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A Comparative Study on Color Image Compression Based on Fractal Geometrical Topologies for Partition Iteration

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Abstract: Fractal geometry has been found to be an unbelievable breakthrough in solving the segmentation and compression problems of digital images. In present study, effect of variations of colour schemes has been studied with the help of various types of geometrical topology for the basic segmentation process. The most and popular RGB colour space performance has been compared with HSI colour space along with quad tree and isosceles geometrical segmentation. It has been found that hue-situation intensity scheme is superior to RGB schemes for the measurement of PSNR. The execution time for isosceles triangle based geometrical segmentation yield lower processing time. The major efficiency of the study is Multifoods compression ratio when HSI scheme has been adopted. Both types of segmentation viz. Quad tree and isosceles triangle approach have produced nearly four times increment in compression ratio. During the transformation all the channels, e.g., RGB and HSI have been treated separately. The results have been compared with those available from recent literature and it has been found that the proposed schemes of sequence of studies are superior to the earlier ones.

Key words: Hue-saturation intensity colour space, fractal geometry, affine transformation, hausdorff distance, contrast and luminance adjustment, translation, rotation

INTRODUCTION

Fractal geometry has been invented nearly three decades ago and widely applied to carry out the compression of data related to the images of irregular shape like snow bobs, clouds, flame, tree leaves, mountain, fountain etc (Jacquin, 1990).The main efficiency of this technique in its inherent capability of having high compression ratio and maintainability of its original appearance according to affine transformation.

Fractal coding is a lossy compression technique used normally for gray scale image through rectangular range and domain blocks (Jacquin, 1992). The block segmentation may be conveniently achieved by quad tree sub-division approach which means the image plane is consecutively divided into four equal areas until matching is achieved between range and domain blocks. The matching has been achieved in order to get compression by iterated function system (Barnsley, 1988). Subsequently a better algorithm based on Partition Iterated Function System (PIFS) was proposed (Jacquin, 1992) and it was found to yield higher and significant compression. In later stages, a number of fractal image compression (Fisher, 1994) fractal image compression based on adaptive threshold value quad tree (Daroine *et al*., 1997; Zhang and Fan, 2006) have been made to improve the coding efficiency and reducing the encoding time, fractal image compression based on Ant Colony Algorithm (Li *et al*., 2008), fast hierarchical codebook search for fractal coding (Hurtgen and Stiler), Region-based fractal image compression using heuristic search (Thomas and Deravi, 1995), Distortion Minimization with Fast Local Search (Hamzaoui *et al*., 2001), image compression based on delauney triangulation and vector quantization (Davoine *et al*., 1996), fast fractal image coding, Speed-up in Fractal Image Coding (Polvere and Nappi, 2000; Wohlberg and Jagged, 1999), fractal compression based on wavelet sub trees, unsupervised clustering algorithms with color transformation, face recognition through color local texture features fractal image compression based on pixels distribution and triangular segmentation (Zhu *et al*., 2008), fractal based various image compression techniques (Jayaraman *et al*., 2011) and (Rafael and

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Woods, 2009), novel prediction and sub-block based algorithm for fractal image compression (Chung and Hsu, 2006; Zhao *et al*., 2010) has done a notable work on color image for improving the quality of retrained image during decoding of fractal images and whole coding approach was based on isosceles triangle segmentation instead of customary quad tree approach. Color imaging and processing has been gradually important with the advent of multimedia technology and internetworking system. The problem of color image is that it occupies at least three times more memory space for storage device which also requires higher processing time and transformation time or larger of the channel band width. These factors have motivated the researchers for color image compression. Normally RGB color space is used in television monitor or CRT oscilloscope display. Most common and straight forward way to encode a color image is to split it into red, green and blue channels and to compress them separately. The same process was followed by Zhao *et al*. (2010). They treated each channel as a separate gray-scale channel. The basic problem of RGB color components are correlation to each other and in addition to signal intensity (Luminance part) and color content (Chrominance part) are co-related and inseparable even if one split them into three separate color channel. But no study is available on fractal compression color images in HSI color space.

In the present study, Hue Saturation Intensity (HSI) color scheme is considered to carry out fractal compression. In this scheme hue contains the color content and saturation indicates purity of color when intensity is equivalent to the intensity of the gray scale images. Fractal coding of two color images have been done following quad tree and isosceles triangle based segmentation approach. It has been found that the proposed study has yielded better PSNR, higher compression ratio and smaller processing time.

MATERIALS AND METHODS

Fractal compression: A fractal may be represented by the set of equations:

$$w\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \quad (1)$$

A fractal is generated when Eq. 1 is recursively iterated starting with an initial value of pixel location (x, y) on the image plane. The, a, b, c, d matrix indicates the rotation and skewing operations and e, f determine the translation of the image.

The set {w} is termed an affine transformation or contractive affine transformation. A fractal may be represented by a set of contractive affine transformation which are given by:

$$W_n P_n, n = 1, 2, 3, \ldots, N \quad (2)$$

Where:
W_n = The affine transformations and
P_n = Denotes their individual importance

This representation is generally called IFS coding. On self similarity concept in fractal based image compression, image blares are seen as rescale and intensely transformed approximate couples of block found elsewhere in the image plane. The compression ratio is proportional to the degree of self similarity. The fractal image compression can be expressed by following steps:

Step 1: The image under test is partitioned into sub-images or range blocks. There may be different scheme to find such blocks, viz. quad tree partitioning, triangular partitioning, horizontal vertical partitioning, polygonal partitioning etc. The main aim in fractal compression is to partition an image into a smaller number of range blocks which should be similar to other portion of the image after undergoing different transformations.

Step 2: The searching of domain block should be done in a statistical manner. The purpose is to search for the best domain which will be mapped to a range. A domain is a region where the transformation mapping starts and a range is the region where it is mapped. If the best matched between the largest range blocks and the transformed domain blocks has got an error which is found to be greater than the similarity threshold (Based on some heuristic knowledge). The range blocks should have similarly with each of these blocks. Range blocks which cannot be matched within the similarity threshold continue to partition into smaller range cells until the maximum number of partition is obtained. If this limit is touch and the nearest domain cell does not match a range cell within the said threshold. This area can be termed as anomalous area.

Step 3: When the match with location is found various transformations like combination of affine and luminance transformation are to be computed. The same can be represented as follows:

$$w\begin{pmatrix}x\\y\\z\end{pmatrix}=\begin{pmatrix}a & b & 0\\c & b & 0\\0 & 0 & p\end{pmatrix}\begin{pmatrix}x\\y\\z\end{pmatrix}+\begin{pmatrix}e\\f\\q\end{pmatrix} \quad (3)$$

Here, z indicates the pixel intensity (luminance) at the location (x, y) and e and f indicate the shift in the position of the range with respect to the domain p and q are the contrast and luminance adjustment to accomplish the affine transformation.

Step 4: The foundation of fractal image compression lies in the construction of the IFS that approximate the original image. An IFS in terms of set theory and distance function, is a union of contractive transformation each of which maps into itself. To realize contractive transformation, the following condition should hold good:

$$d\left(W(P_1), W(P_2)\right) < d\left(P_1, P_2\right) \quad (4)$$

The above equation is true for any metric space.

RGB to HSI conversion and HSI to RGB conversion: HSI stands for Hue, Saturation and Intensity. Hue represents dominant color as perceived by an observer (Rafeal and Woods, 2009). It is a property associated with the dominant wavelength. Saturation refers to the relative purity of the amount of white light mixed with the color content. Intensity reflects the brightness. HSI decouples the intensity information from the color while hue and saturation correspond to human perception, thus making this representation very useful for developing image processing algorithms. HSI color space is a popular color space because it is based on human color perception. The conversation from RGB space to HSI space is given below:

$$I = \frac{1}{3}(R+G+B) \quad (5)$$

$$S=1-\frac{2}{(R+G+B)}\left[\min(R, G \text{ and } B)\right] \quad (6)$$

And:

$$H = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} \quad (7)$$

This HSI color model can be considered as a cylinder, where coordinates r, O and z are saturation, hue and intensity respectively. The cylindrical representation of HSI color model as stated.

Converting colors from HSI to RGB, there are three applicable equations depend on the values of H. Three sectors are lying 120°angular interval in the separating primes. RG sector (0° = H<120°): When H is this sector, the RGB components are given by the equations as:

$$B=I(1-s) \quad (8)$$

$$R = I\left[1+\frac{S\cos H}{\cos\left(60^0-H\right)}\right] \quad (9)$$

$$G = 3I-(R+B) \quad (10)$$

GB sector (120°≤H < 240°): If the given value of H is in this sector, we first subtract 120° from it:

$$H = H-120^0 \quad (11)$$

Then the RGB components are:

$$R = I(1-S) \quad (12)$$

$$G = I\left[1+\frac{S\cos H}{\cos\left(60^0-H\right)}\right] \quad (13)$$

$$R = 3I-(G+B) \quad (14)$$

BR sector (240°≤ H<360°): Finally, if H is in this range, we subtract 240° from it:

$$H = H-240° \quad (15)$$

Then, the RGB components are:

$$G = I(1-S) \quad (16)$$

$$B = I\left[1+\frac{S\cos H}{\cos\left(60^0-H\right)}\right] \quad (17)$$

$$R = 3I-(G+B) \quad (18)$$

Proposed method for fractal coding based on quad-tree and isosceles triangle segmentation: Hue saturation intensively color space is an uncorrelated system unlike

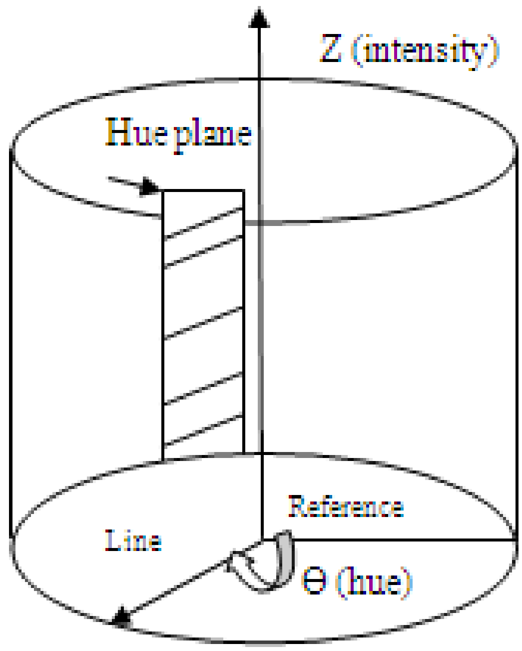

Fig. 1: Cylindrical representation of HIS color model

to RGB system. Here only scope for fractal compression is to treat each channel separately followed by the standard fractal compression algorithm. The range and domain blocks are chosen according to two geometric dimension viz. quad tree and isosceles triangle based segmentation.

The geometric affine transformation is made according to the Eq. 2 and intensively transformation is achieved by taking the mean value of two neighborhood pixels of the matched shrinked image. For isosceles triangle segmentation approach, the earlier method of (Zhao *et al*., 2010) has been followed. Here the compression process have been followed from one channel to another i.e. hue saturation and intensity channel. The operation is done independently as HSI space does not involve any interdependence or co-relation between the channels. The computation time has also been found to be smaller than the RGB schemes where processing of fractal coding was done separately i.e. without considering the co-relation between them. Images were decoded according to the approach of (Zhao *et al*., 2010) as it can conveniently be applicable for both quad tree and triangle segmentation approaches. Figure 1 and 2 show the color image encoding process based on HIS and quad tree approach and color image encoding process based on HIS and Isosceles triangle segmentation, respectively.

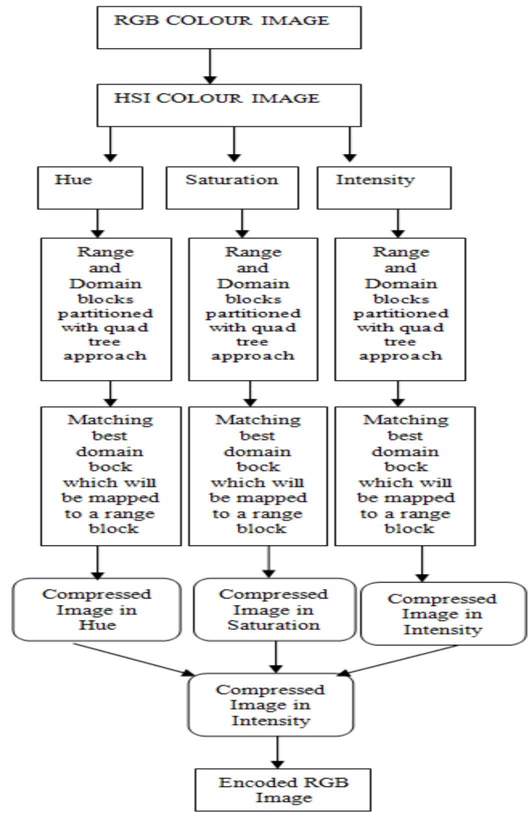

Fig. 2: Show the color image encoding process based on HSI and quad tree approach

RESULTS AND DISCUSSION

The proposed method has dealt with two digital images viz. Lena and pine (256×256×3)] to facilitate comparison with the earlier works. The simulation work has been come out with Mat lab 2014 b under Windows 7 operating system.

Original Lena, compressed Lena, original Pine and compressed Pine have been shown in Fig 3a-d, respectively for quad tree approach. The Original images of Lena, compressed Lena, original Pine and compressed pine images according to isosceles triangle have been shown in Fig. 4a-d, respectively. The decoded images are shown in Fig. 5 and 6.

Figure 5a-f show the original images, Fig. 5 show the composite image and show the retrieved images of Lena and Pine for quad tree approach. More over, in Fig. 6a-f show the original images Fig. 7 show the composite and Fig. 7 show the retrieved images of Lena and Pine for Isosceles Triangle approach.

Although the emphasis of the present study was laid down on the efficiency of compression using fractal geometry, image referral was also achieve to verify the

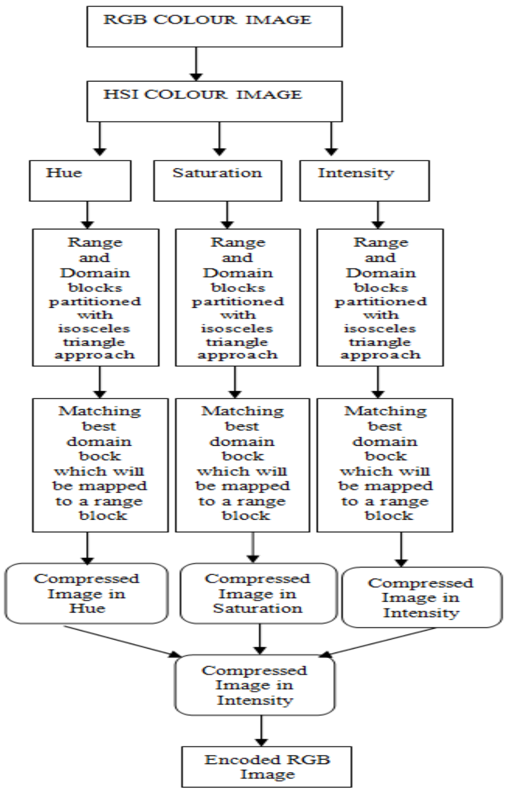

Fig. 3: The color image encoding process based HSI and Isosceles triangle segmentation

Fig. 4: a, c) The original images of Lenna and Pine; b, d) and compressed images of Lenna and Pine for quad tree approach and based on HSI model

Fig. 5: a) The original image of Lenna; b) The compressed image of Lenna; c) The original image of Pine and d) The compressed image of Pine for Isosceles Triangle approach

Fig. 6: a, b) The original images Lenna and Pine; c, d) The composit images of Lenna and Pine and e, f) The retrieved images of Lenna and Pine for quad tree approach

straight of the algorithms involved and then applicability. The quality of image is evaluated by Peak Signal to wave Ratio (PSNR) (Zhu *et al*., 2010) can be calculated by the following example.

Table 1: Comparison between rgb (separately) and hsi method (proposed) based on quad-tree and isosceles triangle code block segmentation

RGB based segmentation approach

RGB coding separately, A.E. Jaquin					Proposed method(RGB and Triangle segmentation)		
Test image	RGB	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Lenna	R	34.58	53	4.129	35.19	52	5. 02
	G	34.10	53		36.25		
	B	33.26	54		37.76		
Pine	R	31.36	58	4.129	36.61	54	4.98
	G	32.87	53		37.28		
	B	3.74	54		38.4		

Table 2: HSI based segmentation approach

Proposed method HSI scheme(quad tree)					Proposed method HSI scheme(Triangle segmentation)		
Test image	HSI	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Lenna	H	35.12	44	23.13	36.47	43	26.78
	S	34.70	42	24.51	37.20	41	27.87
	I	33.42	41	23.72	38.10	42	26.75
Pine	H	32.52	44	22.68	33.10	42	24.62
	S	33.88	42	24.98	36.83	43	25.79
	I	30.92	41	25.72	38.14	41	28.88

$$PSNR = 10\log 10 \frac{2552}{\left(\frac{1}{m\times n}\right)\sum_{c=1}^{M}\sum_{j=1}^{N}\left(x_{i,j}-\hat{x}_{i,j}\right)^2} \quad (19)$$

Where:

$M\times N$ = The size of the image

x_{ij} and $\hat{x}_{ij}$ = Pixel values of original and reconstruction image at position (i, j). Normally better image quality implies larger value of PSNR

The results are listed in Table 1 PSNR, processing (Coding line) and compression ratio using the proposed method and that obtained by Jacquie have been compared.

As shown in the Table 2, the proposed method is has smaller processing time and higher compression ratio compared to those obtained by where 4×4 size for block segmentation was followed. The isosceles triangle method has far better compression ratio and PSNR for H, S and I components. The processing time is also found to be less in HSI scheme for 4×4 block and triangle geometry. Out of these, the letter has yielded better perform parameters.

As compression ratio slightly values intensely with the number of range blocks, the compression ratio is found to be slightly higher in the approach of Jaquin where the number of square range blocks were much less than the triangular block approach. Still, HSI scheme out performs separate RGB scheme in term of PSNR, processing time and compression ratio.

Figure 8 show the comparison chart of PSNR (dB) for Lena in RGB coding separately and proposed method (RGB and Triangle segmentation).

From the comparison chart in Fig. 8, it has been observed that in proposed method (RGB and Triangle segmentation) the value of PSNR (dB) for Lena is increased compared to RGB coding separately.

Fig. 7: a, b) The original images of Lenna and Pine; c, d) The composite images of Lenna and Pine and e, f) The retrieved images of Lenna and Pine for Isosceles Triangle approach

Figure 9 show the comparison chart of PSNR (dB) for Pine image in RGB coding separately and proposed method (RGB and Triangle segmentation) approach. From the comparison chart it has been noticed that PSNR (dB) for Pine image is slightly enhanced in

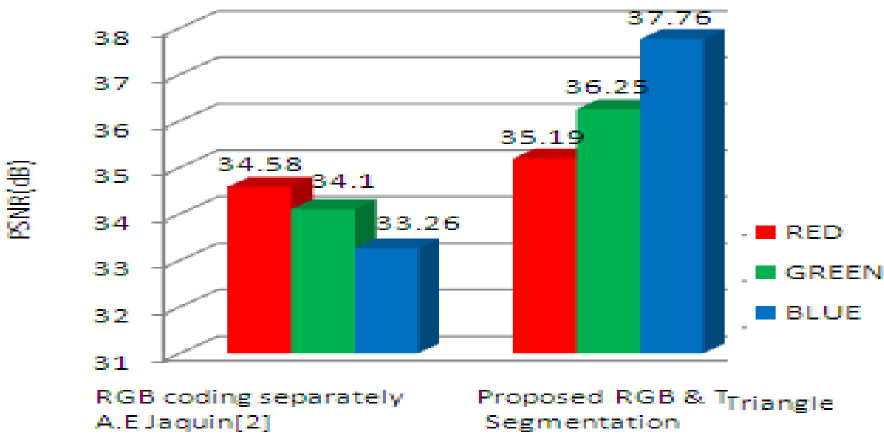

Fig. 8: The comparison chart of PSNR (dB) for Lenna image at RGB coding separately, A.E. Jaquin and Proposed method(RGB and Triangle segmentation) approach

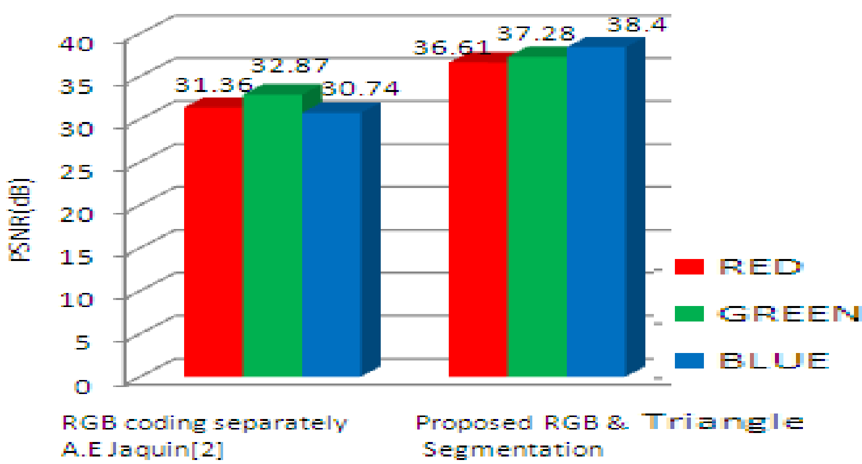

Fig. 9: The comparison chart of PSNR (dB) for Pine at RGB coding separately, A.E. Jaquin and proposed method (RGB and Triangle segmentation) approach

proposed method compared to RGB coding separately (Jacquin, 1992) method.

From Fig. 10 it has been observed that the compression ratio of Lena image is higher (R = 33.10, G = 36.83 and B = 38.14) in Proposed method (RGB and Triangle segmentation) approach than RGB coding separately (Jacquin, 1992).

Figure 10 Show the of compression time (sec) for Lena image at RGB coding separately (Jacquin, 1992) and Proposed method (RGB and Triangle segmentation) approach. From the comparison chart it has been observed that less compression time (sec) required for Lena image in proposed techniques compared than RGB coding separately (Jacquin, 1992) approach.

Figure 11 shows the of compression time (sec) for Pine image at RGB coding separately (Jacquin, 1992) and Proposed method (RGB and Triangle segmentation) approach. From the comparison chart it has been observed that the compression time (sec) required for Pine image is Less in proposed techniques compared than RGB coding separately (Jacquin, 1992) approach.

From Fig. 12, it is very clear that compression ratio slightly increased for Pine image in proposed method (RGB and Triangle segmentation) approach compared than RGB coding separately (Jacquin, 1992) approach.

Figure 13 show the comparison chart of PSNR (dB) for Lena image in proposed HSI scheme (quad tree) and Proposed HSI scheme (Triangle segmentation), in

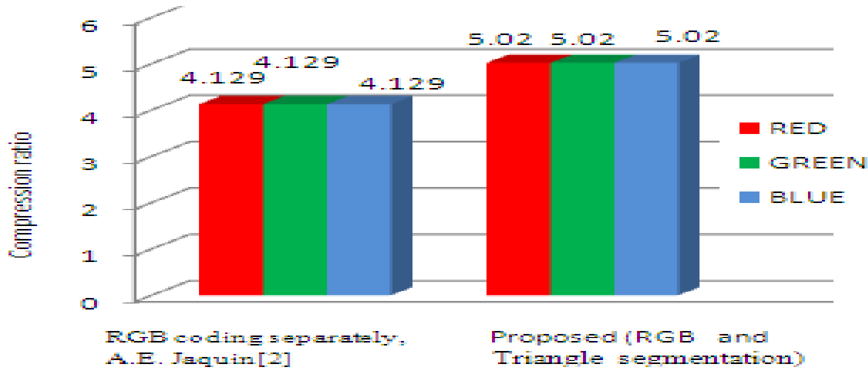

Fig. 10: The comparison chart of compression ratio for Lenna image at RGB coding separately, A.E. Jaquin and proposed method (RGB and Triangle segmentation) approach

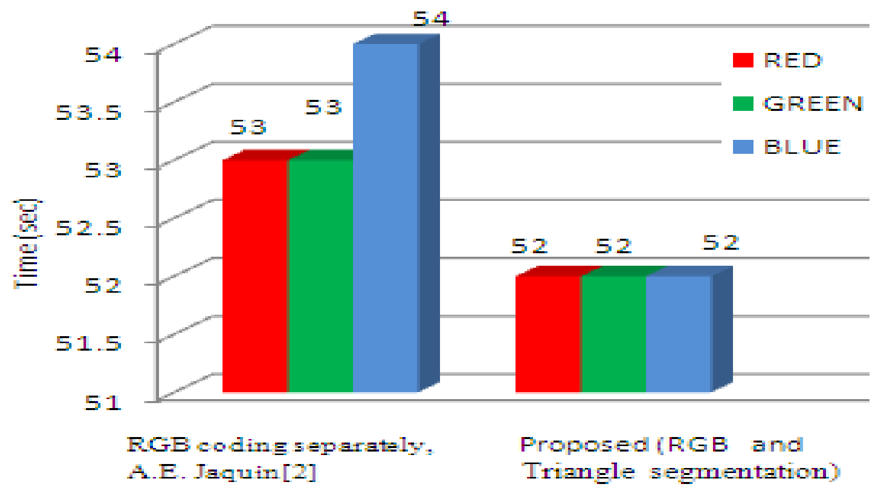

Fig. 11: The comparison chart of compression time (sec) for Lenna image at RGB coding separately, A.E. Jaquin and Proposed method (RGB and Triangle segmentation) approach

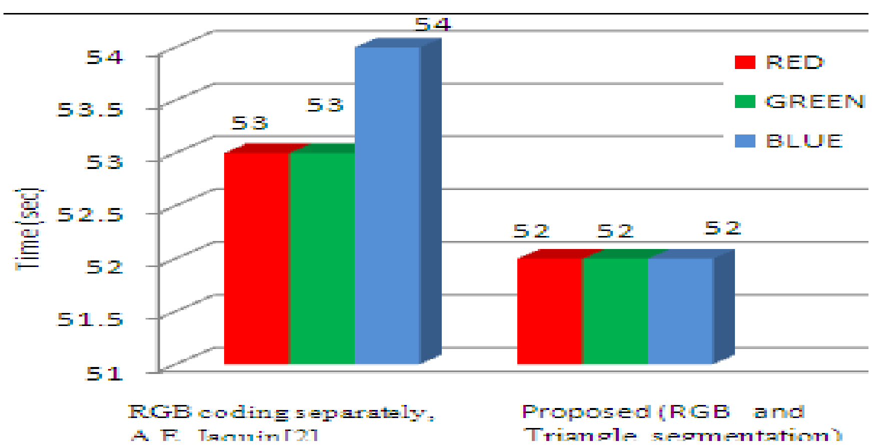

Fig. 12: The comparison chart of Time (sec) for Pine image at RGB coding separately, A.E. Jaquin and proposed method (RGB and Triangle segmentation) approach

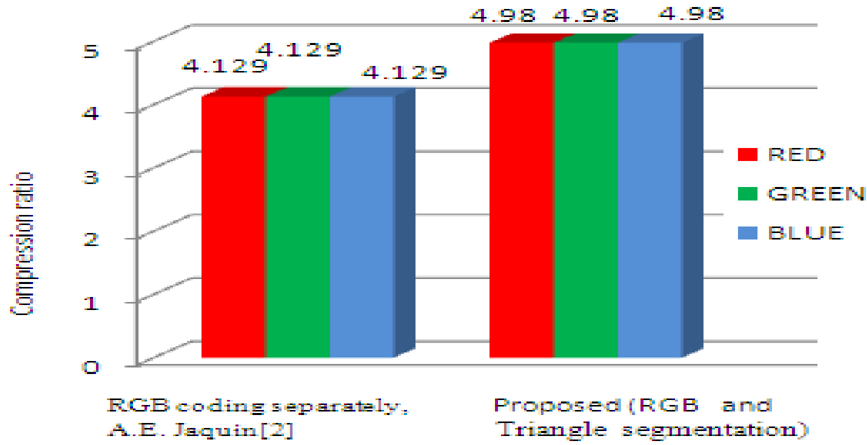

Fig. 13: The comparison chart of compression ratio for Pine image at RGB coding separately, A.E. Jaquin and proposed method (RGB and Triangle segmentation) approach

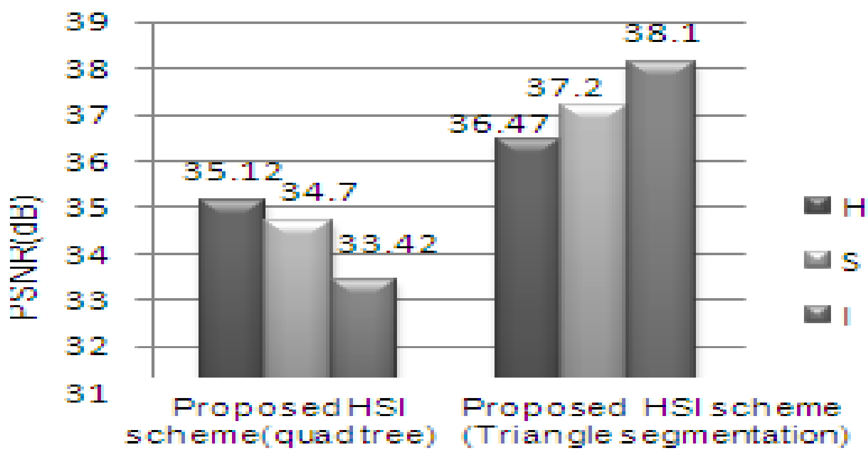

Fig. 14: The comparison chart of PSNR (dB) for Lenna image in proposed HSI scheme (quad tree) and Proposed HSI scheme (Triangle segmentation)

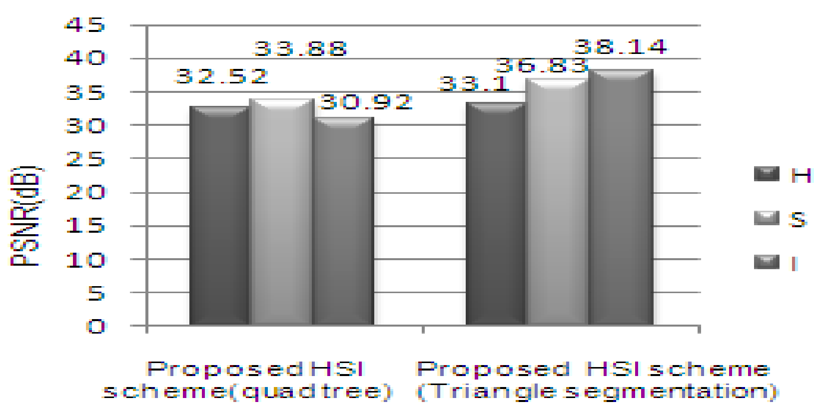

Fig. 15: The comparison chart of PSNR (dB) for Pine image in proposed HSI scheme (quad tree) and Proposed HSI scheme (Triangle segmentation)

Figures 14-16 shows comparison chart of PSNR (dB) and comparison chart of Time (sec) and comparison chart of Compression ratio for Lena image in proposed HSI scheme (quad tree) and Proposed HSI scheme (Triangle

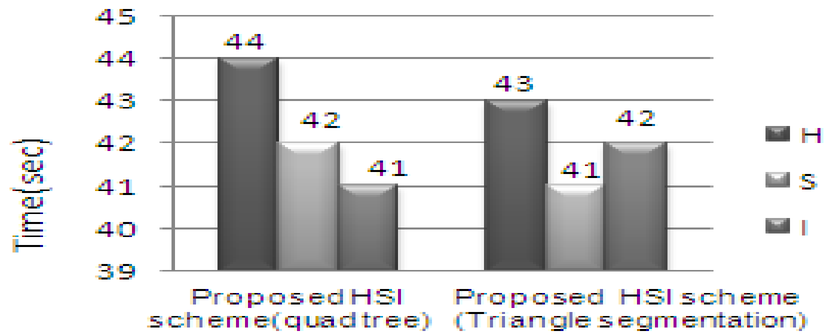

Fig. 16: The comparison chart of Time (sec) for Lenna image in proposed HSI scheme (quad tree) and Proposed HSI scheme (Triangle segmentation)

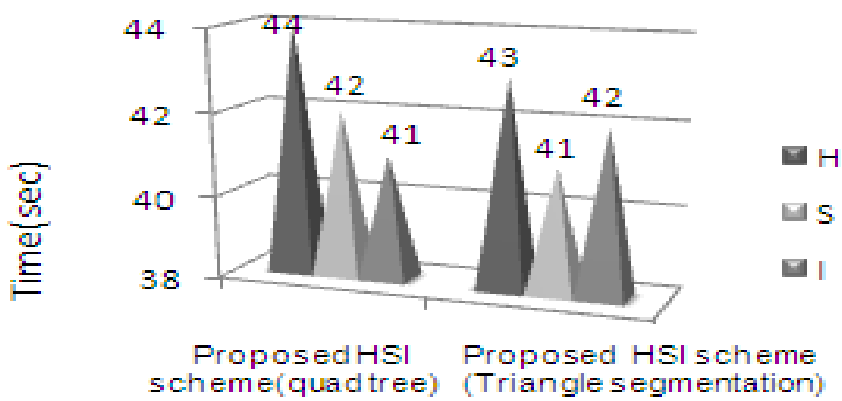

Fig. 17: The comparison chart of Time (sec) for Pine image in proposed HSI scheme (quad tree) and proposed HSI scheme (Triangle segmentation)

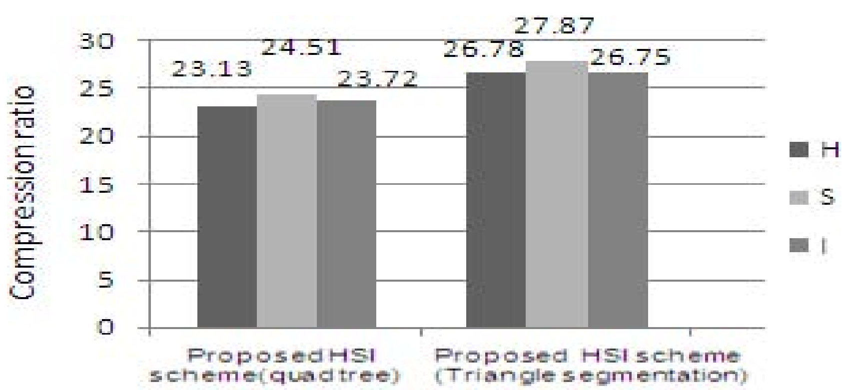

Fig. 18: The comparison chart of Compression ratio for Lenna image in proposed HSI scheme (quad tree) and proposed HSI scheme (Triangle segmentation)

segmentation). And in Fig. 17-21 shows comparison chart of Time (sec) and Compression ratio for Lena image in proposed HSI scheme (quad tree) and proposed HSI scheme (Triangle segmentation) approaches. Figure17-21

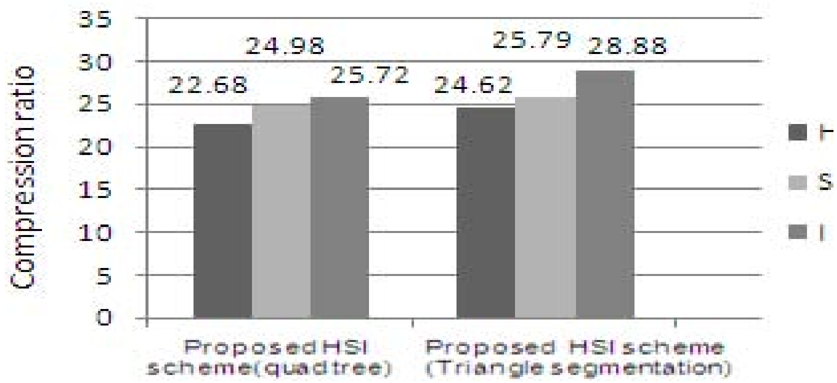

Fig. 19: The comparison chart of Compression ratio for Pine image in proposed HSI scheme (quad tree) and proposed HSI scheme (Triangle segmentation)

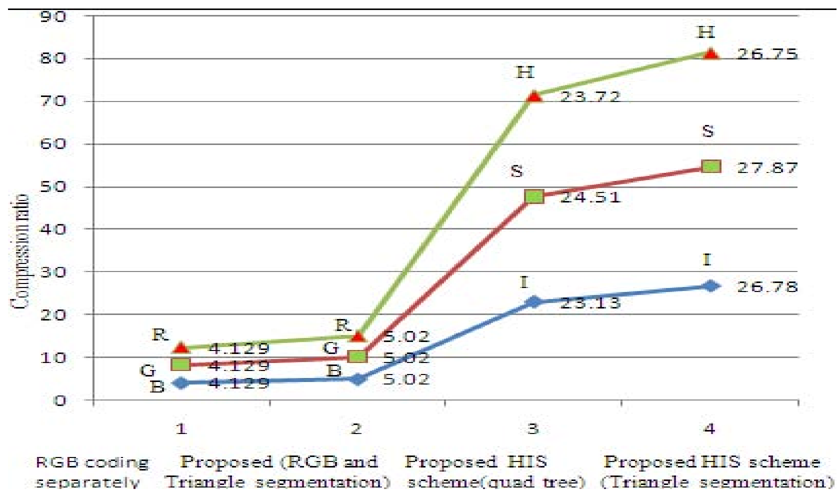

Fig. 20: The comparison graph of Compression ratio for Lenna image in (1) RGB coding separately, A.E. Jaquin [2], (2) proposed method (RGB and Triangle segmentation) approach, (3) proposed HSI scheme (quad tree) and (4) proposed HSI scheme (Triangle segmentation)

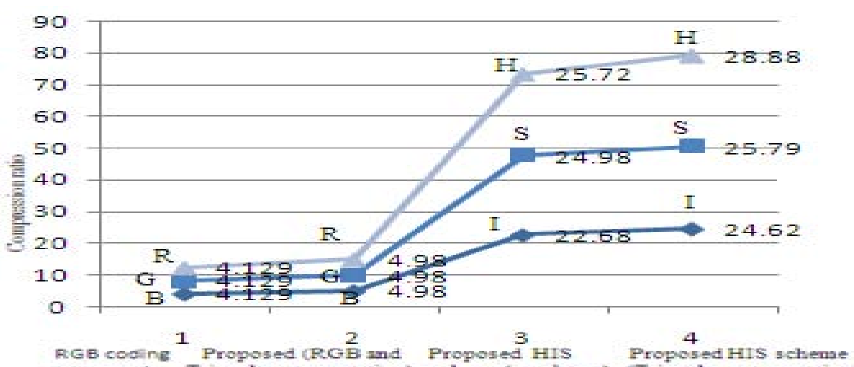

Fig. 21: The comparison graph of Compression ratio for Pine image in (1) RGB coding separately, A.E. Jaquin (2) proposed method (RGB and Triangle segmentation) approach, (3) proposed HSI scheme (quad tree) and (4) proposed HSI scheme (Triangle segmentation)

shows the Compression ratio for Lena image and Compression ratio for Pine image in (1) RGB coding separately, (2) proposed method (RGB and Triangle segmentation) approach, (3) proposed HSI scheme (quad tree) and (4) proposed HSI scheme (Triangle segmentation), respectively.

CONCLUSION

Fractal geometry has created a history in dealing with the objects of irregular shapes and sizes. Most of the the natural objects lies in that category. In the present study, four types of digital images have been considered. Colour images are always attractive to human visualization system owing to their acceptability in numerous shades. On the other hand, they occupy more space in the storage devices and longer transmission time for a facial channels bandwidth. Fractal geometry plays a major role in reducing the number of bits for machine handling and storage. RGB colour space has been found to be a popular, well established and matured process to become compatible with earlier days television system and internetworking imaging. Still the short coming of RGB scheme is then inter correlation between colour and energy component of the picture signal which also equally hold good for video signaling. Even if, when red, green and blue channels are treated separately, still then interrelation is not destroyed. In hue-saturation and intensity scheme, the colour and energy component of any composite picture signal are full segregated and they can be easily processed independently. In the proposed scheme of colour image compression, the figure of merits like PSNR (of the processed image compared to the unprocessed image) does not show remarkable improvement when isosceles triangle based segmentation is adopted. Compression ratio is also increase marginally and it may occur due to the dual complexity of the RGB colour scheme and partitioned iteration on triangular shaped topology on image plane. On the contrary, when HSI scheme is used and each channel is processed separately, the PSNR increased to a lesser extent as noise in image signal does not inherently dependent on the colour scheme. Execution times of the whole process of the entire system have been found to decrease around 8% to 9% for HSI scheme compared to that obtained in RGB scheme. The compression ratio has been found to increase nearly ten times for HSI scheme compared with those obtained in RGB scheme and it hold good for facial images and natural objects and sceneries. The present study is expected to provide some new idea about the better applicability of HSI scheme compared with traditional RGB colour scheme.

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