Comparative study of Image compression

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***Abstract*— In this paper, we present a comparative study of Synthetic Aperture Radar (SAR) image compression techniques which are very much help full for high speed communication. Images have some distinct properties when compared with the natural images. This paper outline the comparison of compression methods such as DCT, SADCT, Tri – DCT, Fractal image compression, JPEG-2000 with encoding and decoding techniques like Set Partition In Hierarchal Tree(SPIHT), set partition embedded block(SPECK), embedded zero tree block coder(EZBC).**

***Keywords*— DCT, SADCT, Tri – DCT, Fractal, JPEG -2000, Set Partition In Hierarchal Tree (SPIHT), set partition embedded block (SPECK), embedded zero tree block coder(EZBC).**

I. Introduction

Image compression has become one of the most important disciplines in digital electronics because of the ever growing popularity and usage of the internet and multimedia systems combined with the high requirements of the bandwidth and storage. There are two basic types of image compression schemes: lossless and lossy compression [1]. In Lossless compression techniques the retrieved Image is similar to the original Image. Lossless compression techniques are variable length coding, LZW coding, bit plane coding, lossless predictive coding, Huffman coding, Golomb rice coding, arithmetic coding etc... In lossy compression the retrieved Image is not similar to original Image. Lossy compression techniques are lossy predictive coding, transform coding and wavelet coding. Usually, lossy compression techniques are more complex and require more computations [2].

JPEG is the international standard for the effective compression of the still digital image compression. The basic transform technique used in JPEG is DCT. The important property of DCT is energy compaction [3]. The 8-point DCT is a key step in many image and video processing applications. This is used in several image and video coding standards, such as JPEG, MPEG – 1, MPEG – 2, H.261 and H.263. The DCT is not only orthogonal in rectangular blocks but also in trapezoid and triangular blocks. So image can be divided into trapezoid and triangular blocks based on the shape of the image and achieve high compression this approach is named as Tri – DCT [4] based image compression which is better than existing shape adaptive algorithm (SADCT) [5].

JPEG - 2000 [6,7,8,9] is developed by International organization for Standardization (ISO), International electro-technical commission (IEC) and recommended by International telecommunication union (ITU). JPEG–2000 has 12 standards (i.e. 12 ways of encoding and decoding techniques). In JPEG-2000 part-1 encoding standard compression is performed in 3 steps 1) Image processing – includes tiling, DC level shifting, multi component transformation 2) compression – discrete wavelet transform (DWT), quantization, entropy encoding [10,11], 3) compressed bit stream formation.

Fractal image Compression [12, 13, 14] is achieved by finding the affine transformations of the image called as Iterated Function Systems (IFS). The image is divided into smaller non-overlapping blocks called as range and overlapping domains which are twice the size of the range blocks. Affine transformations are found which closely match domain block for every range block. These affine transformations are then used to get the attractor which closely resembles the original image.

II. Compression Techniques

a) Joint Photo Expert Group

Discrete Cosine Transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. In JPEG an Image is divided into several 8 by 8 blocks. Then, the two-dimensional DCT is applied to all the 8 by 8 blocks for encoding [15]. The 2-D DCT is defined as [16]

$$\mathrm{F}[p,q] = \sum_{m}^{M-1}\sum_{n}^{N-1} C_{p,q}[m,n] f[m,n] \text{--------} 1$$

Where $m = 1,2,....., M-1$, $p = 1,2,....., M-1$, $n = 1,2,....., \mathrm{N}-1$, $q = 1,2,....., \mathrm{N}-1$, and

$$C_{p,q}[m,n] = k_p \, \mathrm{h}_q \cos\left(\frac{(2m+1)\pi p}{2M}\right)\cos\left(\frac{(2n+1)\pi q}{2N}\right)$$

$$k_p = \sqrt{\frac{2}{M}} \text{ when } \mathrm{p} \neq 0, \; k_p = \sqrt{\frac{1}{M}} \text{ when p=0}$$

$$h_p = \sqrt{\frac{2}{N}} \text{ when } \mathrm{q} \neq 0, \; h_p = \sqrt{\frac{1}{N}} \text{ when q = 0}$$

Where $C_{p,q}[m,n]$ is DCT coefficient and F[p,q] is forward Discrete cosine transform. These DCT coefficients forms a complete set of orthogonal transform i.e sum of multiplication of one coefficient with other coefficient at particular values of p and q equal to zero. Sum of multiplication of DCT coefficients with itself is not equal to zero.

An orthogonal approximation for the 8-point discrete cosine transform (DCT) is one where transformation matrix contains only zeros and ones so number of multiplications and bit shift operations required is less [17]. Ankur Saxena[18] proposed a DCT/DST based transform scheme that applies either the conventional DCT or type-7 DST for all the video-coding intra-prediction modes: vertical, horizontal, and oblique. Zheng-Xin Hou [19] proposes new concepts of the all phase bi-orthogonal transform (APBT) and the dual bi-orthogonal basis vectors. In the light of all phase digital filtering theory, three kinds of all phase bi-orthogonal transforms based on the Walsh transform (WT), the discrete cosine transform (DCT) and the inverse discrete cosine transform (IDCT) are proposed.

b) Tri – DCT

Discrete Cosine Transform is orthogonal in triangular and trapezoidal blocks [20]. A trapezoidal is one with P rows or columns and if the number of pixel in the p^{th} row or column is denoted by h(p), then

$$h(p) + h(P-1-p) \text{ is a constant}$$

For triangular and rectangular blocks above equation must

C_{00}
$$\begin{pmatrix} 0.3333 & & \\ 0.3333 & 0.3333 & \\ 0.3333 & 0.3333 & 0.3333 \end{pmatrix}$$

C_{01}
$$\begin{pmatrix} 0.4082 & & \\ 0.4082 & 0.0000 & \\ 0.4082 & 0.0000 & -0.4082 \end{pmatrix}$$

C_{02}
$$\begin{pmatrix} 0.2357 & & \\ 0.2357 & -0.4714 & \\ 0.2357 & -0.4714 & 0.2357 \end{pmatrix}$$

C_{10}
$$\begin{pmatrix} 0.4082 & & \\ 0.0000 & 0.0000 & \\ -0.4082 & -0.4082 & -0.4082 \end{pmatrix}$$

C_{11}
$$\begin{pmatrix} 0.5000 & & \\ 0.0000 & 0.0000 & \\ -0.5000 & -0.0000 & 0.5000 \end{pmatrix}$$

C_{11}
$$\begin{pmatrix} -0.4082 & & \\ 0.0000 & 0.4082 & \\ -0.4082 & 0.4082 & -0.4082 \end{pmatrix}$$

Fig.1. DCT coefficients for triangular and trapezoidal images

be satisfied. Now construct the rectangular block from a given trapezoidal block with satisfying equation [4]. If $C_{P,Q}[m,n]$ is Discrete Cosine Transform coefficients of the rectangular block then $T_{P,Q}[m,n] = \sqrt{2}\, C_{P,Q}[m,n]$ are the coefficients of trapezoidal and triangular blocks for P+Q = even or odd.

Fig.1 shows DCT Coefficients of triangular block of size 3 by 3 matrixes.

c) FRACTAL IMAGE COMPRESSION

Fractal Image compression (FIC) is a time-consuming encode algorithm. The original idea was proposed by Barnsley and Demko in 1985 [21] and the practical FIC algorithm was not implemented until 1992 by Jacquin [22]. The FIC is based on the self-similarity property of real life images and Partitioned Iterated Function System (PIFS) [23], each range block must search for the best matched block from the large domain pool. A large number of the redundant similar computations will slow down the encoding speed of the FIC. Therefore, the main research direction for FIC is focused on how to reduce the encoding time under the premise of maintaining retrieve Image quality. Particle swarm optimization (PSO) technique reduces the encoding time by utilizing the visual information of the edge property of Image [24]. Instead of the full search, a direction map is built according to the edge-type of Image blocks, which directs the particles in the swarm to regions consisting of candidates of higher similarity. A genetic algorithm with a hybrid select mechanism [25] divides the Image into three classes: smooth, horizontal /vertical edge and diagonal/sub diagonal edge according to DCT coefficients, now apply Genetic Algorithm on these three classes. Ming-Sheng Wu [26] proposed a genetic algorithm (GA) based on discrete wavelet transformation (DWT). For each range block, two wavelet coefficients are used to find the fittest Dihedral block of the domain block. The similar match is done only with the fittest block to save seven eighths redundant MSE computations. Second, embedding the DWT into the GA, a GA based on DWT is built to fast evolutionary speed further and maintain good retrieved quality. Adaptive Fractal Image Compression using PSO technique [27] is used for the MSE based on the stopping criterion between range block and domain block.

d) JPEG – 2000

The wavelet used for lossless compression scheme in jpeg – 2000 is Daubechies bi-orthogonal spline filter [28, 29] and for lossy compression LeGall spline filter [30]. In jpeg-2000 the quantization technique used is uniform scalar quantization with dead – zone about the origin [31]. The region of interest coding is unique feature of jpeg-2000 this is called MAXSHIFT method [32]. The quantized DWT coefficients are coded with tire -1 and tire – 2 coding. In tire - 1each bit planes are coded with a fractional bit plane coding (BPC) [33, 34] followed by binary arithmetic coding (BAC) [35, 36] to generate compressed codes for each code block. The bit plane code is replaced with embedded block coding with optimized truncation algorithm (EBCOT) [37] and variation of binary arithmetic code is a context adaptive BAC called MQ – CODER. MQ-coder is arithmetic coder which gives best results.

EBCOT encodes the bit plane in three pass

1. significance propagation pass (SPP) – in this pass most significant bit of the DWT coefficients are coded
2. magnitude refinement pass (MRP) 3) – current bit which is not most significant bit coded
3. clean up pass – The remaining bit positions are coded with a run-length coding technique

σ = 1 means, first non zero bit of magnitude array (v) has been coded.
σ = 0, otherwise
$σ^1$ = 1, means magnitude refinement coding has been applied to v.
$σ^1$ = 0, otherwise
η = 1, indicates that zero coding operation has been applied in the significant propagation pass.
η = 0, otherwise.

Zero coding tables:

There are three zero coding tables for the purpose of zero coding operation. In EBCOT, there are four possible coding operations used to generate context (CS) and D. There are 19 context values are used based on the σ values of the 8 neighbours.

Context (CS) and D generation methods

1. zero coding (ZC)
2. sign coding (SC)
3. magnitude refinement coding (MRC)
4. run-length coding (RLC)

Significance propagation pass algorithm

1. σ =0 and all neighbourhood has σ =1
2. zero coding and set η = 1 for that bit position
3. if encoded bit =1 than sing coding and set σ =1 else next bit plane and go to step 1
4. repeat 1 to 3 steps until all bit plane are coded

Magnitude refinement pass algorithm:

1. if σ =1 and η = 1, magnitude refinement coding and set $σ^1$ =1
2. if σ ≠ 1 and η ≠ 1, then next bit plane to code
3. repeat step 1 and 2 for all bit planes

Clean up pass algorithm :

1. if σ =0 and η = 0, than check
   I. if m is a multiple of 4
   II. if σ = 0 for the four consecutive locations of the same column, staring form current scan
   III. if σ =0 for the adjacent neighbours of the four bits in the column
2. if all the above are correct than apply run – length coding otherwise apply zero coding

Binary arithmetic code or MQ coder flow chart:

The fractional bit plane coded Images are further coded with binary arithmetic coding or MQ coder and its flow chat is shown in below Fig .2.

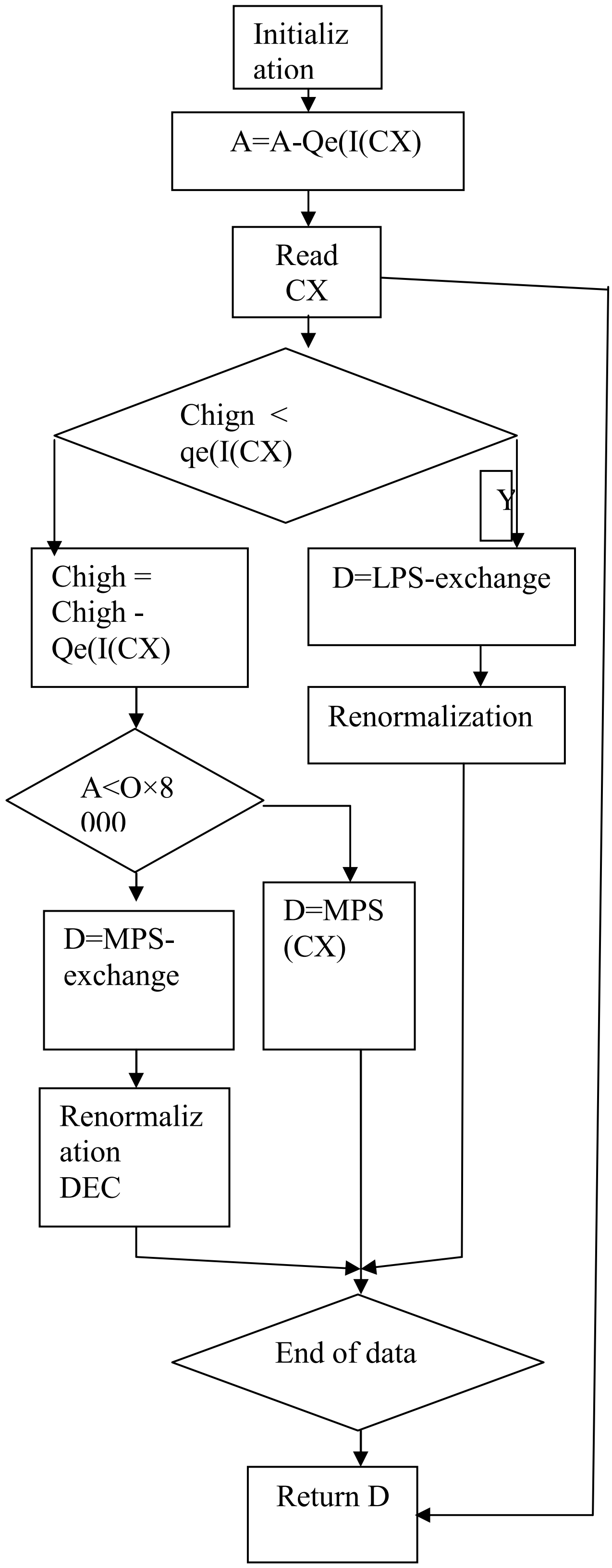

Fig. 2. Flow chat for MQ coder

JPEG2000 Part 2 supports the use of Multi-component transforms (MCTs) to decorrelate multi-component Images along the component direction. Such point transforms can be performed on arbitrary subsets of components, known as "component collections." These Part 2 extensions have been used for compressing 3-D Images in applications such as medical imaging and remote sensing

e) OPTIMIZATION TECHNIQUES

Optimization techniques are useful for Image compression by optimizing the vector quantization technique (VQ). VQ involves three steps codebook generation, vector encoding and vector decoding . Patane and Russo classified all of the VQ algorithms into two groups one competitive learning-based and another k-means-based. In the competitive learning-based methods, the codebook is generated with the process of reparative mutual competitions. The typical methods of competitive learning-based group included the self-organizing map , growing neural gas and neural network . The k-means based algorithms are designed to minimize distortion error by selecting a suitable codebook. A well-known k-means based algorithm is LBG algorithm. LBG algorithm is a vector quantization technique which is introduced by Linde-Buzo-Gray. LBG algorithm is comes under k-means based algorithm. In LBG clustering of data is play a major role. Clustering means division of large data set into smaller data set based on some similarity or grouping of data.

K-means algorithm:

Step 1: Given n objects, initialize k cluster centres.
Step 2: Assign each object to its closest cluster centre.
Step 3: update the centre for each cluster
Step 4: repeat 2 and 3 until no change in each cluster centre

LBG algorithm is simple and less complex for vector quantization but its efficient codebook generation depends on initial random selection values. Recently, the evolutionary optimization algorithms had been developed to design the codebook for improving the results of LGB algorithm.
Rajpoot, Hussain, Saleem, and Qureshi (2004) applied the ant colony system (ACS) algorithm to develop the algorithm for the codebook design. The generation of codebook using ACS was facilitated by representing the coefficient vectors in a bidirectional graph, followed by defining a suitable mechanism of depositing pheromone on the edges of graph. Chen, Yang, and Gou (2005) proposed an improvement based on the particle swarm optimization (PSO). The result of LBG algorithm was used to initialize global best particle by which it can speed the convergence of PSO. In addition, Wang et al. (2007) proposed a quantum particle swarm algorithm (QPSO) to solve the 0–1 knapsack problem. Zhao, Fang, Wang, and Pang (2007) employed a quantum particle swarm optimization to select the computed the local points from the pbest and gbest for each particle and further defines two parameters, u and z, update the position of corresponding particle. The
Firefly algorithm was introduced by yang in 2008 which gives best codebook for vector quantization of SAR image compression. It is may be considered as a typical swarm based approach for optimization, in which the search algorithm is inspired by social behaviour of fireflies and the phenomenon of bioluminescent communication. It is based on the brightness, attractiveness and absorption coefficient of environment. The three assumptions are 1. All fireflies are unisex so one is attracted by other irrespective of sex 2. Always brighter firefly will attracts the less brighter firefly, if there is no brighter one then less one moves randomly 3. Brightness of firefly is determined by objective function. The relation between brightness or intensity of light and distance is given by

$$I=I_0 e^{-\gamma r} \quad \text{------------------------------}2$$

Where I_0 is initial intensity, γ is absorption coefficient of environment r is distance between two fireflies. The relation between attractiveness and distance between two fireflies is given by

$$\beta=\beta_0 e^{-\gamma r} \quad \text{------------------------------}3$$

Where β_0 is attractiveness function when distance between two fireflies is zero. The distance between two fireflies i and j at X_i and X_j is a Cartesian distance which is given by

$$r_{i,j}=\sqrt{\sum_{k=1}^{d}(X_{I,K}-X_{J,K})^2} \quad \text{------------------}4$$

The movement of i^{th} firefly towards j^{th} is given as

$$X_i = X_i + \beta_0 e^{-\gamma r_{i,j}}(X_i - X_j) + \alpha e_i \quad \text{------}5$$

Where α is randomization parameter and e_i is a vector of random numbers draw from Gaussian distribution or uniform distribution. In general β_0=1, α lies between 0 to 1, γ lies between 0.1 to 10. There are two important issues in the firefly algorithm that are the variation of light intensity and formulation of attractiveness.

III. RESULTS

In this section, we perform several simulations and compare the performances of the JPEG standard, the TRI-DCT, fractal Image compression, JPEG – 2000. The basic measure for performance of a compression algorithm is compression ratio (Cr) is defined as

Cr = original data size/compressed data size.

There is tradeoff between the Cr and picture quality. Higher the compression ratio lowers the picture quality. Quality and compression ratio C_r can vary according to the source Image Characteristics.

Another statistical measure is mean square error (MSE) which is given as

$$MSE=\frac{1}{N_1 N_2}\sum_{n_1}^{N_1-1}\sum_{n_2}^{N_2-1}\left(x[n_1,n_2]-\bar{x}[n_1,n_2]\right)^2$$

Peak Signal to Noise Ratio which is defined as,

$$\mathrm{PSNR}=10\log_{10}\left(2^B-1/MSE\right)$$

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Where B is bits/sample x [n1, n2] pixel value of the original Image and $\bar{x}$ [n1, n2] is the decompressed pixel value of the Image. N1 and N2 are the size of the Image. Decompressed Image of size 128 by 128 and 256 by 256 after JPEG Image compression is shown in Fig.3. Respectively

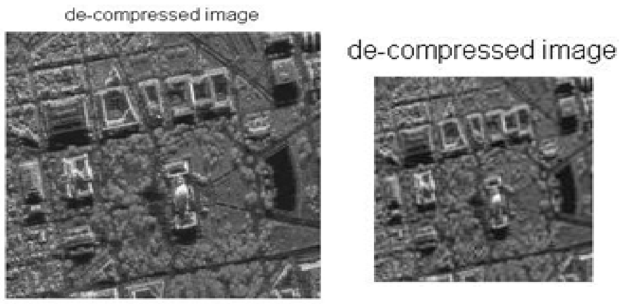

Fig.3. jpeg de-compressed SAR image of size 256 by 256 and 128 by 128

As the size of the Image is increased, time taken for cpu time is high as shown in Table 1.

Table 1 comparison results for jpeg for different sizes

method	image size	MSE	PSNR	CPU time
JPEG	128 * 128	254.9284	24.0666	9.0781
JPEG	256*256	254.8081	24.0687	39.5469

Fractal Image compression

Compressed and de compressed Images of size 128 by 128 after fractal Image compression with range block size of 2 and 4 are shown in Fig.4.Respectively. It is observed that compare to range block size of 4, range block size 2 reconstructed Image qualities is good.

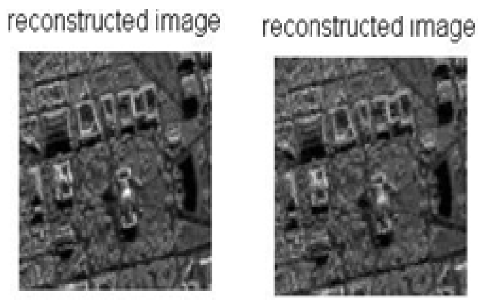

Fig.4. fractal de-compressed SAR Images with range block size of 2 and 4 respectively

Below table shows the cpu times for successive iterations of fractal Image compression and MSE, PSNR and elapsed time for different block sizes.

range block size 2	range block size 4
cpu0 = 35.1563	cpu0 = 179.8594
cpu0 = 11.1406	cpu0 = 162.9688
cpu0 = 5.2813	cpu0 = 117.4063
cpu0 = 2.3594	cpu0 = 70.6406
cpu0 = 1.5938	cpu0 = 40.2500
cpu0 = 0.8750	cpu0 = 22.1875
cpu0 = 0.7344	cpu0 = 12.3750
cpu0 = 0.5000	cpu0 = 6.2969
cpu0 = 0.4531	cpu0 = 4
cpu0 = 0.5781	cpu0 = 2.7031
mse = 53.4912	mse = 58.3436
psnr = 39.6814	psnr = 30.4709
Elapsed time - 4.060896s	Elapsed time - 2.491946 s

JPEG – 2000

In jpeg – 2000, for second level of decomposition PSNR is 71.7119. As shown in Table.2, as the decomposition level is increased PSNR value and compression ratio is reduced. Fig.5. shows the input and decompressed SAR Images of jpeg 2000 Image compression technique.

Table.2 results of jpeg 2000 for Image of size 128 by 128

Decomposition level	MSE	PSNR	Compression ratio %	CPU time
2	0.0044	71.7119	96.2012	167.875
4	0.0195	65.2211	96.2348	559.265
8	0.0082	69.008	82.9897	579.04

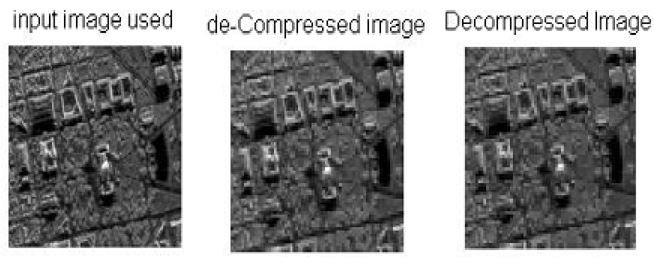

Fig.5. jpeg -2000 compressed and decompressed SAR Images for 2 and 4 decomposition levels respectively

IV. Conclusions

In this paper, a comparative study of SAR Image compression techniques like DCT, Tri-DCT, JPEG – 2000, Optimization Techniques, Fractal image compression is studied with experimental results and comparisons. Among all the techniques JPEG – 2000 with SPECK coding gives best results. compare to all other techniques.

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