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SPIHT: A Set Partitioning in Hierarchical Trees Algorithm for Image Compression

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Abstract

Image compression is a necessary technique for image transmission in a channel. In this paper, it is aimed to improve efficiency and dealing with the performance evaluation of image compression techniques for various kinds of images from uncontrolled environments. The key special of this paper is, the image compression is carried out using wavelet based image compression and decomposition techniques. SPIHT based image compression is proposed for achieving better image compression in high compression ratio. The simulation results of SPIHT technique are compared with the various existing compression techniques such as VD, DCT and DWT. All the technique used in this paper are implemented in MATLAB software and the performance is compared using the parameters such as PSNR, MSE, CR and compressed size.

Keywords: Image Comression, Image Processing, Wavelet Tranform, SPIHT, CT, DWT, Image Transmission

1 Background Study

The image signals are represented in analog form. For computerized image processing such as storing, transmitting of the image, the images are converted into digital form. In order to reduce the data redundancy the and irrelevance in the data it should be stored and transmit in an effective form. Image compression is one of the form for removing data redundancies [5] and reduce the transmission time. Also the compressed file extensions are $*.\mathrm{sit}$,$*.\mathrm{tar}$,$*.\mathrm{zip}$, and indicates that the different types of software used to compress files [11]. In recent times the memory requirement for media files is increasing. For this reason the process of image compression is essential in recent era. In order to fulfill the bandwidth limitation, storage capacity and fast transfer the image should be compressed before transmitting and storing. Image Compression is the process of minimizing the size of an image file without much degradation in the quality of the image and also to reduce irrelevance and redundancy of data contained in the image. There are two main types in image compression, namely Lossy and Lossless. The entire functionality of the lossy and lossless compression techniques are shown in Figure-1 and Figure-2 respectively. Some of the existing approaches used for image compression are Lossless Compression, Run Length Encoding, Entropy Encoding, Huffman Encoding [4], Arithmetic Encoding, LZW Coding, Lossy Compression, Transform [3], DCT, DWT, Fractal Compression.

Lossless compression is mostly preferred for applications such as medical imaging, technical drawings, clip art, comics and etc. Run Length Encoding method is mostly used for sequential data with repetitive information. The Entropy Encoding method can also be used for measuring the similarity in data streams. This method can be employed for any type of data independent of the characteristics. Constant Area Encoding is a type of encoding is improved version of run length encoding. This method is most preferred lossless compression method. Lossy type of image compression is used for images such as that of natural landscapes with comparably a lower bit rate. In this compression technique, there are more chances of loss of fidelity which is acceptable. Transform Coding is a core technique that is recommended by JPEG which produces a low quality output. Fractal Compression is based on fractals used for digital images. In digital image processing the fractal lossy compression technique can be used in applications such as image segmentation [1], image analysis [2] and texture coding [6]. The reduction of redundancy, which is the primary goal of image compression is achieved by defining the original image through contracted parts of the same image [7].

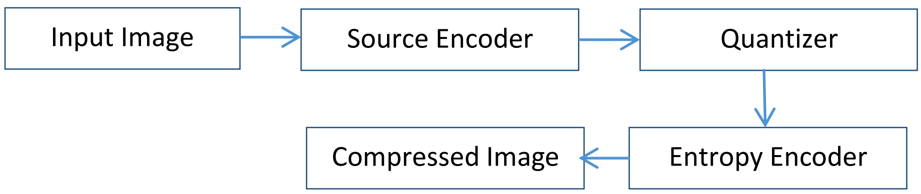


Figure-1: Block diagram for Lossy Compression

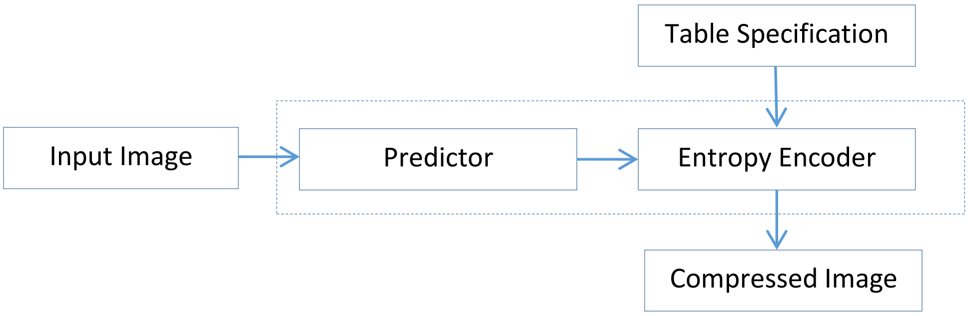


Figure-2: Block diagram for Lossless Compression

2 Proposed Approach

The set partitioning in hierarchical tree algorithm is proposed [6] and utilized for lossless image compression nowadays. One of the most powerful wavelet based image compression techniques is SPIHT. The main advantages of SPIHT method are it can provide Good Image quality with high PSNR and it is the best method for progressive Image transmission. First, the image is decomposed into four sub-bands. The decomposition process is repeated until reach the final scale. Each decomposition consists of one low-frequency sub-band with three high-frequency sub-bands. The extension and efficient implementation of EZW-[Embedded Zero Wavelet] algorithm [6, 8] is SPIHT algorithm.it is represented by the equation as follows

$$I_n(T) = \begin{cases} 1, max_{(i,j)\in T}\{|C_{i,j}|\} \geq 2^n \\ 0, \quad otherwise \end{cases} \tag{1}$$

$I_n(T)$, is the importance of a set of coordinate T.
$C_{i,j}$, is the coefficient value at each coordinate (i, j).

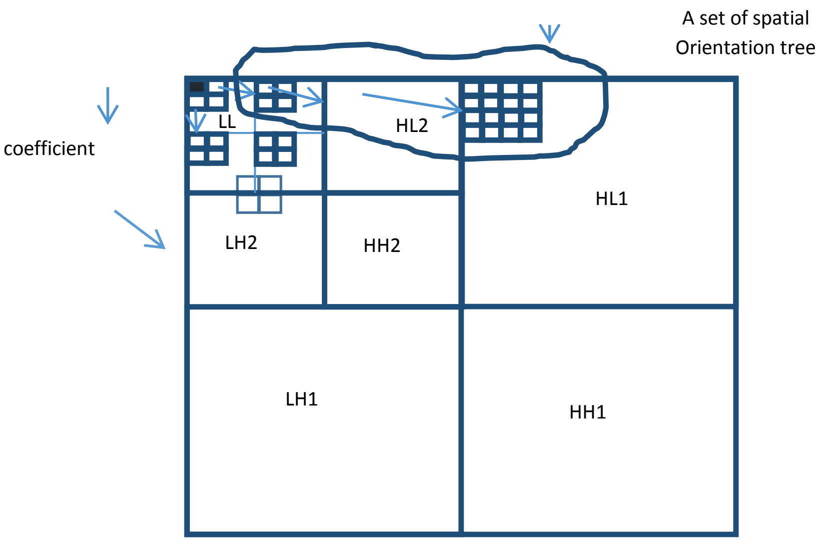


Figure-3: Parent Child Relationship in SPIHT

3 SPIHT_Algorithm ( )

Step-1: Initialization

$Result\ n = [log_2 max\{|C(i,j)|\}];$
$Let\ LSP = 0;$
$Let\ LIP = (i,j) \in H$
$Let\ LIS = (i,j) \in H \quad \forall D(i,j) \neq \emptyset\ also\ entries(LIS) \in A$

Step-2: Sorting Process

$for\ i = 1\ to\ length\ of(LIP(i,j))$
$S_n(i,j),$
$if\ S_n(i,j) = 1 then\ shift\ (i,j) into\ LSP\ and\ outout\ the\ sign\ of\ C(i,j)$
$end\ i$
$for\ i = 1\ to\ length\ of\ (LIS\ (i,j))$
$if\ LIS(i,j) \in A\ then\ result = S_n(D(i,j))$
$if\ S_n(D(i,j)) = 1\ then$
$for\ all(k,1) \in O(i,j)$
$result\ S_n(k,1)$
$if\ S_n(k,1) = 1\ then\ add(k,1) \rightarrow LSP, result\ the\ sign\ of\ C_{k,1}$
$if\ S_n(k,1) = 0\ then$
$add(k,1)\ at\ end\ of\ LIP$
$if\ L(i,j) \neq 0\ then\ shift\ (i,j) to\ end\ of\ LIS, and\ the\ entries \in type\ B, else\ delete\ entry(i,j) from\ LIS$
$for\ i = 1\ to\ length\ of\ (LIS\ (i,j))$
$if\ LIS(i,j) \in B\ then\ result = S_n(L(i,j))$
$if\ S_n(L(i,j)) = 1\ then$
$add\ each\ h_m\ to\ the\ end\ of\ the\ LIS\ under\ A, else\ delete\ (i,j) from\ LSP.$
Step-3: Refinement Process
$for\ i = all\ (i,j) in\ LSP\ \forall i\ not\ appear\ in\ sorting\ process$
$n^{th}\ important\ bit\ of\ |C_{i,j}|$
$end\ i$
Step-4: Quantization Pass
$n--$ // decrement n
$goto\ \textbf{Step}-\textbf{2}$

The complete SPIHT algorithm does compression in three steps such as sorting, refinement and quantization. The SPIHT algorithm encodes the image data using three lists such as LIP, LIS and LSP. LIP contains the individual coefficients having the magnitudes smaller than the threshold values. LIS contains the overall wavelet coefficients defined in tree structure having magnitudes smaller than the threshold values. LSP is the set of pixels having magnitude greater than the threshold value of the important pixels. The Complete parent child relationship is shown in Figure-3.The largest coefficient in the spatial orientation, tree can be obtained by a maximum number of bits is $n_{max}$and it can be represented as:

$$\boldsymbol{n_{max}} = [\boldsymbol{log_2}(\boldsymbol{max_{i,j}}\{|\boldsymbol{C_{i,j}}|\})] \tag{2}$$

In the sorting process, all the pixels in the LIP list are verified whether they are important and then the pixels and the coordinates with the coefficients in all the three lists are tested using the equation (2).Only one coefficient is found as important and it will be eliminated from the subsets, then inserted into the LSP or it will be inserted into the LIP. In the refinement process, the nth MSB of the coefficient in the LSP is taken as the final output. The value of n is decreased, again sorting with refinement is applied until n=0.Since, SPIHT algorithm controlled the bit rate exactly and the execution can be terminated at any time. Once the encoding process is over, then the decoding process is applied.

4 PSNR-[Peak Signal Noise Ratio] and MSE-[Mean Square Error]

PSNR is used to find out the ratio between the maximum power of a signal and the noise corrupted signal that affects the reliability of the signal representation It is a measurement to measure the quality of the image. The high PSNR value denotes the reconstructed image quality is high, and the low PSNR value denotes the reconstructed image quality is low [8, 9]. MSE is the metric used to verify the mean square error of the image. The MSE is used to estimate the difference between two images in terms squared error value.

$$\boldsymbol{MSE} = \frac{\boldsymbol{sum}(\boldsymbol{sum}(\boldsymbol{squaredErrorImage}))}{(\boldsymbol{row} \times \boldsymbol{columns})} \tag{3}$$

$$\boldsymbol{PSNR} = \mathbf{10}.\boldsymbol{log_{10}}\left(\frac{\mathbf{255^2}}{\boldsymbol{MSE}}\right) \tag{4}$$

5 Experiment and Results

Various images in terms of name, size, quality, format are compressed using SPIHT. The qualities of the images are evaluated by the PSNR and MSE values computed for each image before and after compression. In Table-1, shows the PSNR value obtained using MSE calculated for various compressed and decompressed images respectively. The following Table-2 shows the PSNR value comparison between the existing and propose approaches. Table-2 and Figure-4 shows that the SPIHT is best in terms of compression and decompression.

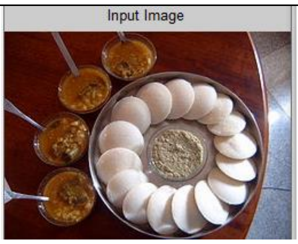
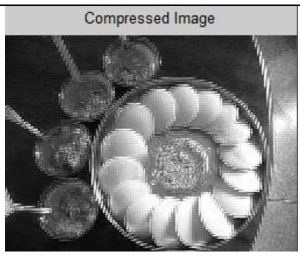
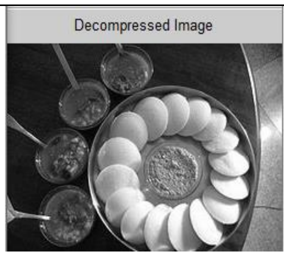
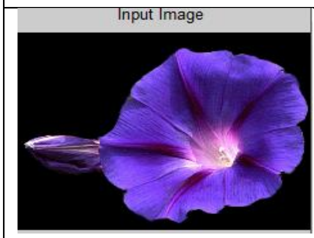
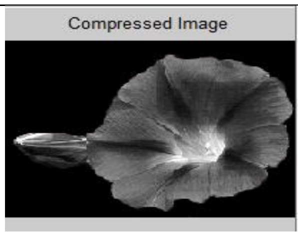
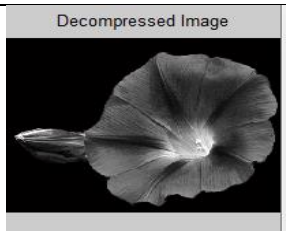
Input Image	**Compressed Image**	**Reconstructed Image**	**PSNR**	**Image type**
			18.51 27.61	*.gif
			24.76 35.41	*.bmp
			23.34 32.91	*.JPEG
			26.29 36.98	*. tif
(a). Input Image	(b). Compressed Image	(c). Decompressed Image		

Table-1: Experiment Result Obtained Using SPIHT

	PSNR After Compression			PSNR for Decompression		
Images	DCT	DWT	SPIHT	DCT	DWT	SPIHT
Flower	17.56	13.45	18.51	19.45	19.01	27.61
Lena	23.19	22.84	24.76	33.23	33.45	35.41
Man	22.45	19.98	23.34	31.23	31.98	32.91
URL	26	23.45	26.29	34.98	35.1	36.98

Table-2: PSNR comparison Obtained by Various Techniques

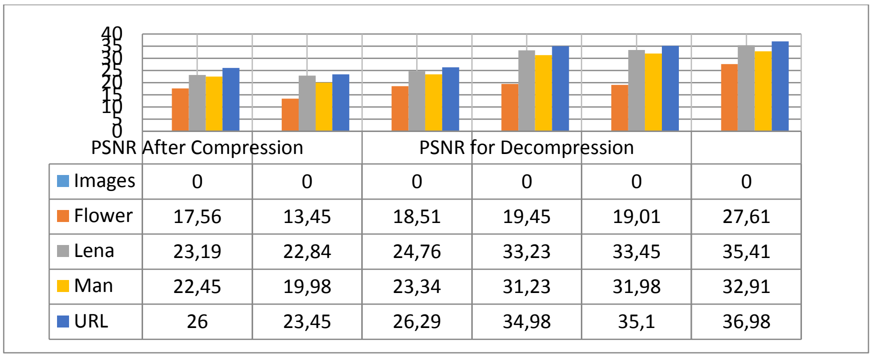


Figure-4: Performance Evaluation of SPIHT in terms of PSNR

Conclusion

By examining the PSNR and MSE values obtained from SPIHT algorithm is compared with the DCT, DWT based results. SPIHT proves and promises that it can compress and reconstruct the image without changing the originality and the quality of the input image. From the experiment results it can be concluded that the SPIHT algorithm is effective and efficient than the existing approaches in terms of PSNR, MSE and computational time. In future, machine learning approached and artificial intelligence techniques can be used for image compression and compare with SPIHT results.

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