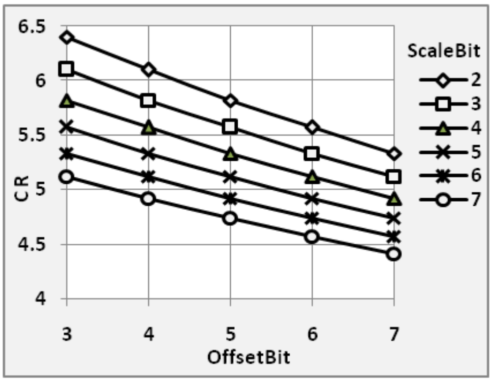

Fig (7) The effect of AvgBits on CR

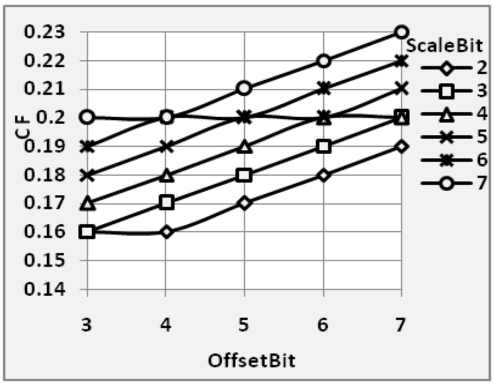


Fig (8) The effect of AvgBits on CF

## 7. Conclusions

The following remarks summarize the noticed behaviour in the above listed results:-

1. The case of ScaleBits 2 when AvgBits 7 leads to high PSNR with appropriate CR.
2. The case of ScaleBits and AvgBits 2 , ScaleBits and AvgBits 3 leads to high CR (6.4).
3. ET is inversely proportional to AvgBits.
4. Quantization increases CR and ET but decreases PSNR and BitRate.
5. MAD and MSE are inversely proportional to AvgBits.
6. PSNR is directly proportional to AvgBits.
7. MAD and MSE are almost kept the same value for the combination of AvgBits .
8. CR is inversely proportional to AvgBits.
9. BitRate is directly proportional to AvgBits .
10. CF and BitRate are increase with increase of AvgBits and ScaleBits.
11. CR is inversely proportional to AvgBits , ScaleBits.

## 8. Reference

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