The Compression of Fractal Color Image by YP⁰PR Color Space Using Zero-Mean Method

Eman A. Al-Hilo and Abbas F. Al-Rufaee

Abstract—This paper introduces an improvement on zero-mean fractal color image compression techniques, using the YP⁰PR color space. The two color images (Lena and Parrot) were used to test the best PSNR, CR, ET, by fractal image coding by Zero-Mean method. In Lena image the calculated results were found to be (PSNR=30.99), (CR=10.52), (ET=63.68), while in Parrot image is (PSNR=29.59), (CR=10.52), (ET=47.44).

Index Terms—Component, YP⁰PR, color space, TV color space, zero-mean method, image compression.

I. INTRODUCTION

Modern society has become more and more dependent on image communication in various forms [1]. The study of image compression becomes more essential because image communication requires large memories for storage and bandwidth-consuming channels for transmission even for moderate resolution. In this research using the (YP⁰PR) TV color space, to measure efficiency transport of the image using Zero-Mean method, where we will examine the parameters (PSNR, CR, ET) by introduce different values of parameters (MinScale & MaxScale, Step Size, Block Size, Dom Size and permissible error value (ε₀)).

Different techniques have been introduced in fractal compression to overcome the large time consumed during the search process (i.e. matching between the domain-range pairs) or to obtain better quality and compression ratios [2], [3]. The researchers studied the fractal color image compression using different methods [4], [5]. In this study, an improvement has been done on zero-mean fractal color images compression techniques. Most image compression systems compress color images as several independently decomposed grayscale images. The most popular way to decompose a color image is to split this image into a primary luminance monochrome image and several secondary monochrome luminance image. The equations 1.2 have been used to transform between YP⁰PR and RGB color space [6].

\[
\begin{align*}
[Y] & = \begin{bmatrix} 0.213 & 0.715 & 0.072 \\ -0.115 & -0.385 & 0.500 \\ 0.500 & -0.454 & -0.046 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \\
[\bar{P}b] & = \begin{bmatrix} 0.213 & 0.715 & 0.072 \\ -0.115 & -0.385 & 0.500 \\ 0.500 & -0.454 & -0.046 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \\
[\bar{P}r] & = \begin{bmatrix} 1.000 & 0.000 & 1.575 \\ 1.000 & -0.187 & -0.468 \\ 1.000 & 1.856 & 0.000 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}
\end{align*}
\]

In 1997, Huawu Lin, studied several techniques introduced to improve the compression performance [7]. While Kasambe and Patel in 2007 studied the color image in color space RGB,YIQ and YUV [8]. In 2009 L. E. George studied moment feature and its effect on speeding Fractal image coding based on the Zero-Mean [9], [10]. In 2012 Kawther H. Al-Khafaji study the fractal compression by Traditional and Zero-Mean methods [11]. Al-Laythawe (2014) studied Gray Level of FIC using Zero-Mean Method [12]. Al-Hilo and R. Zehwar (2015) have studied the effect of YUV and YIQ color space on fractal color image compression [13], [14].

II. IFS CODING FOR ZERO-MEAN BLOCKS

The traditional affine mapping described by equation (3)

\[
r_i = sd_i + o
\]

where,

\[
r_i : \text{the } i\text{th pixel value in the range block.}
\]

\[
d_i : \text{the pixel value in the domain block.}
\]

\[
s,o: \text{represent the scaling and offset coefficients.}
\]

Taking the average of both sides in equation (3) gets [9]:

\[
\bar{r} = s\bar{d} + o,
\]

where,

\[
\bar{r} = \frac{1}{m}\sum_{i=0}^{m-1} r_i,
\]

\[
\bar{d} = \frac{1}{m}\sum_{i=0}^{m-1} d_i
\]

Subtract equation (4) from equation (3) get:

\[
\hat{r}_i - \bar{r} = sd_i - s\bar{d}
\]

Equation (7) could be rewritten as

\[
\hat{r}_i = s(d_i - \bar{d}) + \bar{r},
\]

The coefficients (o) in classical IFS mapping equation replaced by new parameters (\(\bar{r}\))in equation (8). The scale (s) parameter could be determined by applying the least mean square difference (\(\varepsilon^2\)) between the approximated (\(\hat{r}_i\)) and actual (\(r_i\)) values [4]:

\[
\varepsilon^2 = \frac{1}{m}\sum_{i=0}^{m-1}(\hat{r}_i - r_i)^2,
\]

\[
\frac{\partial \varepsilon^2}{\partial s} = 0,
\]
Combine equations (9) with (10) gets:

\[
S = \begin{cases} 
\frac{1}{m} \sum_{i=0}^{m-1} d_i r_i - \bar{r} \bar{d}, & \text{if } \sigma_d^2 > 0 \\
0, & \text{if } \sigma_d^2 = 0
\end{cases},
\]

\[
\epsilon_2 = \sigma_r^2 + s \left[ \sigma_d^2 + 2\bar{d}\bar{r} - \frac{2}{m} \sum_{i=0}^{m-1} d_i r_i \right]
\]

\[
\sigma_d^2 = \frac{1}{m} \sum_{i=0}^{m-1} d_i^2 - \bar{d}^2,
\]

\[
\sigma_r^2 = \frac{1}{m} \sum_{i=0}^{m-1} r_i^2.
\]

III. ZERO-MEAN ENCODING METHOD

The encoding process could be written as in Fig. 1 [15]:

IV. ZERO-MEAN DECODING PROCESS

The decoding process show in the Fig. 2 [15]:

Fig. 2. Flowchart of the Zero-Mean decoding.

V. TEST RESULTS

Many tests were perform to exam color (Fractal Image Compression) system by Zero-Mean technique. These tests used Lena and parrot image (256×256, 24 bit per pixel) as a testing object. The parameters Min Offset take value (0) and Max Offset take value (255) in all tests. Also, the values of other parameters were fixed when exam the effect of each parameter.

A. Max and Min Scale Tests

This set of tests was applied to study the effect of Min Scale and Max Scale parameters on the compression performance. The values of coding parameters were taken asScale Bits=2 and Offset Bits=8 Dom Size=(128×128), Block Size=(4×4), Step Size=2, \(E=0.8\), TMSE=6. Table I show the reconstructed images for the best MaxScale and Min Scale values for Lena and Parrot images. Table II show the effect of Max Scale and Min Scale parameters on the compression performance parameters for Lena and Parrot images. Fig. 3, Fig. 4, Fig. 5 show the effects of Min Scale on PSNR, CR, and ET respectively.
TABLE I: THE RECONSTRUCTED IMAGES FOR THE BEST MAXIMUM AND MINIMUM SCALE TESTS

| Original Image | MaxScale = 1 | MinScale = -1 | Original Image | MaxScale = 1 | MinScale = -1 |
|----------------|--------------|---------------|----------------|--------------|---------------|
|                | (24 bits/pixel) | PSNR=30.99 | CR= 10.52 | ET=63.68 | (24 bits/pixel) | PSNR= 29.59 | CR= 10.52 | ET= 47.44 |

The results indicate that PSNR is inversely proportional to the values of both Min Scale and Max Scale and in the case of Min Scale (-1) and Max Scale (1) leads to high PSNR. Also, CR is not affected by the variation of Max Scale and Min Scale values and ET increase with the increases of Min Scale values.

TABLE II: MAXIMUM AND MINIMUM SCALE TESTS

| Lena Image | Parrot Image |
|------------|--------------|
| PSNR | CR | ET sec | PSNR | CR | ET sec |
| 29.69 | 10.52 | 61.02 | 27.96 | 10.52 | 46.33 |
| 30.92 | 10.52 | 61.79 | 29.33 | 10.52 | 46.33 |
| 30.87 | 10.52 | 62.45 | 29.57 | 10.52 | 47.47 |
| 30.79 | 10.52 | 62.18 | 29.52 | 10.52 | 47.11 |
| 30.89 | 10.52 | 61.98 | 29.29 | 10.52 | 46.46 |
| 30.99 | 10.52 | 63.68 | 29.59 | 10.52 | 47.44 |
| 30.92 | 10.52 | 65.22 | 29.72 | 10.52 | 48.61 |
| 30.88 | 10.52 | 65.21 | 29.63 | 10.52 | 48.32 |
| 30.89 | 10.52 | 62.68 | 29.41 | 10.52 | 47.63 |
| 30.98 | 10.52 | 65.37 | 29.56 | 10.52 | 48.70 |
| 30.76 | 10.52 | 67.33 | 29.60 | 10.52 | 50.89 |
| 30.68 | 10.52 | 67.48 | 29.62 | 10.52 | 51.09 |

The test of Domain Size parameter done to study their effects on the compression performance. The values of coding parameters were taken as Scale Bits=2 and Offset Bits=8, Block Size=(4×4), Step Size=2, ε=0.8, TMSE=6. Table III show the effect of Dom Size parameters on the PSNR, CR, ET. Fig. 6, Fig. 7, Fig. 8 show the effects of Dom Size on the compression performance parameters PSNR, CR, and ET respectively.

The results indicate that The Domain Size value (128×128) leads to best PSNR. Also, PSNR inversely proportional to the Dom Size value, CR is not affected by Domain Size variation, But ET decreases rapidly with the increase in Domain Size.

TABLE III: DOMAIN SIZE TESTS

| Lena Image | PARROT IMAGE |
|------------|--------------|
| PSNR | CR | ET sec | PSNR | CR | ET sec |
| 29.59 | 10.52 | 28.69 | 28.34 | 10.52 | 28.34 |
| 29.63 | 10.52 | 28.34 | 28.34 | 10.52 | 28.34 |
| 30.52 | 10.52 | 28.36 | 28.36 | 10.52 | 28.36 |
| 30.52 | 10.52 | 28.34 | 28.34 | 10.52 | 28.34 |
| 30.52 | 10.52 | 28.34 | 28.34 | 10.52 | 28.34 |
| 30.52 | 10.52 | 28.34 | 28.34 | 10.52 | 28.34 |

The results indicate that PSNR is inversely proportional to the values of both Min Scale and Max Scale and in the case of Min Scale (-1) and Max Scale (1) leads to high PSNR. Also, CR is not affected by the variation of Max Scale and Min Scale values and ET increase with the increases of Min Scale values.

C. Block Size Tests

This tests designed to investigate the effect of the Block Size parameter on the compression performance parameter. Table IV shows the effect of Block Size parameters on the compression performance on Lena and Parrot image. Fig. 9,
Fig. 10, Fig. 11 show the effects of Block Size parameter on PSNR, CR, and ET respectively.

**TABLE IV: BLOCK SIZE TESTS**

| Original image | BlockSize (2x2) | BlockSize (4x4) | BlockSize (8x8) | BlockSize (16x16) |
|----------------|-----------------|-----------------|-----------------|-------------------|
| PSNR           | 34.59           | 30.59           | 26.53           | 23.87             |
| CR             | 62.43           | 10.52           | 45.85           | 201.4             |
| ET             | 26.48           | 63.68           | 52.96           | 42.57             |
| Lena Image     |                 |                 |                 |                   |
| Parrot Image   |                 |                 |                 |                   |

The results indicate that Block Size value (2x2) shows highest value of PSNR with less CR than the case (4x4). But with value (4x4) leads to appropriate PSNR and CR than other sizes. Also, CR increases with the increase of Block Size.

**TABLE V: STEP SIZE TESTS**

| Original image | StepSize(1) | StepSize(2) | StepSize(3) | StepSize(4) |
|----------------|-------------|-------------|-------------|-------------|
| PSNR           | 31.41       | 30.99       | 30.56       | 30.33       |
| CR             | 12.52       | 10.52       | 10.52       | 10.52       |
| ET             | 240.8       | 63.68       | 29.64       | 17.21       |
| Lena Image     |             |             |             |             |
| Parrot Image   |             |             |             |             |

The results indicate that Step Size value 2 leads to appropriate CR and PSNR than other Step Size values. Also, The CR does not effected with Step Size variations but PSNR and ET decreases rapidly with the increase in Step Size.

**D. Step Size Tests**

This test design to study the shift Step Size coefficient on the compression factor of reconstructed image. The Block Size was taken as (4x4); the values of other coefficients were taken similar to those mentioned in the previous test set. Table V presents the effects of Step Size on the compression performance parameters for both image for Lena and Parrot. Fig. 12, Fig. 13, Fig. 14 to show the the effects of Step Size on the compression performance parameters PSNR, CR, and ET respectively for both image for Lena and Parrot.

**E. Permissible Error Levels (Eo) Tests**

This factor \((E_o)\) was studied during this test to find their effect on the compression coefficient of reconstructed image. The purpose of using the conditional parameters is to reduce the computational load of the searching process within the domain pool, i.e. when the matching process reaches an error \((E_o)\) less than the value of \((E_o)\) then the searching process within domain pool is stopped. So, this conditional stopping helps in reducing the search mapping instance, and
consequently decreases the computation cost of the search process. See Table VI and Fig. 15, Fig. 16, Fig. 17 to show the results. The results indicate that the permissible error value (0.8) leads to best PSNR with ET. PSNR is inversely affected by permissible error level, CR remain constant, But the encoding time decreases rapidly with the increase of permissible error value ($\epsilon_0$).

**TABLE VI: PERMISSIBLE ERROR LEVELS ($\epsilon_0$) TESTS**

| $\epsilon_0$ | PSNR Lena | CR | ET (sec) | PSNR Parrot | CR | ET (sec) |
|--------------|-----------|----|----------|-------------|----|----------|
| 0.1          | 30.99     | 10.52 | 75.01   | 29.61       | 10.52  | 72.02   |
| 0.2          | 30.99     | 10.52 | 74.65   | 29.61       | 10.52  | 72.59   |
| 0.3          | 30.99     | 10.52 | 73.77   | 29.61       | 10.52  | 71.91   |
| 0.4          | 31.00     | 10.52 | 74.67   | 29.61       | 10.52  | 69.85   |
| 0.5          | 31.00     | 10.52 | 72.23   | 29.60       | 10.52  | 64.94   |
| 0.6          | 30.99     | 10.52 | 70.29   | 29.60       | 10.52  | 57.01   |
| 0.7          | 31.00     | 10.52 | 67.41   | 29.60       | 10.52  | 51.89   |
| 0.8          | 30.99     | 10.52 | 63.68   | 29.59       | 10.52  | 47.44   |
| 0.9          | 30.99     | 10.52 | 60.90   | 29.59       | 10.52  | 46.27   |
| 1            | 30.99     | 10.52 | 57.22   | 29.58       | 10.52  | 41.75   |
| 2            | 30.64     | 10.52 | 36.21   | 29.35       | 10.52  | 25.91   |

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

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