Performance Assessment of Image Compression and Reconstruction Employing Wavelet Transform with Lifting Scheme: An Effective Approach

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ABSTRACT

In the analysis for image compression and subsequent reconstruction, the primary objective is to minimize the data redundancy in terms of spatial and frequency domain without much affecting the image quality. Lossless reversible image compression model is proposed in case of continuous and discrete time utilizing integer wavelet transform (IWT) that incorporates lifting scheme (LS) excellently. As compared to wavelet decomposition, here both approximation as well as detailed contents of the image under consideration are further decomposed, which enhances the compression ratio. Bi-orthogonal wavelets are constructed using LS that makes use of both high pass and low pass filter values along with addition and shift operations on the resulting wavelet coefficients quite suitably. Forward as well as inverse lifting schemes are implemented to reduce the computational complexity and achieve superior image compression performance that accounts for encoding time, decoding time, peak signal to noise ratio (PSNR) and better compression ratio (CR). The present paper projects the utility of IWT and LS in the domain of image compression and reconstruction that will immensely benefit the researchers and experimentalists involved with image and signal processing.

Keywords – Compression ratio, Lifting scheme, Integer wavelet transform, Wavelets.

I. INTRODUCTION

Redundancy of data has to be minimized by for improved transmission and storage of data that needs much reduced memory size. Original image restoration size is performed at the receiving end so as to keep the image quality reasonably intact without sacrificing the inherent quality. There are lossy and lossless image compression models. Lossless image compression can be applied in field of satellites, internet teleconferencing, medical, security and seismic images. Predictive or transform coding technique is preferred for these types of image compression as the existing approaches [1]. But they did not have appreciable performance parameters in terms of peak signal to noise ratio (PSNR) or compression ratio (CR). Lossless image compression takes into account finer details without compromise on the accuracy and image quality even for non smooth image domains or surfaces. Integer wavelet transform has proved to be a potential candidate owing to its inherent merits like multi resolution functionality and enhanced compression ratio performance. Lifting scheme (LS) is easier to implement with less number of

computations. Forward lifting scheme for image compression and inverse lifting scheme for image reconstruction has been proposed employing integer wavelet transform (IWT) that is reversible in nature. Compared to conventional discrete wavelet transform (DWT) and its counterparts, the computational complexity is remarkably less for IWT employing LS [1-3].
The following section II deals with integer wavelet transform and subsequently section III explains about methodology of lifting scheme used in the process of image compression and reconstruction. Proceeding next, section IV presents the results obtained using simulation using the MATLAB platform using a sample gray scale image in our analysis and the performance assessment of IWT-LS technique is investigated in this context. Eventually, section V leads to conclusion and justifies the superior image compression model using the proposed technique.

II. INTEGER WAVELET TRANSFORM (IWT)

Wavelets are very small basic functions that are well defined over a limited time and characterized by dilation and translation property. Any arbitrary function can be modeled using many such wavelets and in this connection Fourier analysis has been the best tool for classical wavelet construction that can be extended for discrete wavelet transform (DWT) also. Appreciable amount of resolution can be obtained using DWT and for wavelet filter decomposition the 1-D filter bank is further converted to a 2-D filter bank with the aid of sub-sampling operations successively. These sub bands are simply designated as LL, HL, LH, HH and is shown as below in Fig.1 for single level decomposition [3,4].

LL	HL
LH	HH

Fig.1 Single level decomposition for wavelet filter

In the similar fashion, Fig.2 represents double level or two-level decomposition for any image and is illustrated below.

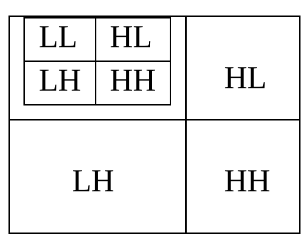

Fig.2 Double level decomposition for wavelet filter

For all the above Fig. 1 and Fig. 2, the notations LL, HL, LH and HH aptly represent:

1. **LL-** Represents approximation image content of the image resulting from low pass filtering in both horizontal and vertical directions.
2. **HL**- Represents vertical details resulting from vertical low pass filtering and horizontal high pass filtering.
3. **LH-**Signifies horizontal details resulting from vertical high pass filtering and horizontal low pass filtering.
4. **HH**-Signifies diagonal image details resulting from high pass filtering both vertically and horizontally.

For lossless image compression, efficient algorithm is proposed in IWT where both approximation and detailed contents of the image are further decomposed and it provides better compression parameters [5]. Round off integer values are preferred compared to floating point numbers in order to avoid rounding errors and store these integer numbers quite conveniently. To facilitate faster computation of filter coefficients, the recursive algorithm of LS is used in the context of image compression and restoration [5, 6]. This leads to much faster implementation of wavelet transform and can be easily implemented for irregular sampling also. The low pass and high pass filters essentially constitute the polyphase matrix. Simple shifting and addition operations are performed on the wavelets using LS to produce bi-orthogonal or popularly known as second generation wavelets [6-8]. This establishes the robustness of IWT along with LS that is discussed in the following section.

III. PROPOSED METHOD: LIFTING SCHEME

The proposed method of LS is essentially separates the odd and even coefficients, thereby producing bi-orthogonal second generation wavelets. It is much faster than DWT in its implementation and is performed in Split, Predict and Update phases for the purpose of image compression. Reconstruction of the image is obtained with Update, Predict and Merge operations [9]. Forward LS is used for the image compression and on the contrary inverse LS is used for the image reconstruction.

The IWT-LS transformation involves spatial domain and the image decomposition yields two filter functions, one for low pass and other for high pass filter designated as $h_{LP}(z)$ and $g_{HP}(z)$ respectively. These wavelet filter function values are entered in the said polyphase matrix where they are further split. Predict and next update operators are performed on those coefficients to obtain both detailed and approximation content of the image or signal under consideration [9, 10]. The LS yields bi-orthogonal wavelets and the important property of such wavelets is that they can be employed for irregular or non smooth image surfaces also [10-13]. Dilation and translation attributes are not necessarily a part of such second generation wavelets and is a striking attribute for such wavelets [7, 9].

Fig.3 represents the decomposition level of the image into both approximation as well as detailed content with the help of high pass and low pass filtering.

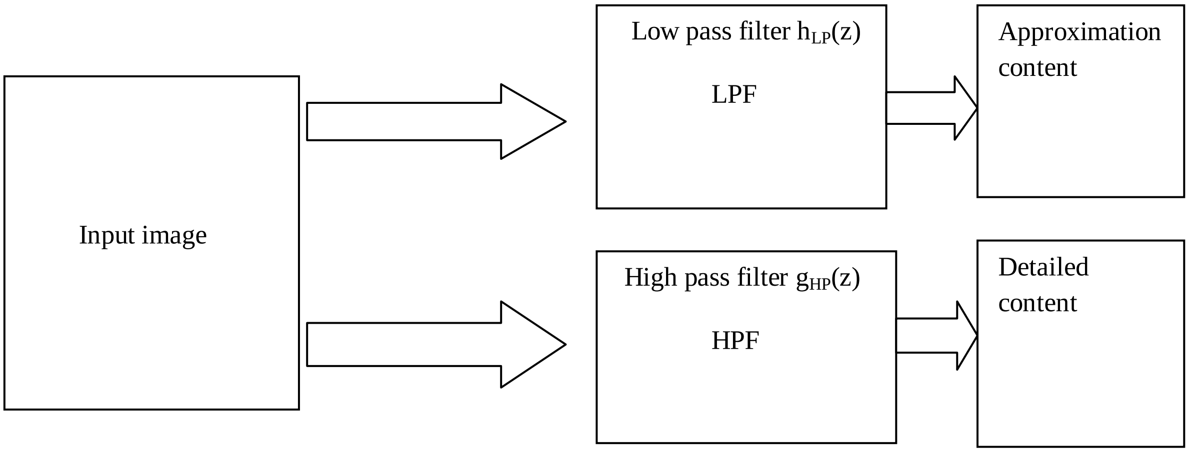

Fig. 3 Image decomposition for LPF and HPF

The successive steps for forward LS are [5,7,9] :

1.SPLIT- Divide into odd & even samples the input coefficients.

2.PREDICT- Predict the odd sample as linear combination of even values and subtracting it from the odd values to produce prediction error.

3.UPDATE- Final step consists of updating the even values by adding them to the prediction error.

The same has been represented in Fig. 4 for forward LS that is mainly used for image compression.

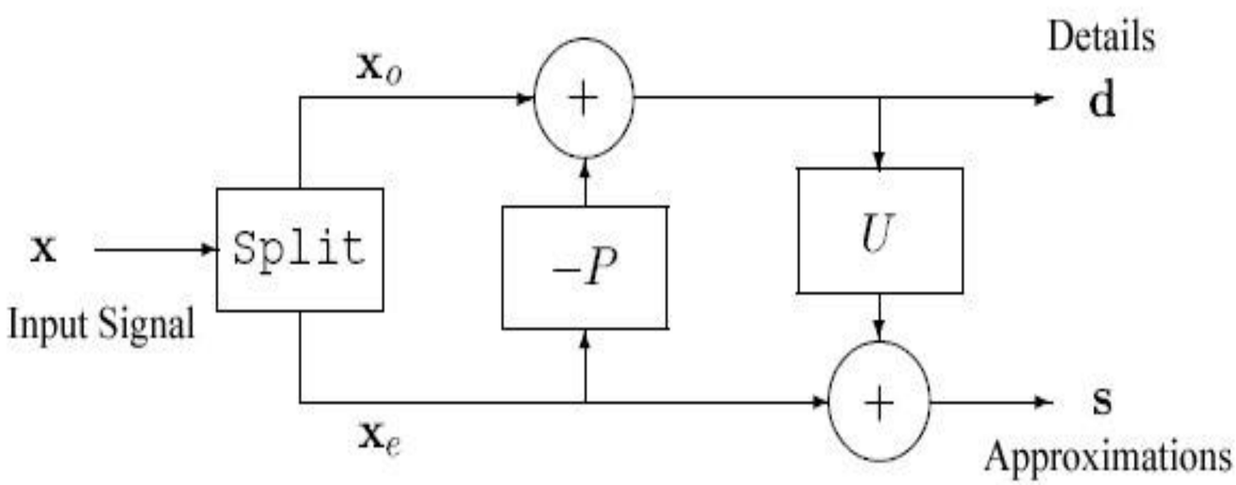

Fig. 4 Forward Lifting scheme steps consisting of split predict and update

The inverse LS is applied for image reconstruction. The basic steps involved are Update, Predict and Merge respectively [5,7,9]. Fig. 5 projects the basic steps for inverse LS.

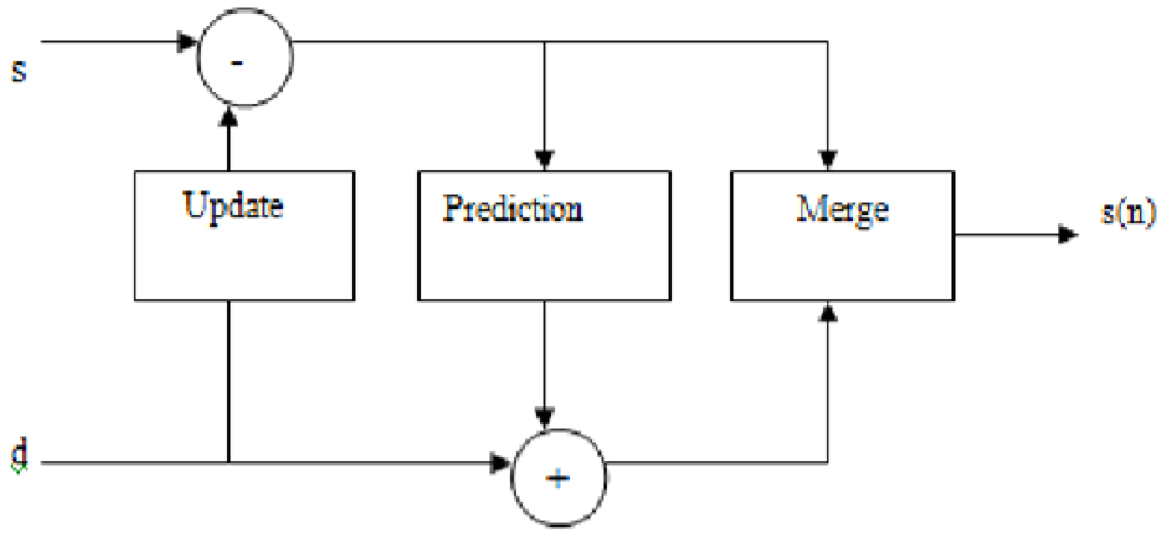

Fig. 5 Inverse Lifting scheme steps consisting of update, predict and merge

The output s(n) is the reconstructed image that is similar to the original input image x. The symbols 's' and 'd' in Fig. 4 and Fig. 5 denote the approximation and detailed content of the image respectively. Therefore, image compression and its restoration is performed utilizing the IWT-LS approach in our present work.

IV. RESULTS WITH DISCUSSIONS

In our current investigation, sample gray scale image of grain is considered. Simulation is performed using MATLAB tool implementing the forward and inverse lifting scheme. The performance assessment of the image compression model is carried out by evaluating peak signal to noise ratio (PSNR), encoding time, decoding time and compression ratio (CR).

Fig. 6 shows the simulation result and the computed parameters for the grain image under consideration. The same results are tabulated in Table 1 for the said image.

Table 1 Performance evaluation of grain image for image compression and reconstruction

S.No.	**Parameter for grain image**	**Computed values**
1	PSNR	34.63880
2	Encoding time	4.99730 sec
3	Decoding time	0.15441 sec
4	CR	8.90955

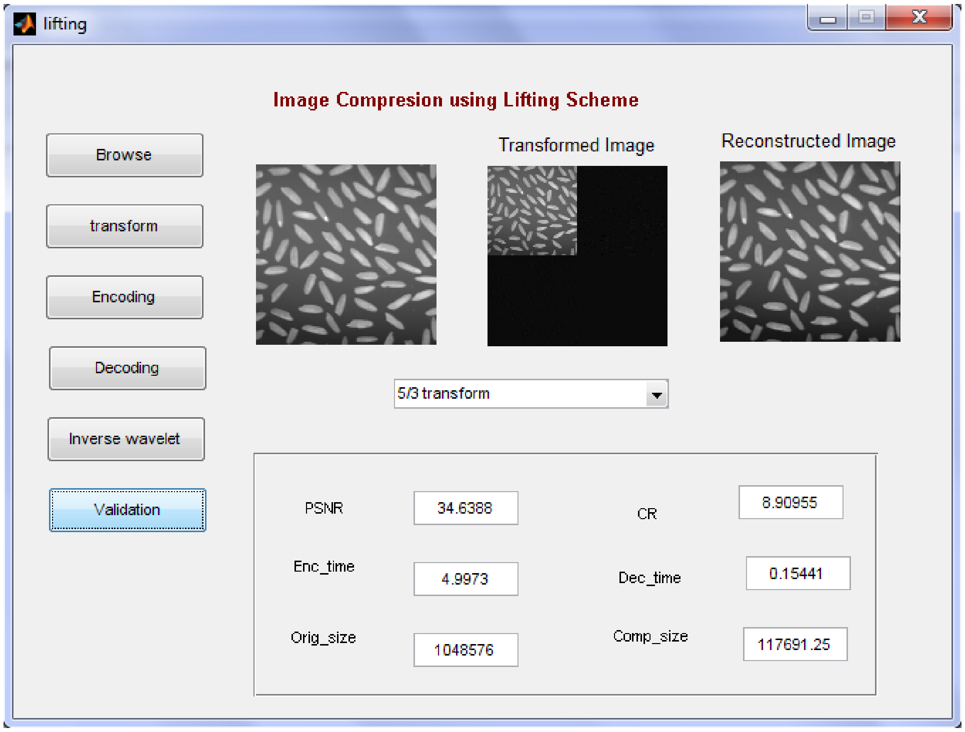

Fig. 6 Grain image simulation result for image compression and reconstruction

The simulation results justify the accuracy and simplicity of the proposed lossless image compression model. Parameters PSNR, CR, encoding and decoding time are significantly improved without any loss in the original image quality. As seen from Fig. 6, the 5/3 transform particularly represents five filter taps for high pass filtering and three filter taps for low pass filtering respectively. This value can be redesigned according to the necessity of filter taps and nature of image.

Therefore, LS clubbed with IWT facilitates the use of in-place computation of wavelet transform using second generation wavelets. Color level images can also be applied as further extension with more number of filter coefficients. This certainly establishes the superior performance of IWT-LS technique in implementation point of view and shall generate huge interest particularly in the vast area of digital image processing.

V. CONCLUSION

In the present paper, lossless image compression model using the Lifting Scheme is projected and the simulation results agree considerably well to the efficacy of the compression model that validates the superior performance of such proposed model. Rapid progress of the social media and digital networks has invariably created the demand for more amount of image data transfer on a regular basis. The proposed IWT-LS based compression technique provides a possible solution in this aspect as it has the tremendous potential to speed up the splitting and decomposition process by exploiting the features of both low pass and high pass filter taps in its design. The implementation of IWT along with LS provides perfect reconstruction of compressed image because of its simplified approach, less storage requirement, saving of transmission bandwidth and reduced computation time without any compromise on the image quality. In this connection, it is important to mention that both the approximation and detailed image content of the concerned image are retained resulting in a better lossless and reversible compression technique. Such lossless image compression applications are much in demand in the broad areas of HDTV, multi spectral remote sensing, heavily edited images, security and military images, medical images and other seismic data that can suitably be extended in the relevant context of image and video processing systems.

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