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Evaluation of Quality of Images Subjected to Compression Algorithms

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ABSTRACT
Compression is performed to reduce the redundancy and retain information pertaining to data. In this paper, five image compression techniques have been simulated. The techniques are baseline Joint Photographic Experts Group(JPEG) , Block Truncation Coding (BTC) ,Hybrid Discrete Wavelet Transform-Discrete Cosine Transform (DWT-DCT) method, Pyramid and Set Partitioning In Hierarchical Trees (SPIHT) methods. The aim of this paper is to find the best compression algorithm which satisfies our requirements. The results of simulation are shown and compared for different quality parameters of it by applying on 512x512 sized color images of Lena , Baboon and Goldhill and satellite images of earth.CPU time utilization, entropy, Peak Signal To Noise Ratio (PSNR),bits per pixel are some of the factors considered to distinguish between the different methodologies. The results show that the best method for compression which yields a better outcome for standard images is hybrid dwt-dct method whereas for satellite images the best method is SPIHT. Considering CPU computation time , the fastest method of compression is Pyramid method. On the basis of requirement one of the above mentioned algorithms can be used.

Keywords
BTC,Bits per pixelDWT,DCT,Entropy,Image compression, JPEG ,Pyramid,PSNR,SPIHT

1. INTRODUCTION
Data compression is the technique to reduce the redundancies in data representation in order to decrease data storage requirements and hence communication costs. Reducing the storage requirement is equivalent to increasing the capacity of the storage medium and hence communication bandwidth.

Data is represented as a combination of information and redundancy. Information is the portion of data that must be preserved permanently in its original form in order to correctly interpret the meaning or purpose of the data. Two fundamental components of compression are redundancy and irrelevancy reduction. Redundancy reduction aims at removing duplication from the signal source. Whereas reduction of irrelevancy omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System(HVS)[1].

1.1 CLASSIFICATION OF COMPRESSION ALGORITHMS
Data compression is a method that takes an input data D and generates a shorter representation of the data c(D) with less number of bits compared to that of D. The reverse process is called decompression, which takes the compressed data c(D) and generates or reconstructs the data D* as shown in Figure 1. Sometimes the compression (coding) and decompression (decoding) systems together are called a “CODEC”.

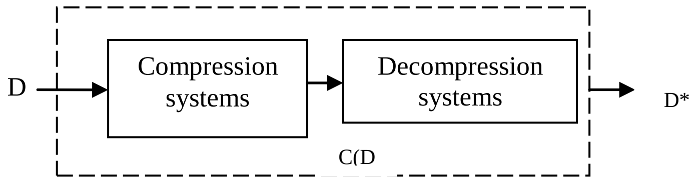

Figure 1 : Compression Decompression System

The reconstructed data D* could be identical to the original data D or it could be an approximation of the original data D, depending on the reconstruction requirements. If the reconstructed data D* is an exact replica of the original data D, the algorithm applied to compress D and decompress c(D) is lossless. On the other hand, the algorithms are lossy when D* is not an exact replica of D[2]. The data compression algorithms can be broadly classified in two categories – lossless and lossy.

2. PROPOSED WORK
The five algorithms that have been considered are (2.1) Baseline JPEG, (2.2) Block Truncation Coding (BTC),(2.3) Hybrid DWT-DCT method , (2.4) Pyramid and (2.5) SPIHT. Each one of the techniques are described below:

2.1 According to [3],The **JPEG** file format was designed to deal with color images as it can store 24 bits per pixel of color data(instead of 8 bits per pixel) and restore millions of colors. There are 3 steps for JPEG compression:

i. **Transformation**: the DCT cuts the image into blocks of 64 pixels and processes each block independently, shifting and simplifying the colors so that there is less information to encode.

ii. **Quantization**: The values in each block are divided by a quantization coefficient. This is the compression step where the data loss takes place. Pixels are changed only in relation to the other pixels within their block.

iii. **Encoding** : the reduced coefficients are then encoded usually with Huffman encoding. With high compression ratio, the block boundaries becomes obvious, causing the blocking artefact which is frequently observed in JPEG images.

2.2 According to [4], **BLOCK TRUNCATION CODING (BTC)** works by dividing the image into small sub blocks of size 4x4 pixels and then reducing the number of gray levels with in each block. This reduction is performed by a quantizer that adapts to the local image statistics. The basic form of BTC divides the whole image into N blocks and codes each block using a 2 level quantizer. The two levels, a and b are selected using the mean (X') and standard deviation) of gray levels within the block is then compared with the mean and then is assigned to one of the two levels.

The X' and are calculated using the equations (1) and (2).

(1)

(2)

Where, m is the number of pixels in each block, and is the original pixel of the block. If the pixel value of each block is greater than or equal to mean, it is represented by '0'. The collection of 1s and 0s for each block is called a bit plane,B. In BTC , two statistical moments a and b are computed using the equations (3) and (4) and are preserved along with the bit plane for reconstructing the image. The compressed image is transmitted or stored as a set {B,a,b}.

$$a = X' - \sigma\sqrt{\frac{q}{m-q}}$$

$$b = X' + \sigma\sqrt{\frac{m-q}{q}} \qquad (4)$$

Where , q is the number of pixel values greater than or equal to X', and (m-q) is the number of pixels whose gray levels are less than X'. While reconstructing the image, the 0 in the bit plane is replaced by 'a' and 1 in the bit plane is replaced by 'b'.An example how the encoding and decoding of a 4x4 block is performed in the figure 2.

a) X'=9, $\sigma = 4.91$

2	9	12	15
2	11	11	9
2	3	12	15
3	3	4	14

b) q=9

0	1	1	1
0	1	1	1
0	0	1	1
0	0	0	1

2	12	12	12
2	12	12	12
2	2	12	12
2	2	2	12

c) a=2,b=12

Figure 2 :a) original block b) the encoded and c)decoded image block.

2.3 According to [5] ,The **Image Pyramid** is a data structure designed to support efficient scaled convolution through reduced image representation. It consists of a sequence of copies of an original image in which both sample density and resolution are decreased in regular steps.

These reduced resolution levels of the pyramid are obtained through a highly efficient iterative algorithm. The bottom, or zero level of the pyramid, *G*0,is equal to the original image. This is lowpass-filtered and sub sampled by a factor of two to obtain the next pyramid level, *G*1. *G*1 is then filtered in the same way and sub sampled to obtain *G*2. Further repetitions of the filter/subsample steps generate the remaining pyramid levels. The levels of the pyramid are obtained iteratively as follows. For $0 < l < N$:

$$G_l(I,J) = \sum_{m=-2}^{2}\sum_{n=-2}^{2} w(m,n)G_{l-1}(2i+m, 2 \qquad (5)$$

This process as a standard REDUCE operation, and we can rewrite it as follows

$$Gl = \text{REDUCE}\,[Gl\text{-}1]. \qquad (6)$$

Where, weighting function *w*(*m*,*n*) is the "generating kernel." For reasons of computational efficiency this should be small and separable. Pyramid construction is equivalent to convolving the original image with a set of Gaussian-like weighting functions. The convolution acts as a lowpass filter with the band limit reduced correspondingly by one octave with each level. Because of this resemblance to the Gaussian density function we refer to the pyramid of lowpass images as the "Gaussian pyramid."

Bandpass, rather than lowpass, images are required for many purposes. These may be obtained by subtracting each Gaussian (lowpass) pyramid level from the next lower level in the pyramid. Because these levels differ in their sample density it is necessary to interpolate new sample values between those in a given level before that level is subtracted from the next-lower level. Interpolation can be achieved by reversing the REDUCE process. We call

this an EXPAND operation. Let *Gl*,*k* be the image obtained by expanding *Gl* k times. Then *Gl*,*k* = EXPAND [G *Gl*,*k*-1] or, to be precise, *Gl*,0 = *Gl*, and for *k*>0,

$$G_{l,k} = 4\sum_m\sum_n G_{l,k-1}\left(\frac{2i+m}{2}, \frac{2j+n}{2}\right) \qquad (7)$$

Here only terms for which (2i+m)/2 and (2j+n)/2 are integers contribute to the sum. The expand operation doubles the size of the image with each iteration, so that *Gl*,1, is the size of *Gl*,1, and *Gl*,1 is the same size as that of the original image.The levels of the bandpass pyramid, *L*0,*L*1, ..., *LN*, may now be specified in terms of the lowpass pyramid levels as follows:

$$\begin{aligned} Ll &= Gl\text{—EXPAND}\,[Gl+1] \\ &= Gl\text{—}Gl+1,1. \end{aligned} \qquad (8)$$

Just as the value of each node in the Gaussian pyramid could have been obtained directly by convolving a Gaussian like equivalent weighting function with the original image, each value of this bandpass pyramid could be obtained by convolving a difference of two Gaussians with the original image.

2.4 According to [6,7], **Hybrid DWT-DCT** based method consists of the following steps:

i. Data compression : the original image of size 256x256 (or any resolution, provided divisible by 32) is first divided into blocks of size 32x32. Each 32x32 block is then decomposed using the 2-D DWT. The high-frequency coefficients HL,LH, and HH are discarded. At this level, seventy five percent of data are compressed. The low frequency coefficients (LL) are passed to the next stage. The passed LL components are further decomposed using 2-D DWT . After the DWT sub sampling, the 8-point DCT is applied to these DWT coefficients. To achieve further compression, a JPEG-like quantization is performed. In this stage, most of thehigher frequency components are rounded to zero. The quantized coefficients are further scaled using scalar quantity known as scaling factor (*SF*). The entire hybrid DWT-DCT compression process is illustrated in Figure 3(a).

ii. Data reconstruction :The bit stream after the *SF* is the compressed data of interest. It is rescaled by same *SF* for the reconstruction procedure. Furthermore, the output rescaled data are dequantized by using the same JPEG quantisation table used for the compression procedure. The dequantized data are passed through 2-D inverse DCT. The data obtained after inverse 2-D DCT is then passed through the 2-D inverse DWT at first level. During the 2-D inverse DWT, zero values are padded in place of the detail coefficients. Finally, the output from first level 2-D DWT passed through the 2-D inverse DWT in second level and hence the final image is reconstructed. The entire reconstruction procedure is illustrated in Figure 3(b).

2.5 According to [9], Set Partitioning In Hierarchical Trees (**SPIHT**) is a wavelet based image compression technique. It provides the highest image quality, progressive image transmission, adaptive and error protection. The SPIHT multistage encoding process employs three lists and sets:

1. The list of insignificant pixels (LIP) contains individual coefficients that have magnitudes smaller than the threshold.
2. The list of insignificant sets (LIS) contains sets of wavelet coefficients that are defined by tree structures and are found to have magnitudes smaller than the threshold (insignificant). The sets exclude the coefficients corresponding to the tree and all sub tree roots and they have at least four elements.
3. The list of significant pixels (LSP) is a list of pixels found to have magnitudes larger than the threshold
(significant).
4. The set of offspring (direct descendants) of a tree node, $O(i, j)$, in the tree structures is defined by pixel
location (i, j). The set of descendants, $D(i, j)$, of a node is defined by pixel location (i, j). $L(i, j)$ is defined as $L(i, j) = D(i, j) - O(i, j)$. The threshold, T, for the first bit-plane is equal to $2n$
and

n = [log2(max$(i, j)\{|c(i, j)|\}$⌋ , (1)

where $c(i, j)$ represents the (i, j)th wavelet coefficient. All the wavelet coefficients are searched in order to obtain the maximum $c(i, j)$ after executing the discrete wavelet transform. For operations in the subsequent bit-planes of threshold T, n is reduced by 1. For each pixel in the LIP, one bit is used to describe its significance. If it is not significant, the pixel remains in the LIP and no more bits are generated; otherwise, a sign bit is produced and the pixel is moved to the LSP. Similarly, each set in the LIS requires one bit for the significance information. The insignificant sets remain in the LIS; the significant sets are partitioned into subsets, which are processed in the same manner and at the same resolution until each significant subset has exactly one coefficient.

Finally, each pixel in the LSP is refined with one bit. The above mentioned procedure is then repeated for the subsequent resolution. SPIHT produces a better compression rate and image quality than JPEG at low bit-rates.

In the decoding side ,the input data consists of three control lists(LIS,LIP,LSP) and identical to the ones used by the encoder at the moment it outputs that data. Computational complexity of the encoding and decoding is the same.

A comparative study on five compression algorithms is being done on the basis of their compression ratio, PSNR value, entropy of the original and the reconstructed image.

3. PICTURE QUALITY MEASURE

According to [8],There are several dimensions of Picture Quality Evaluation (PQE) generally splitted into subjective and objective measurements. **Subjective measurements** are the result of human observation and **objective measurements** are performed with the aid of instrumentation, calibrated scales and mathematical algorithms. The objective quality is well established and can detect the picture quality distortions that are too small for the human to see. The subjective quality based on group of observers is very time consuming and exhausting. Following objective measures are used to access the quality of the reconstructed image with respect to original image.

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (f(i,j) - f'(i,j))^2 \qquad (9)$$

$$\text{PSNR} = 10 \log \frac{(2^n - 1)^2}{MSE} \qquad (10)$$

4. RESULT AND ANALYSIS

After implementing and executing the above mentioned five compression algorithms on medical, satellite and standard images [10],[11],[12], the figure 4,5,6,7,8 show a comparison between the outcome of each method for the three types of images used, i.e, satellite ,medical and standard images.

Each methods have its own advantages and disadvantages like, JPEG method provides good compression ratio but the reconstructed image has blocking artifacts. BTC method is the easiest and fastest method but the reconstructed image's quality is way away from the original image. In Pyramid method, the compression ratio can further be increased by increasing the level of subsampling, but again the reconstructed image is blurred, which has lost its original quality. DWT-DCT method which is a combination of both wavelet and dct based provide good compression ratio along with good PSNR value. It overcomes both false contouring effects and blocking artifacts and ringing artifacts, but the problem associated with this algorithm is the execution time which is more than any other algorithms considered.SPIHT method provides progressive encoding using hierarchical trees. Table 1, 2, and 3 shows the bits per pixel, entropy of original and reconstructed and peak signal to noise ratio of goldhill.jpg, satellite.jpg and medical.jpg respectively. From Table 1 considering all the factors, Hybrid DWT-DCT method is considered the best method for standard images like Goldhill. From Table 2 considering all the factors, SPIHT is considered the best method for satellite images. From Table 3 considering all the factors, SPIHT is considered the best method for medical images.

Figure 9 shows the CPU time used by each algorithm for a system consisting of 3 GB RAM,64 bit OS AND Intel®Core ™ i3 CPU M370@ 2.40GHz . From this we can find out ,pyramid method requires the least time and SPIHT requires maximum time. Applications where quality of image isn't a constrain can use Pyramid method. The same experiments were carried on satellite images of earth as shown in Table 2. The best quality image retrieved after decompression was for SPIHT method. Images retrieved after Hybrid DWT-DCT method had noise due to which the quality of image was inferior to the result of JPEG method. Graph 4 shows the difference in the quality of retrieved image(both standard and satellite images). From this we can infer that the method which may be considered best in the case of standard image compression may not produce good results for applications which requires accuracy (such as satellite imaging). From Figure 11 one can infer for all types of images SPIHT proves to be the best method for compression as the quality of image is highest when compared to rest of the methods. Figure 10 shows the amount of information required to code an image. From this one can find that for normal images like goldhill.jpg needs maximum information using BTC but in the case of satellite and medical images, DWT-DCT needs maximum information to encode images.

5. OUTPUT

Figure 4 : Showing comparison between medical , goldhill and satellite reconstructed image after being subjected to JPEG

Figure 5: Showing comparison between medical , goldhill and satellite reconstructed image after being subjected to BTC

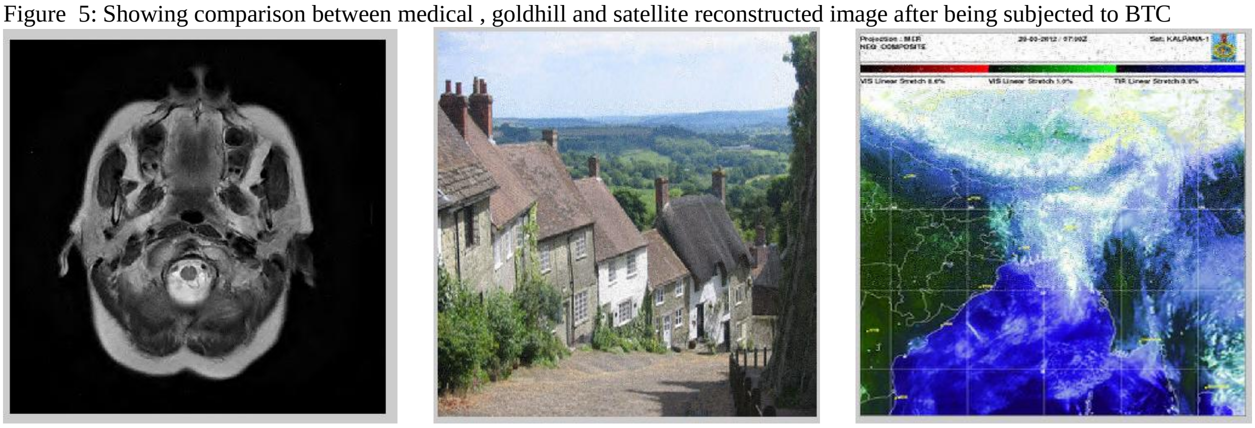

Figure 6: Showing comparison between medical , goldhill and satellite reconstructed image after being subjected to Hybrid DWT-DCT

Figure 7 : Showing comparison between medical , goldhill and satellite reconstructed image after being subjected to SPIHT

Figure 8: Showing comparison between medical , goldhill and satellite reconstructed image after being subjected to Pyramid

TABLE 1: GOLDHILL.JPG(512x512)

Measures → / Methods ↓	BPP	ENTROPY OF OI	ENTROPY OF RI	PSNR
JPEG	0.975	7.6568	7.5799	56.48
BTC	2.000	7.6568	7.7142	55.66
DWT-DCT	0.325	7.6568	7.6761	56.39
PYRAMID	0.125	7.6568	7.5587	56.29
SPIHT	0.400	7.6568	7.6160	56.45

TABLE 2 : SATELLITE.JPG(512X512)

Measures → / Methods ↓	BPP	ENTROPY OF OI	ENTROPY OF RI	PSNR
JPEG	0.912	7.2338	7.7745	56.141
BTC	2.000	7.2338	7.3866	55.195
DWT-DCT	0.356	7.2338	7.8073	55.93
PYRAMID	0.125	7.2338	7.7197	56.376
SPIHT	0.400	7.2338	7.4455	56.597

TABLE 3: MEDICAL.JPG (512X512)

Measures → / Methods ↓	BPP	ENTROPY OF OI	ENTROPY OF RI	PSNR
JPEG	0.805	7.6804	7.7745	56.1321
BTC	2.000	7.6804	7.3866	55.7648
DWT-DCT	0. 325	7.6804	7.8073	56.2602
PYRAMID	0.125	7.6804	7.7197	55.8623
SPIHT	0.315	7.6804	7.4455	56.5301

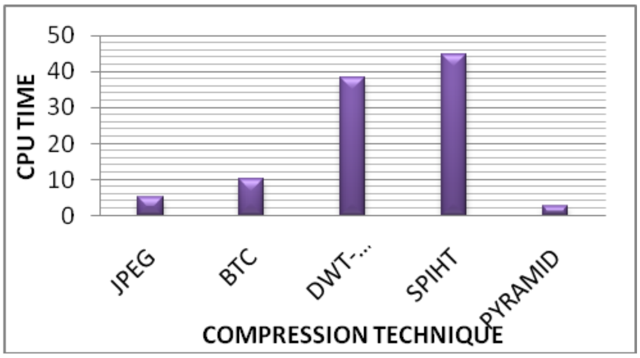

Figure 9 : Showing Graph Comparing the CPU time taken by each technique

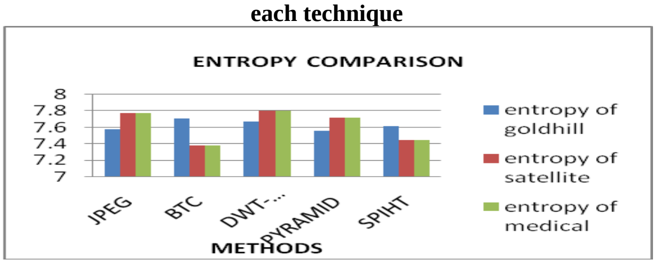

Figure 10 : Graph showing Variation of entropy for the reconstruction of image

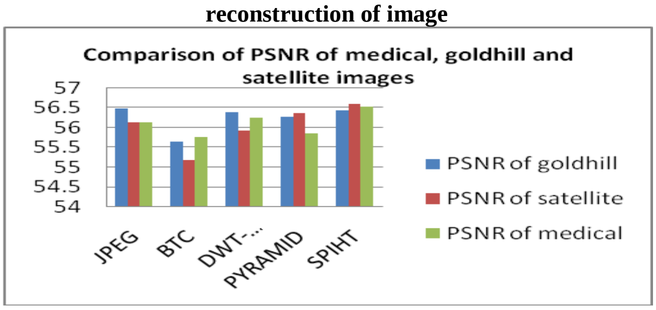

Figure 11: Graph showing Comparison of PSNR of medical, satellite and goldhill images

6. CONCLUSION

As we have seen the compression ratio, entropy and PSNR values of each techniques obtained after implementing JPEG,BTC,DWT-DCT,PYRAMID and SPIHT methods , we can.

conclude that each method has its own advantages and disadvantages. So, on the basis of requirement of the application one can choose one of the above techniques to send compressed data.

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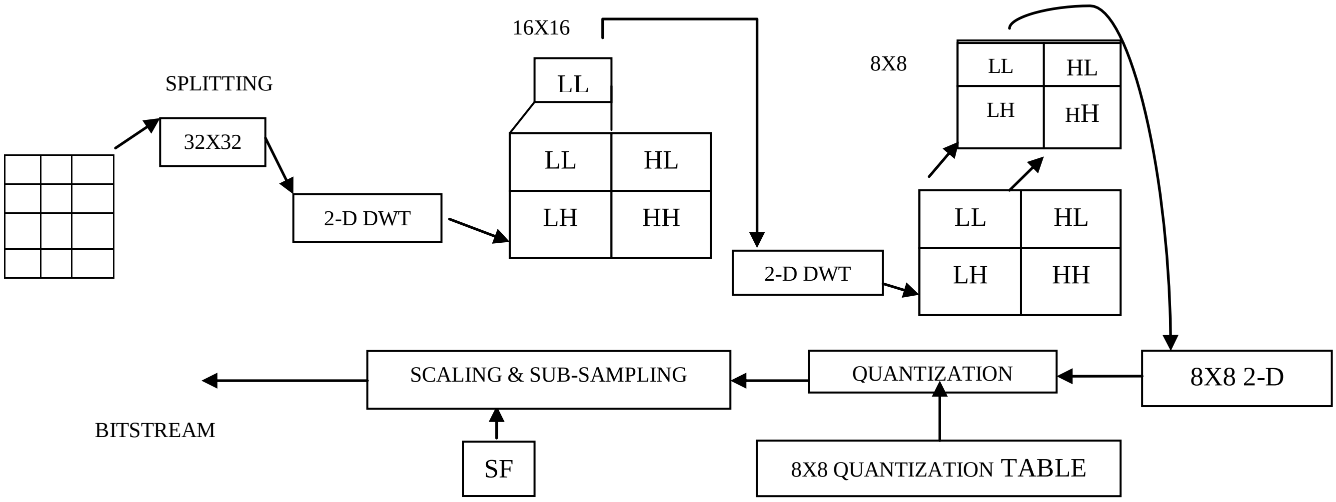

Figure 3 (a) :Hybrid DWT-DCT Compression algorithm

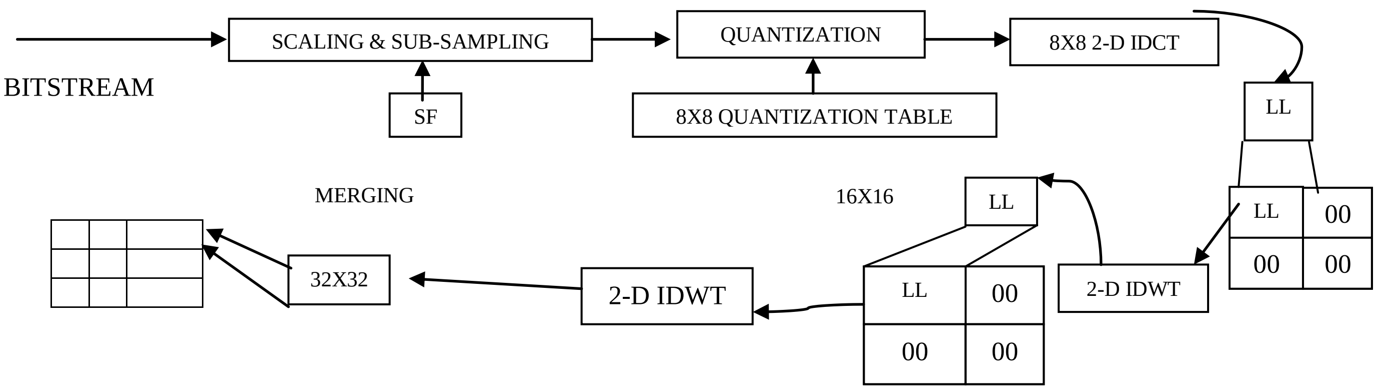

Figure 3 (b) : Hybrid DWT-DCT Decompression algorithm