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An Efficient Lossless Image Compression Algorithm Using Lifting-DWT And Laplacian Pyramid

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Abstract: The need for image compression has been increasing everyday as it can save the space needed to store and transmit the images in real time like medical applications. There are numerous techniques that have evolved till now but the one that combines simplicity, lesser loss and low memory requirements could bear higher potential. In this paper a lossless method of image compression using lifting-DWT and Laplacian pyramid is proposed. The image of size 342x390 is pre-processed and applied to lifting-DWT to generate level-1 LL band features. The Laplacian pyramid is used to generate LL band features to Laplacian level-1 features. The process is repeated for level-2 features.

Keywords: Lossless Compression; Pre-processing; Lifting DWT; Laplacian Pyramid; PSNR.

I. INTRODUCTION

Compression is a process by which the description of computerized information is modified so that the capacity required to store or the bit-rate required for transmission is reduced [1]. Image Compression in a brief way can be described as a process that tends to operate on the image and hence perform modification on the elements of the image to perfectly scale down its size to a visually appealing level. By performing this process, it is possible to bring down the size required to archive the image and also the bandwidth allocated to transfer that image could be truncated. It results in less prolong processing of image. In clear words it means that the image has shrunk in its dimensions by undermining its quality to a permissible level. Many real time applications depend upon vast number of images for their working. Two essential components in compression are redundancy and irrelevancy. Redundant data can be found in any image. Data duplication in an image can be termed as redundancy. It may be seen as repeating pixel across the image, which is more frequently repeated in the image. This redundant information of the image is beneficial in saving the storage space of that image [2]. Irrelevancy reduction points to omission of the unnoticed parts of the image by human visual system or by the naked eyes, which are not so relevant. Compression can be classified in to two types Lossy and Lossless compression technique. In Lossless compression the image can be remodeled exactly the same as the original. There is no information loss in this technique and also the quality of the image is unaltered. In Lossy compression loss and missed information is acceptable to certain limit. Lossless methods cannot provide highly compressed images [3].Image Compression is achieved via Coding, Spatial domain compression and Transform domain methods. Coding methods are directly applied to raw images treating them as a sequence of discrete numbers. Examples: Arithmetic, Huffman Run-Length, LZW coding, etc. Spatial domain image processing methods directly process the pixel hence trying to eliminate the spatial redundancy. In Transform domain, the image is represented using an appropriate basis set and the goal is to obtain a sparse coefficient matrix. Examples: DWT, DCT [4], etc.

II. LITERATURE SURVEY

Mehwish Rehman et al., [5] discussed different image compression techniques and their merits demerits and their applications. Anilkumar Katharotiya et al., [6] proposed two image compression techniques in which first technique was based on Discrete Cosine Transform (DCT) and the second one was based on Discrete Wavelet Transform (DWT). They concluded that both techniques have both advantage and disadvantage but, they are quite efficient for image compression and can get reasonably better compression ratio without loss of much information. Their experiments showed that DWT technique is much efficient than DCT technique in quality and efficiency wise and DCT is better than DWT in performance time wise. Md. Ahasan Kabir et al., [7] proposed an algorithm for medical image compression based on Lifting based wavelet transform coupled with SPIHT coding algorithm, of which they applied the lifting structure to improve the drawbacks of conventional wavelet transform. The algorithm provided better PSNR and MSSIM values for medical images only at low bit rate. Veera Swamy et al., [8] proposed a design of Lifting Based Technique and implemented it on FPGA and observed that this algorithm gives better results than existing compression techniques. Eswara Reddy and Venkata Narayana, [9] proposed and

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compared Hand designed and lifting based wavelet transforms which were used to compress the test images competitively by using Set Partitioning In Hierarchical Trees (SPIHT) algorithm and by incorporating lifting concepts that resulted in practical advantages, such as, superior low bit rate, performance, bit-level compression, accuracy and resolution. Peter J. Burt and Edward H. Adelson, [10] observed that the Laplacian pyramid encoding scheme requires relatively simple computations, the computations are local and may be performed in parallel, and the same computations are iterated to build each pyramid level from its predecessors. Simrandeep Singh et al., [11] studied the multi-resolution pyramid method used to integrate the multiple multi-focus images together. Integrated resultant image is having all the focused objects and contain maximum detail. Adelson et al., [12] described a variety of pyramid methods that they have developed for image data compression, enhancement, analysis and graphics and have discussed a number of examples in which the pyramid has proven to be valuable. Sylvain Paris et al., [13] demonstrated edge-aware image filters based on the direct manipulation of Laplacian pyramids. Their approach produced high quality results, without degrading edges or introducing halos, even at extreme settings. Laplacian pyramids have previously been considered unsuitable for such tasks, but their approach showed otherwise. Florence Tushabe and Wilkinson, [14] proposed a preprocessing method for image compression based on attribute filtering. This method was completely shape preservingand computationally cheap.

III. PROPOSED METHODOLOGY

A. Proposed Image Compression Block Diagram

The proposed image compression block diagram using Pre-processing, Lifting DWT and Laplacian pyramid with different decomposition levels is shown in Fig. 1.

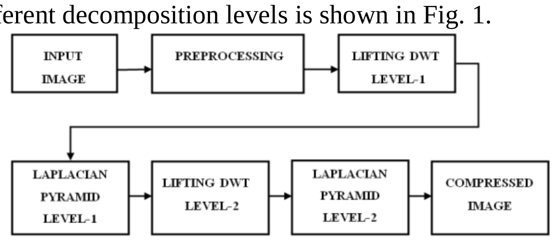

Fig.1. Block diagram of proposed image compression

i) Pre-processing

Image pre-processing is the technique of enhancing data images prior to computational processing. This is an operation on images at the lower level of abstraction that decreases image content, suppresses information that is not relevant, performs geometrical transformations or enhances some image features important for further processing. It does not increase image information content and use the considerable redundancy in images. If neighbouring pixels corresponding to one object in real images having similar brightness value are considered, if a distorted pixel can be picked out from the image, it can be restored as an average value of neighbouring pixels. There are several categories of pre-processing in which edge detection and morphological operations are utilized in this paper. Edges are pixels where the intensity image function changes abruptly. Edge detectors are collection of local image pre-processing methods used to locate changes inthe brightness function. Morphological operations affect the structure or shape of an object. They are used in preprocessing, post processing or for getting a description of the shape of objects or regions.

ii) Lifting DWT-Level 1

Lifting scheme is one of the techniques that are used to realize DWT architecture. Lifting scheme is used in order to reduce the number of operations to be performed to half and filters can be decomposed into steps in lifting scheme. The memory required and also computation is less in case of lifting scheme. The implementation of the algorithm is fast and inverse transform is also simple in this method.The basic block representation of one-level LiftingBased-DWT is as shown in Fig. 2.The three basic steps in Lifting based DWT are:

- SPLIT STEP: In this stage the input signal x is divided in to two disjoint sets, the odd x_o and the even samples x_e
- PREDICT STEP: In this module, the prediction operation P is used to estimate x_o from x_e and results in an error signal D. Detailed coefficients D results in high pass filtering

$$D = X_o - P(X_e) \quad (1)$$

- UPDATE STEP: The D is updated by applying it to the update operation U, and theresulting signal is combined with x_e to obtain A, whichrepresents the smooth part of the original signal

$$A = X_e + U(D) \quad (2)$$

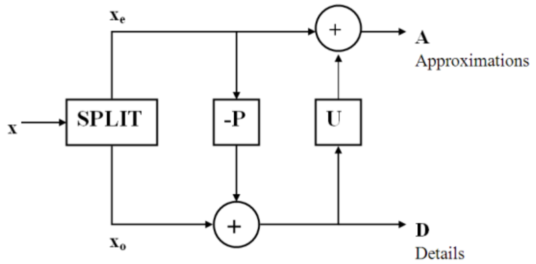

Fig.2.Basic block of one-level lifting scheme

iii) Laplacian Pyramid-Level 1

Image pyramids intend to develop filter-based representations to decompose images in order to extract features of interest and reduce redundancy at multiple scales and also to attenuate noise. They prove very useful for efficient coding, image enhancement, image analysis and restoration. They can be described as collection of low or band pass copies of an original image in which both the band limit and sample density are reduced at multiple scales. The Laplacian Pyramid is a pattern selective approach where the composite image is constructed not a pixel at a time. The basic idea is to perform a pyramid decomposition on original image, then integrate all these decompositions to form a composite representation.The Laplacian Pyramid is a decomposition of the original image into a hierarchy of images such that

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each level corresponds to a different image frequency band. The two operations in computing Laplacian pyramid are: reduce and expand. The reduce operation applies a low-pass filter and then down-samples by a factor of two and the expand operation up-samples by a factor of two in each dimension and then applies the same low-pass filter. This operation yields a sub-band transform whose basis functions are Gaussian functions. In other words, the transform represents an image as a sum of shifted, scaled, and dilated Gaussian functions. The Laplacian pyramid for an image I and its first level decomposition for LL band image Im are:

$$L_i = G_i - \text{EXPAND}(G_{i+1}); \quad (3)$$
$$L_i = G_i - \text{EXPAND}(\text{REDUCE}(G_i)) \quad (4)$$

The EXPAND operator will reconstruct the low-pass filtered image by interpolating between pixels in the reduced image. The original image can always be reconstructed from its Laplacian pyramid by reversing this process. The pyramidcan be viewed as an image transformation code.

iv) Lifting DWT-Level 2

The process of performing the decomposition for compression is repeated using Lifting DWT to obtain level-2 features explained in the previous section.

v) Laplacian Pyramid-Level 2

The process of obtaining the coefficients for compression is repeated using Laplacian Pyramid to obtain level-2 features explained in the previous section.

B. Error Metrics

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. The MSE represents the average of the squares of the errors between the compressed and the original image. The lower value of MSE describes lower error.

The PSNR is inversely proportional to MSE and it computes the peak signal-to-noise ratio between two images measured in decibels. This ratio is used as a quality measurement between the original and a compressed image. The higher value of PSNR describes better image quality.

To compute the PSNR, first the mean-squared error is calculated using the following equation:

$$\text{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - Im(i,j)]^2 \quad (5)$$

In equation (4), m and n are the number of rows and columns in the input images respectively. I(i,j) and Im(i,j) being input image and compressed image respectively. Then the PSNR is calculated using the following equation:

$$\text{PSNR} = 10\log_{10}\left(\frac{R^2}{\text{MSE}}\right) \quad (6)$$

R is the maximum possible pixel value of the image(255).

IV. RESULTS AND DISCUSSIONS

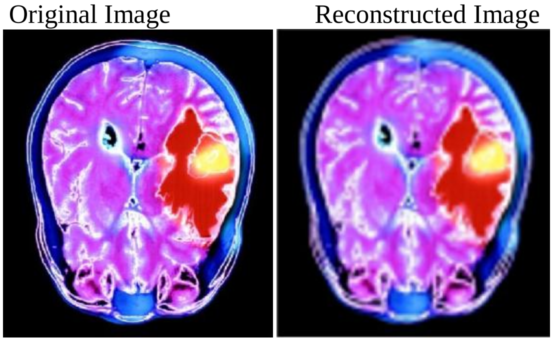
A color image of Lena having the size of 512x512 and a magnetic resonance imaging (MRI) scan of the axial section of the human brain having the size of 342x390 are taken as test images. After level-2 compression the test image sizes become 128x128 and 97x85 respectively. The original and its reconstructed images are shown below along with the PSNR values for different techniques.

C. DWT

Original Image Reconstructed Image

The PSNR obtained using DWT for a color image of Lena is 28.4233

Original Image Reconstructed Image



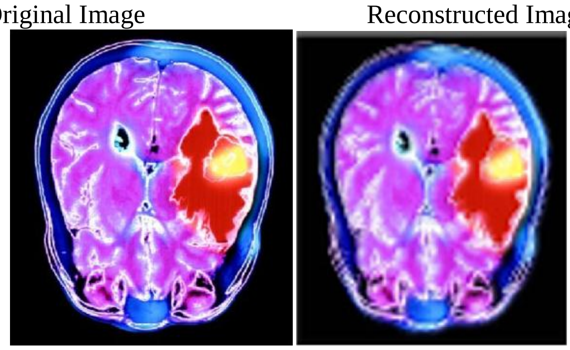
The PSNR obtained using DWT for a color MRI of brain is 28.9209

D. Lifting DWT

Original Image Reconstructed Image

The PSNR obtained using Lifting-DWT for a color image of Lena is 33.7767

Original Image Reconstructed Image



The PSNR obtained using Lifting-=DWT for a color MRI of brain is 31.4925

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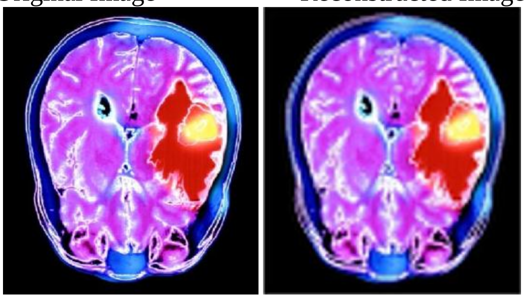
E. Lifting DWT With Laplacian Pyramid

Original Image Reconstructed Image

The PSNR obtained using Lifting-DWT with Laplacian Pyramid for a color image of Lena is 34.3915

Original Image Reconstructed Image



The PSNR obtained using Lifting-DWT with Laplacian Pyramid for a color MRI of brain is 32.6899

F. Performance Comparison Between Proposed Method and Existing Methods

TABLE 1: PSNR COMPARISON

Sl. No.	Author	Technique	Image	PSNR(dB)
1	Md.Masudur Rahman et al.	JPEG2000 technique with adaptive subband threshold	Barbara-Gray	28.02
			Lena-gray	32.42
2	Chengyou Wang et al.	Bayer Patterned Image Compression Based on Structure Conversion and APBT	Lena-Color	32.39
3	Proposed Method	Lifting DWT with Laplacian Pyramid	Barbara-Gray	32.0850
			Lena-Gray	35.2784
			Lena-Color	34.3915
			MRI of Brain-Color	32.6899

V. CONCLUSION

The comparison of PSNR between proposed and existing methods are tabulated in TABLE I. It is observed that the proposed method has better PSNR compared to existing methods since the combination of Laplacian pyramid at different levels are used.

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