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A New Hybrid Fractal based Color Image Compression in YCbCr Scheme and Discrete Cosine Transform with Quadtree and Isosceles Triangle Segmentation Approach

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Abstract

Color Image compression has become an important technology to decrease memory space and to reduce transmission time. The present study provides comparative values between RGB and YCbCr color spaces with respect to PSNR, execution time and compression ratio. Fractal coding is a valuable method which utilizes for compression of color image. This method is most suitable for irregular shape of images. Long encoding times still remain as main disadvantage of this compression technique. A hybrid fractal coding technique based on YCbCr scheme and Discrete Cosine Transform (DCT) with quadtree and isosceles triangle segmentation is proposed in the present study. The study needs six phases, first, conversion of input RGB image to YCbCr scheme; second, the resulting image (YCbCr) is partitioned separately based on quadtree approach and isosceles triangle segmentation approach; third, DCT is applied to every block of the partition, fourth, scanning of every block value and zigzag manner is applied to prevent zero co-efficient; fifth, both quad tree and isosceles triangle segmentation approaches are applied separately for having partitioned resulting image; sixth, to compress the image, Run Length Encoding (RLE) approach is utilized. Test results demonstrate that proposed strategy gives higher compression ratio, PSNR value with high processing speed without degrading the image quality.

Keywords: Affine Transformation, Discrete Cosine Transform (DCT), Fractal Compression, Isosceles Triangle Segmentation, Iterated Function System (IFS), Partitioned Iterated Function System (PIFS), Quadtree Partition, Run Length Encoding (RLE), YCbCr Transform

1. Introduction

Image compression and pattern reorganization is an important field of digital image processing. Now a day's volume of data is increasing with advancement of technology with respect to processor capacity and application of those in signal processing kits. The increasing sampling rate of the image plane and high bit quantizing of image intensity or colour level have become very common and popular in cases of biomedical imaging, internet and video image processing. The basic problem arises from the limitation of hardware architecture and invention of commensurate algorithm. Adequate care and caution are needed for the storage, processing and transmission of the large number of data arising out of the aforesaid factors. There are already a large number of data compression techniques known to the scientist community and it includes lossy and lossless compression methods. Lossless compressions are necessary for archival images, forensic documents and bio medical imaging. Lossless compression are mainly based on various coding method like Run Length Encoding (RLE), LZW coding, Huffman coding while lossy compression are applicable in those cases when certain number of data bits may be lost during

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compression method. Discrete Cosine Transformation (DCT), JPEG and MPEG etc. are the most common among them. It is essential to know the shape and size of the images prior to subject them in compression process. There are certain objects in the nature for which the exact size of the object cannot be measured either in terms of geometrical scale or digital duration. Among them, the size of the leaves of a tree, the size and shape of river water flow, snow, and cloud and fire flame are most noteworthy. These objects do not have any precise or particular size and often vary in both shape and size with time. The processing of these images occupies a major and problematic part of digital image processing.

Principle idea of fractal coding was proposed by in[1], as the expansion proposed computation in[2,3] proposed the first practical approach, based on Partitioned Iterated Function System (PIFS), which utilized self-similarity concept. This technique is mainly based on image block transformation and has an excellent searching strategy such as image partitioning into range blocks, to characterize the given image according to shades, midrange and edge blocks[4,5]. Fractal image compression has been used for various image compression[6–12], image segmentation and pattern reorganization such as facial recognition[13] and in many others. A contractive transformation is used for fractal coding[14] for image compression. The transformations used in IFS, consists of affine mappings, called Collage theorem. This compression is based on self similarity; the strategy is involves partitioning of the image into non-overlapping areas, called range blocks and domain blocks. The size of the domain blocks is constantly twice that of the range blocks. Subsequent, to get the best matched domain block with respect to each range block, a contractive affine transformation is utilized. If best matched found, an IFS code is generated to get the original image[15]. To overcome the existing disadvantages for fractal based image compression, quad tree technique and isosceles triangle segmentation approaches are used separately. To reduce encoding time, a hybrid fractal based colour image compression in YCbCr scheme and Discrete Cosine Transform with quad tree and isosceles triangle segmentation and run length encoding techniques are used in a combined way in the proposed study. Left of the paper is represents as: Mathematical background and some basic terminology describes Section 2, and Section 3 represent the proposed methodology, Section 4 represent the results and discussed, and lastly Section 5 represent the conclusion.

2. Mathematical Background and Some Basic Terminology

2.1 Self-Similarity Property

It is a property of self similarity, where every image has some similar portions with respect to image texture. These similar portions are obtained by mapping based on fractal method and provide an IFS code for that self- similar portion. If any self-similar portion is not found for any image, again partition is method is repeated on the basis of fractal and finally the IFS code for that self- similar portion is obtained. This is called self-similarity property and it depends on the texture of the image. Fractal geometry based transformation is independent of scaling factor and scale. Figure 1, lena image has some similar portion in the shoulder and this area overlaps some similar portion identical to it. The same types of similarity are found in the certain portion of the hat and in the right side of the back ground. The self-similarity is also found between the two points of hat and right side of the hat which falls in the background and it is shown in Figure 1. The notable thing is that self-similarity normally occurs in any image in a discontinuous manner and may be some scattered portion of image, may be found in the foreground and background, of these images.

2.2 Iterated Function System and Attractor

In this function system; image is partitioned based on three triangular pieces. This partitioned iteration

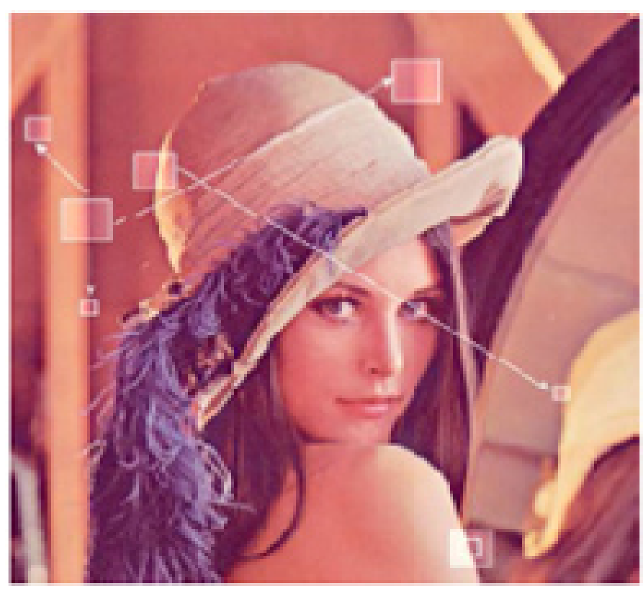


Figure 1. Demonstrates the self-similarity in Lena.

is applied again until the shape and sizes are in regular shapes. Figure 2 shows the contraction transformations by iterated function system, and IFS mainly collection of contractive mappings.

Here IFS be indicate by W and the collection of εtransforms by $w_1, w_2, w_3, \ldots, w_n$, then W(X) can be represented as

$$W(X) = w_1(X) \cup w_2(X) \cup w_3(X) \ldots \cup w_n(X) \quad (1)$$

Here X indicates the grayness level of the image where the transform is utilized.

2.3 The Collage Theorem

In 1993 Barnsley has proposed the concept of the contraction mapping, applied to IFS's, called the Collage Theorem. If considered image f, a contractive transformation is W such that function is

$$d_2(f, W(f)) \le \varepsilon, \quad (2)$$

$$\text{then } d_2(f, f_w) \le \frac{\varepsilon}{1-\varepsilon} \quad (3)$$

Where ε indicate the contractivity factor of W, f_w represent the fixed point and ε will be greater. This implies that we can start with any image g and iterate $W^{on}(g)$ to get an image which is close to f.

$$W^{on}(g) \longrightarrow f_w \approx f. \quad (4)$$

Collage Theorem conveys us one stage nearer to fractal image encoding. And the decoding phase consists of iterating W on any initial image g in order to reform g to recover f_w.

2.4 Affine Transformation

Barnsley proposed the concepts of contractive mapping based on IFS and it is called affine transformation which can be represented as T: $R^2 \rightarrow R^2$. This transformation is mapped a plane to itself. The affine transformation is

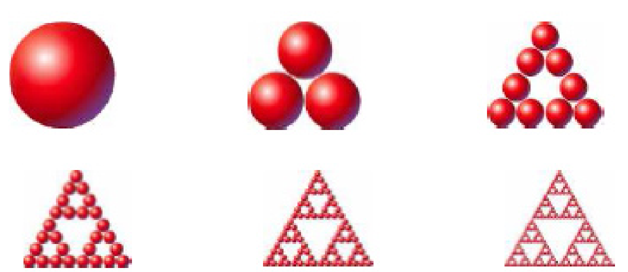


Figure 2. Demonstrate the contracting transformations of iterated function system.

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \quad (5)$$

Here a, b, c, d, e, f indicate the rotation, translation, skew and contraction, etc.

Let $\dot{w}_i$ (x, y) represent the affine transformation on $I^2 \rightarrow \mathbf{I}^2$, and then

$$\dot{w}_i(x, y) = A_i \begin{pmatrix} x \\ y \end{pmatrix} + b_i \quad (6)$$

For some 2 × 2 matrix A_i and 2 × 1 vector b_i

Consider $D_i \subset I^2$ indicates the sub domain and the unit square I^2, and consider R_i indicates the range of $\dot{w}_i$ working on D_i, which implies is $\dot{w}_i(D_i) = R_i$.

It also is represent as w_i: F→F working in the images $f(x, y)$ by

$W_i(f)(x,y) = s_i f(\dot{w}_i(x,y)) + o_i$ provided $\dot{w}_i$ is invertible and $(x, y) \in R_i$, s_i controls the contrast and o_i controls the brightness of the image. A spatial affine transformation and its inverse system are shown in Figure 3.

2.5 Fractal Image Coding

Fractal based image compression used the concepts of self-similar of irregular shaped[3,16]. The process involves partitioning of the image into non-overlapping areas, called range blocks and domain blocks[17]. The size of the domain block is twice that of the range blocks. A contractive affine transformation searches the best matched domain blocks among other such blocks. When the best matched domain block is found for every range block, an IFS code is applied to have the original image. The fractal based compression process may be summarized as follows-

- Initial image is divided into small range blocks with non-overlapping range blocks.

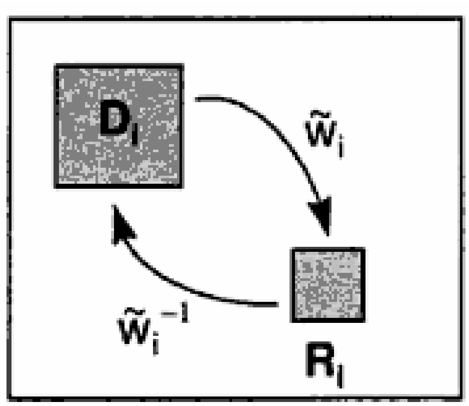


Figure 3. Spatial affine transformation and its inverse.

- For each range block, a large block, called domain block is found out.
- Domain block is shrinked by four neighborhood region method to the size of range block. Thus domain block is marked.
- Domain block is transposed and turned. In this way, eight affine transformations can be made to have corresponding transformation matrices.
- Each range block is compared with domain block in D pool and most similar domain block is retained. The similarity between blocks can be measured by average Mean Square Error (MSE).
- For each range blocks, the compression ratio is measured by affine transformation whole image is ultimately made up of, each transformation.

These processes are shown in Figure 4.

2.6 Quadtree Partitioning

A quad tree based image partition divides the image in the shape of square or rectangular segmentation. It is demonstrates the structure of a tree where root node represent the original image and leaf or external nodes are the partitioned image. Figure 5 shows the quadtree partitioning approach.

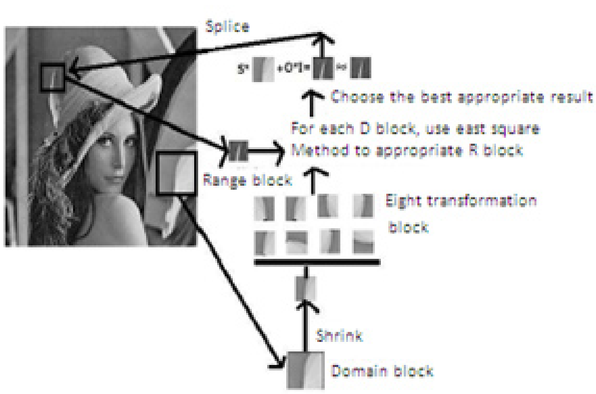


Figure 4. Represent the schematic diagram of the fractal encoding process.

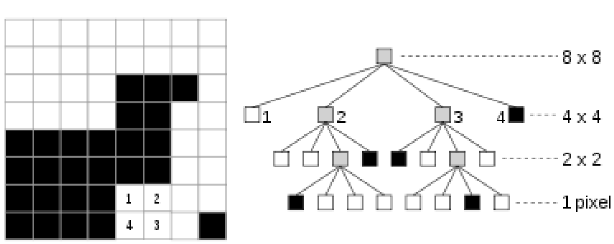


Figure 5. Quadtree partition techniques.

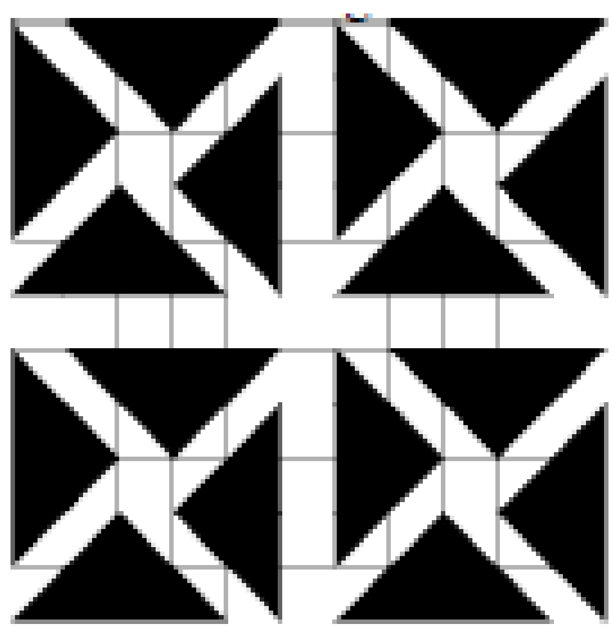
The concept of image compression based on fractal block coding strategy was first proposed by in[3]. But main drawback of this strategy is fixed sizes of range blocks. Due to fixed size, the mapping may not cover all portions of the image. To overcome this problem a quad tree-based fractal encoding scheme[18] has been used in the study.

2.7 Isosceles Triangle based Partition

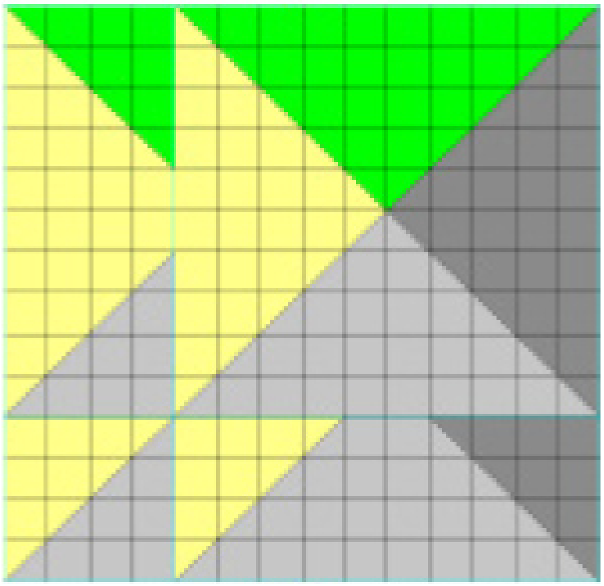
In isosceles triangle division each domain and range blocks have been separated into isosceles triangles partition instead of rectangles, Figure[19] demonstrates the range bocks, domain block and partition of domain and range blocks strategy. This division technique is agreeable to drawing closer the corner to corner edge and utilizing the self-similarity property of the image helps to develop the edge data of original image. In Figure 6 (a), demonstrates the non-overlapping range blocks as treated as $R_1, R_2, R_3 \ldots, R_n$ is 4, and $R_1, R_2, R_3 \ldots, R_n$ cover the entire image. Figure 6(b) shows the domain block partition and Figure 6(c) demonstrate the partition of range and domain blocks. The sizes of the domain blocks are four times of range blocks.

2.8 RGB to YCbCr T and YCbCr to RGB Transformation

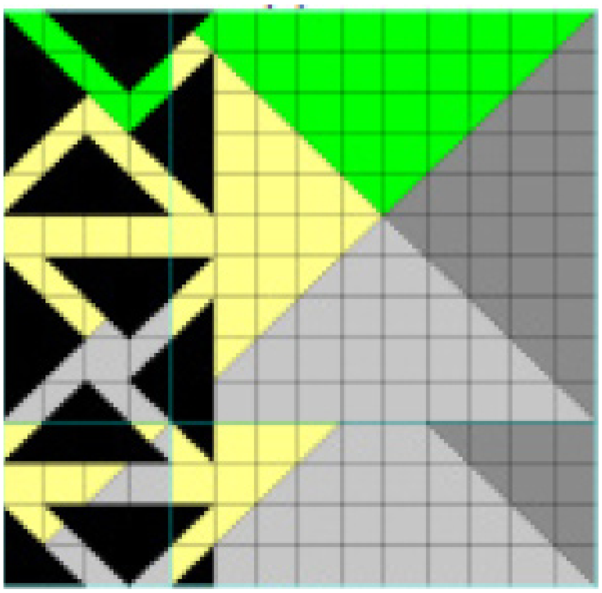
RGB based image compression is not sufficient to represent the images. For generating the colour images, three components of RGB need to have equal bandwidth.



(a)



(b)



(c)

Figure 6. **(a)** Demonstrate the partition of range block. **(b)** Demonstrate the partition of domain block. **(c)** Demonstrate the partition of range and domain blocks[19].

In such manner, different colour schemes[20–22] as YUV, YCbCr and YIQ etc. are needed to represent the images. In present study RGB to YCbCr conversion is utilized, three planes images R, G and B are omitted and the maximum signal energy of the new converted YCbCr image is contained in the Y plane and accomplished higher compression ratio in the Cb and Cr planes without degrading the quality of transformed image when retrieved to the original RGB space. The same strategy is utilized to find out the Y value during conversion from RGB to YCbCr. The conversion is as follows.

$$Y = 0.299\ R + 0.587\ G + 0.114\ B \tag{7}$$

$$Cb = -0.169\ R - 0.331\ G + 0.500\ B = 0.564\ (B - Y) \tag{8}$$

$$Cr = 0.500\ R - 0.419\ G - 0.081\ B = 0.713\ (R - Y) \tag{9}$$

Here *Y* indicates a monochrome compatible luminance component, and *Cb*, *Cr* indicates chrominance components containing color information.

$$R = Y+1.402(Cr-128) \tag{10}$$

$$G = Y-0.34414(Cb-128)-0.71414(Cr-128) \tag{11}$$

$$B = Y+1.772(Cr-128) \tag{12}$$

Where R, G and B take the typical values from 0 to 255 (8-bit precision), Y is the same range (0 - 255), and Cb, Cr components have values in the range (16 - 240).

3. Proposed Method

Fractal based colour image compression using YCbCr scheme and DCT with quadtree partitioning and isosceles triangle segmentation approaches are proposed. Proposed approaches are separated as follows: 1. RGB image is converted in to YCbCr scheme. 2. Partition the converted YCbCr scheme into non-overlapping areas, called range and domain blocks, the size of domain block is twice that of the range block dimension and the same is carried out based on quad tree partitioning and isosceles triangle segmentation approaches. 3. Discrete cosine transform is used to every block of the segmented image for both partitioning approaches (quadtree partitioning and isosceles triangle segmentation). 4. To prevent the zero co-efficient every block values are scanned and used in a zigzag manner. 5. After using the zigzag manner image is segmented using quadtree partitioning strategy and isosceles triangle segmentation approach separately. 6. Finally compression Run length encoding used to bring the segmented image into coded form. The image is partitioned (quadtree partitioning and isosceles triangle segmentation) separately. The size of the range block is 4×4 and 8×8 domain blocks. Discrete Cosine Transform (DCT) technique is used of the partitioned image for quantizing DCT coefficients, rearranging these in a zigzag manner and enhanced the compression efficiency. Few non-zero tokens for each block are proceeded by their count and final value can be obtained[17]. Figure 7 shows the zigzag scanning of the image. The DCT coefficients are then decomposed by quadtree partitioning approaches to compress the image. Fractal based image compression used the property of self-similarity by partitioning into many 8×8 blocks. This technique prevents the repetitive compression on the similar block and utilized before encoding the quantized partitioned image blocks. Search the best matched domain blocks until best matches are found. Run length encoding technique is used for further compression the quantized values. This process represents a string by replacing

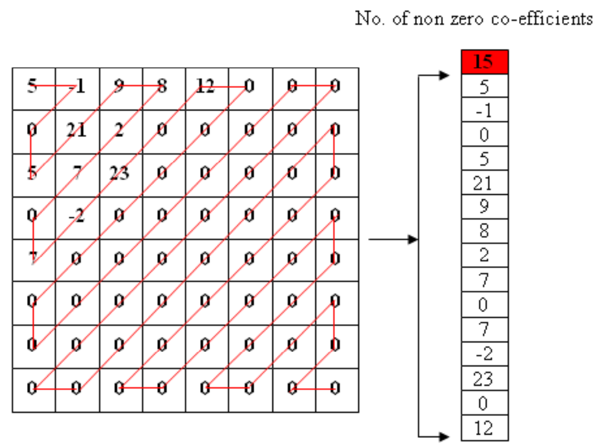


Figure 7. Method of the zigzag scanning.

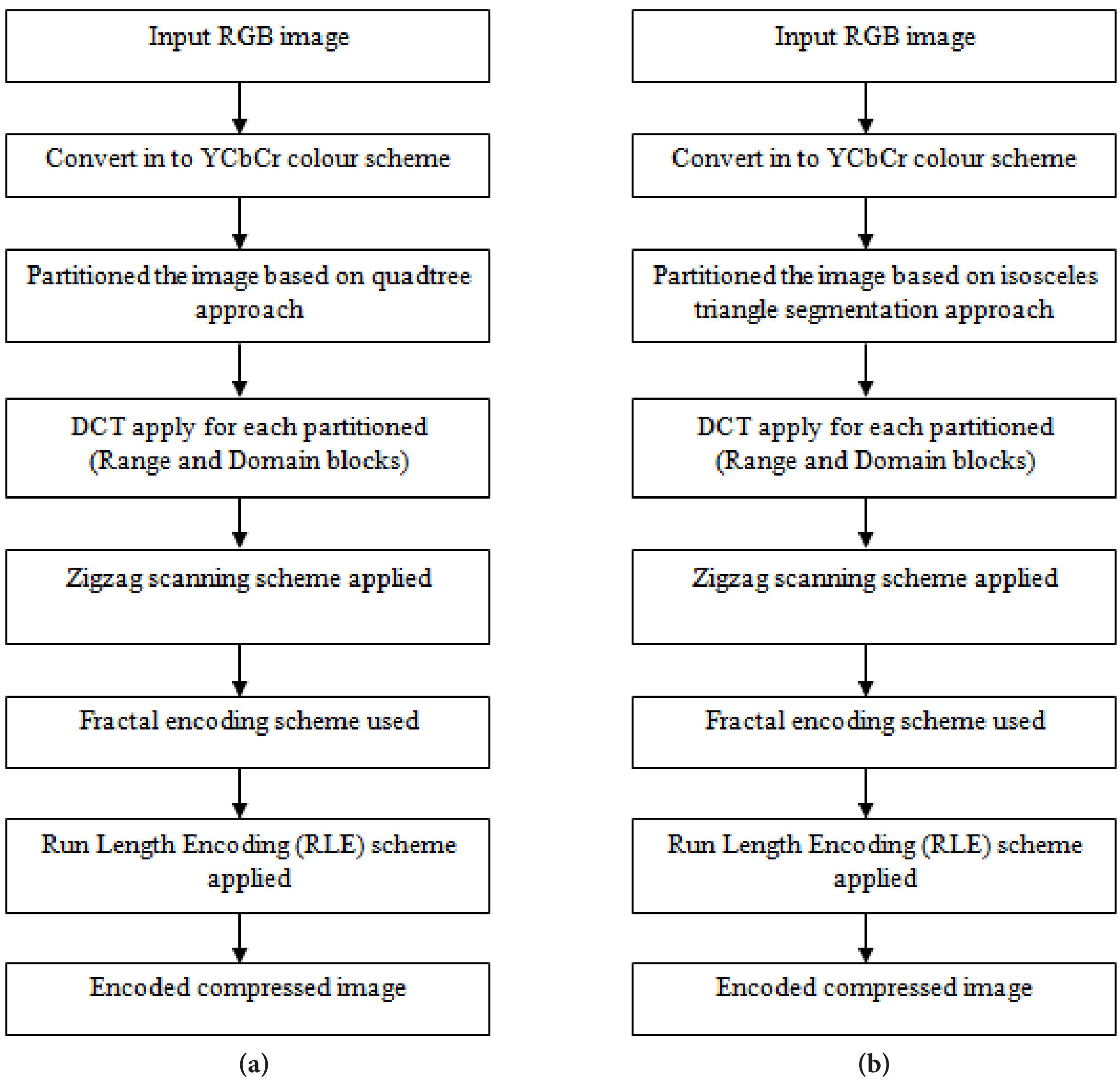


Figure 8. **(a)** Compression procedure based on quadtree partitioning. **(b)** Compression procedure based on isosceles triangle partition.

each sequence of consecutive identical characters with (character and length). This method works us when the characters repeat often[17,23]. The compressed image is decompressed by reversing the entire procedure. Figure 8(a) shows the flow diagram of compression procedure based on quadtree partitioning and Figure 8(b) shows the same for compression procedure based on isosceles triangle segmentation, respectively.

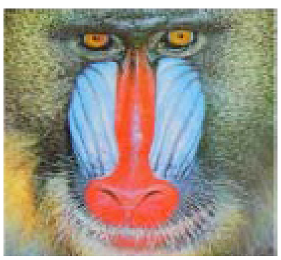
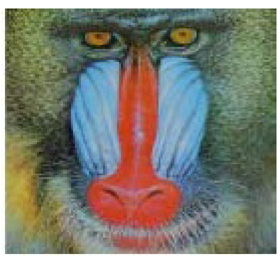
Original image	Reconstructed image (decompressed)
 **(a)**	 **(b)**
 **(c)**	 **(d)**
 **(e)**	 **(f)**
 **(g)**	 **(h)**

Figure 9. **(a), (c), (e), (g)** Original images of peppers, baboon, boat and rose. **(b), (d), (f), (h)** Show the reconstructed images of peppers, baboon, boat and rose.

The proposed compression and decompression algorithms are as follows

- The compression algorithm is

Step 1: Input RGB image.
Step 2: Then conversion RGB to YCbCr.
Step 3: Partition the input YCbCr scheme in to non-overlapping range areas called range block and non-overlapping domain areas called domain blocks based on quadtree approach and isosceles triangle segmentation.
Step 4: Apply DCT to every partitioned.
Step 5: Each block of DCT coefficient are quantized.
Step 6: Zigzag scanner used in every block values.
Step 7: Apply fractal encoding scheme in both quad tree and isosceles triangle segmentation.
Step 8: Finally RLE is used to compress the image.

- The decoding algorithm is

Step 1: Input compressed image.
Step 2: Run Length decoding technique is applied.
Step 3: Applied fractal based image decoding approach.
Step 4: Inverse zigzag scanning is utilized to the image.
Step 5: Applied inverse DCT to get the YCbCr image.
Step 6: Convert YCbCr to RGB image.
Step 7: Get decompressed image.

4. Implementation, Results and Discussions

Proposed method is implemented and tested through the simulation results for both quadtree and isosceles triangle segmentation approaches, separately. The simulation results are carried out using Core I3 processor, 3 GB RAM and Windows 7 operating system. Here four color images namely bird, rose, boat and peppers images of size 256×256×3 are taken. Figure 9 (a), (c), (e) and (g) show the original images of peppers, baboon, boat and rose and Figure 9 (b), (d), (f) and (h) show the reconstructed images of peppers, baboon, boat and rose, respectively. Figure 9 (a), (c), (e) and (g) show the original images of Peppers, Baboon, Boat and Rose and (b), (d), (f) and (h) show the reconstructed images of Peppers, Baboon, Boat and Rose, respectively. Table 1 shows the comparison between quadtree approach and isosceles triangle segmentation approach based on PSNR (dB), encoding time (sec) and compression ratio for YCbCr colour space. It can be noticed that the value of PSNR (dB), encoding time

Table 1. Comparison of YCbCr values between quadtree and isosceles triangle segmentation approaches with respect to PSNR, compression ratio and encoding time

RGB Images	Y Cb Cr	Quadtree Approach			Isosceles Triangle Segmentation		
		PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Peppers	Y	21.91	43.03	42.45	22.01	43.0	44.41
	Cb	57.93	45.54	42.32	59.33	43.23	44.10
	Cr	58.63	46.44	43.02	60.53	43.13	45.13
Baboon	Y	23.76	42.01	42.32	25.90	41.09	43.39
	Cb	59.43	45.00	43.01	61.01	44.04	43.87
	Cr	60.01	42.21	44.58	60.47	42.04	44.90
Boat	Y	20.90	41.91	41.51	21.03	40.33	42.01
	Cb	56.77	43.21	44.44	58.17	43.01	45.78
	Cr	57.87	43.42	43.23	59.88	42.31	45.07
Rose	Y	23.11	41.01	42.04	24.98	40.00	44.11
	Cb	58.89	42.07	44.34	60.39	41.01	44.00
	Cr	59.37	43.02	45.01	62.21	42.08	46.31

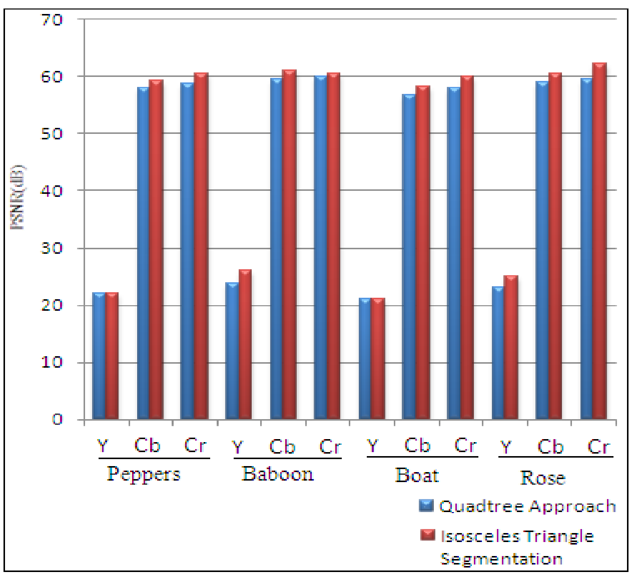


Figure 10. Comparison value of PSNR (dB) of four different colour images for YCbCr colour space with quadtree and isosceles triangle segmentation.

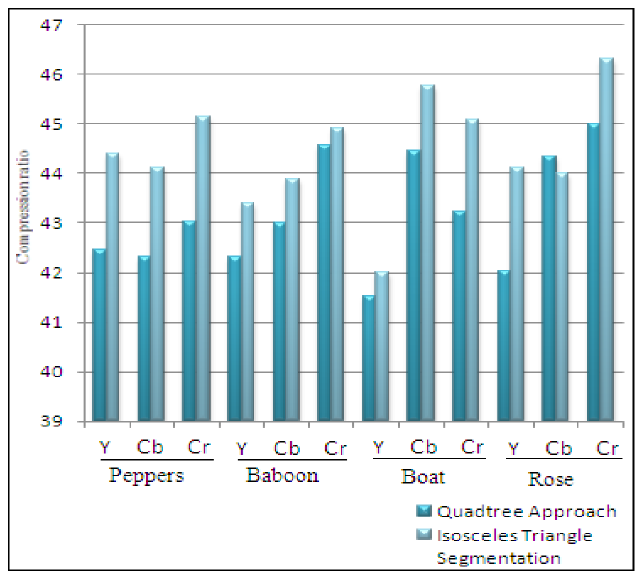


Figure 11. Comparison value of compression ratio of four different colour images for YCbCr colour space with quadtree and isosceles triangle segmentation.

(sec) increases slightly in isosceles triangle segmentation approach compared to quadtree approach. Moreover it is also found that proposed isosceles triangle segmentation approach required less processing time compared to proposed quadtree approach. Figure 10 and Figure 11 show the comparison value of PSNR (dB) and compression ratio of four different colour images for YCbCr colour space with quadtree and isosceles triangle segmentation approach. Is has been observed that values PSNR (dB) and compression ratio of Y, Cb and Cr for different input colour images namely peppers, baboon, boat and rose are increased slightly in isosceles triangle segmentation approach compared to quadtree approach. Figure 12 shows the comparison values of execution time (sec) of four different images for YCbCr colour space with quadtree and isosceles triangle segmentation approach. It has been found that execution time required for isosceles triangle segmentation approach is less compared to quadtree approach.

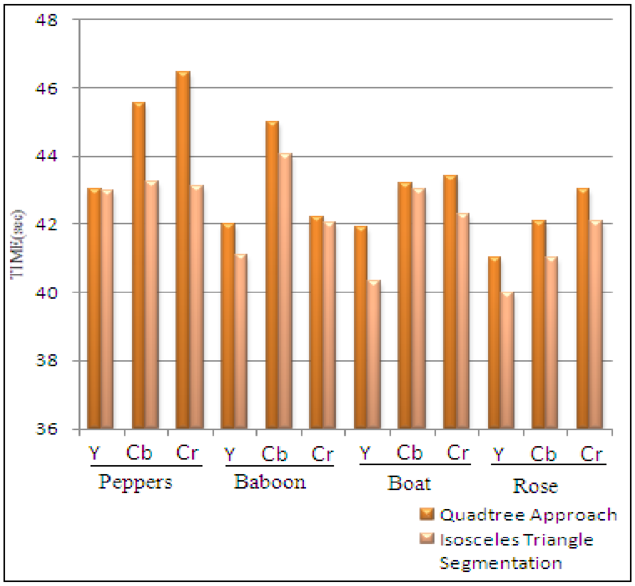


Figure 12. Comparison value of time (sec) of four different colour images for YCbCr colour space with quadtree and isosceles triangle segmentation approaches.

5. Conclusions

The main aim of proposed study is to minimize the number of bits needed to store the image in the memory devices and to provide good quality of compressed image with minimum possible bit utilization. A novel hybrid fractal color image compression based on YCbCr colour difference scheme and discrete cosine transform with quadtree and isosceles triangle segmentation is proposed. It has been found that proposed YCbCr color space provides higher PSNR (dB), larger compression ratio and requires less processing time to compress the colour image. This study proposes two types of image segmentation approaches viz., quad tree partitioning and isosceles triangle segmentation. It has also been found that proposed isosceles triangle based image segmentation approach provide higher PSNR (dB), compression ratio and lower processing time to compress the colour image compared to those obtained with quad tree geometry but with same methodology.

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