# HARDWARE IMPLEMENTATION OF SATELLITE IMAGE ENHANCEMENT USING DWT LIFTING SCHEME WITH SPARTAN3 FPGA KIT

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**Abstract— Enhancement of a digital or satellite image can be done in either of the areas viz, contrast , resolution and sharpness. In this paper we are introducing the hardware implementation of image enhancement using DWT lifting scheme. Noise removal and preservation of useful information are important aspects of image enhancement. The Discrete Wavelet Transform has been widely used in image processing, digital communications and other application fields, because the DWT can decompose the signals into different sub-bands with both time and frequency information and facilitate to achieve a high compression ratio.**

**Keywords—**Satellite Image augmentation, DWT, IDWT, Lifting Scheme, FPGA

## I. INTRODUCTION

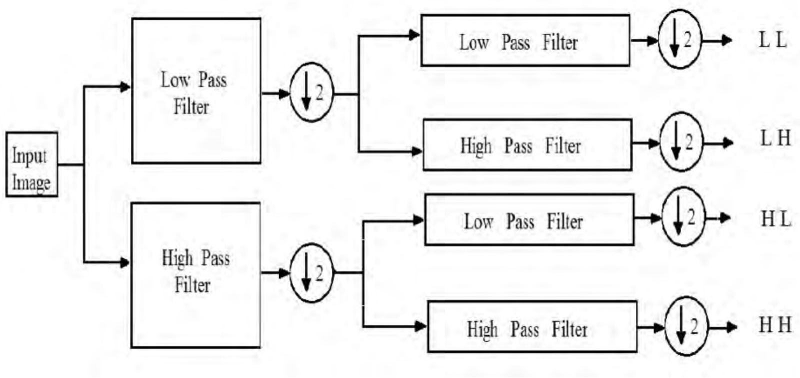


Fig.(1). Basic Block Diagram DWT With Filter Banks

Since the Importance of Digital Image Processing was realized, a number of researches were running from time to time for improving the satellite image quality. The Focus aim of this paper is to increase the quality of the satellite image in properties like contrast, resolution and sharpness. In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. In figure(a) ,the basic block diagram representation of DWT is shown.

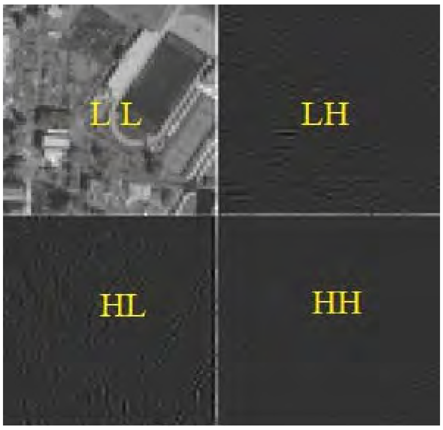


Fig. (2). LL, LH, HL, and HH subbands of a satellite image

As DWT decomposes the input image into four frequency subbands as illustrated in figure(b) and estimates the singular value matrix of the Low-low subband image then it reconstructs the enhanced image by applying IDWT.In the proposed paper we modifying the DWT working scheme with new method known as lifting scheme. The decomposition of an image is performed by applying the one dimensional discrete wavelet transform primarily along the rows of the image, and the secondary process is decomposing results along the columns resulting four decomposed subband images namely to low-low(LL), low-high (LH), high-low (HL), and high-high (HH) [2]. So DWT is said to be a suitable tool to be used for designing a pose invariant face recognition system.

## II. EXISTING METHODS

The latest publications on the topic uses the following equations listed below:

$$\mathrm{A} = \mathrm{U_A} \sum\nolimits_{\mathrm{A}} \mathrm{V_A}^{\mathrm{T}} \ldots\ldots\ldots\ldots.(1)$$

$U_A$ ,the orthogonal square matrix known as hanger

$V_A$, the orthogonal square matrix known as aligner

$\sum_A$, the matrix containing the intensity information of a given image.

$$\xi = \max\left(\sum \mathrm{N}(\mu = 0, \mathrm{var} = 1)\right) / \max\left(\sum \mathrm{A}\right) \ldots\ldots\ldots(2)$$

ξ**,** the damping ratio

$\sum \mathrm{N}(\mu = 0, \mathrm{var} = 1)$, the SVD of the synthetic intensity matrix.

$E_{equalized_A} = U_A\ (\xi \sum_A)\mathbf{V_A}^{\mathbf{T}}$ …………….....(3)

Contrast is determined by the difference in color and brightness of an object with other objects [1,5].The estimated new LL is

$\mathrm{LL_{A(new)}} = \mathrm{U_{LLA}} \sum_{\mathrm{LLA}} \mathrm{V_{LLA}^T}$………………..(4)

Resolution refers to the number of pixels in an image. Interpolation based Image resolution enhancement technique is widely used method to improve the quality. Bicubic interpolation is more reliable than the other techniques and produces smoother edges. In order to increase the quality of the enhanced image, preserving the edges is essential. DWT separates the image into different subband images and High frequency subbands contains the high frequency component of the image. The low resolution image (LL), without quantization is used as the input for the resolution enhancement process. This input image is gone through the interpolation process. So, the input low resolution image is interpolated with the half of the interpolation factor, α/2, used for interpolating the high frequency subbands shown above. In order to obtain a sharper augmented image, an intermediate stage in high- frequency subband interpolation process is implemented [2,3]. The difference between the LL subband image and the low resolution input image are in their high frequency components. This difference image can be use in the intermediate process to correct the estimated high frequency components. The estimation process is performed by interpolating the high frequency subbands by factor 2 and then including the difference image into the estimated high frequency images, which again undergo another interpolation with factor α/2 in order to reach the required size for IDWT process.

Fig.(3).
Difference Image

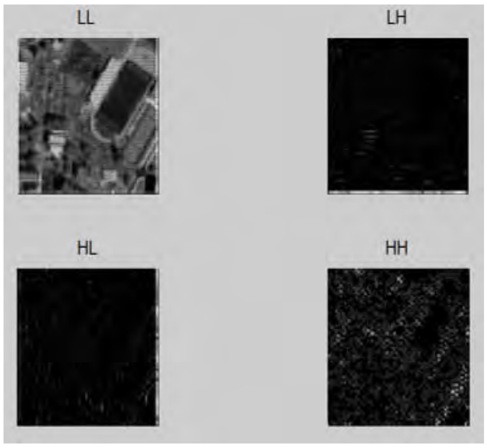


Fig. (4).
Interpolated Image
Output of DWT

This sharpness is boosted as per the concept that, the interpolation of highly isolated high-frequency components then followed by interpolating the low-resolution image directly. In all steps, of the all existing satellite image augmentation techniques, Daubachies (db.9/7) wavelet transform as mother wavelet function and bicubic interpolation technique have been used. The Sharpness can be increased by implementing the process of detecting the positions of the edges through threshold decomposition and these edges are sharpened by using morphological filters. Mathematical morphology (MM) is a theory and technique for the analysis and processing of geometrical structures, as per set theory, lattice theory, topology, and random functions. The Sharpness augmentation is through a way of threshold decomposition.

The advantages are:-

- It causes bulk decrease in the edge detection to a simple binary process.
- It makes the estimation of edge direction straightward.

Edge Detection and detection and direction estimation may be carried out by identifying simple patterns, related to Prewitt Operators. Then the edges were then sharpened by using morphological filters [4]. The main aim of edge enhancement is improving the visual perception of images that are unclear due to blur present in the image.

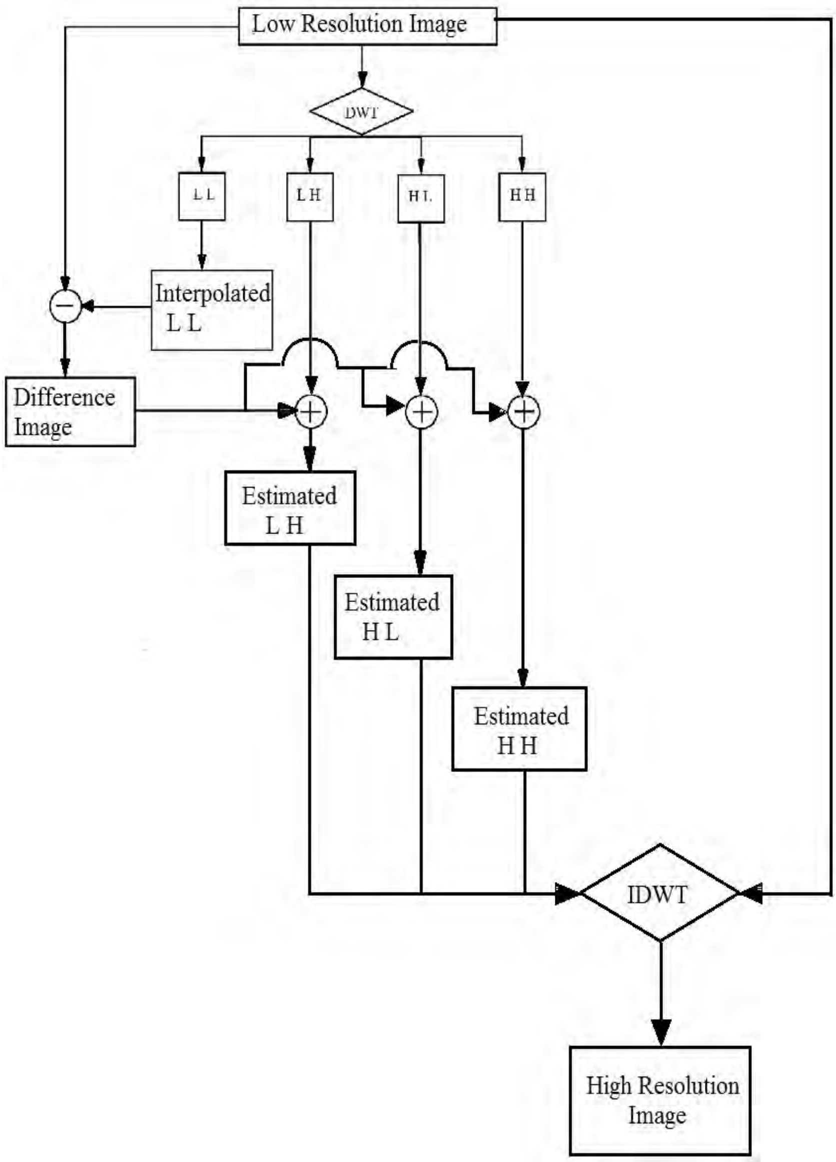


Fig. (5). Image augmentation with intermediate stage

Noise removal and preservation of useful information are important aspects of image enhancement, which are having much kind of methods to solve the problems related to them. To increase the quality of an image process of preservation of edges is a necessary need.

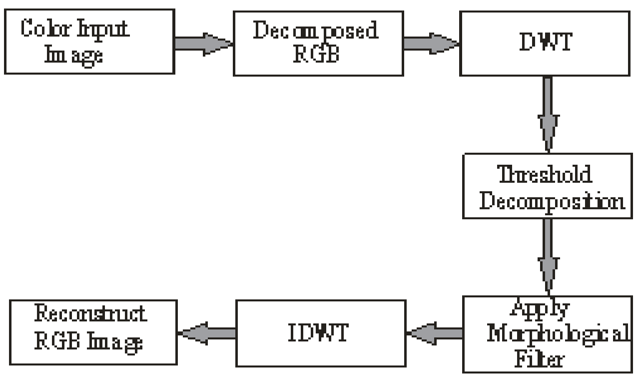


Fig. (6). Image Augmentation with threshold decomposition using morphological filters

The input low contrast color image is decomposed into R,G,B. DWT is apply to each color separately. The LL subband of each color component of the image is decomposing into series of binary levels can then be recombined to produce the final grey scale image with identical pixel values to those produced by the grey scale processing. As a result of success of threshold decomposition, operators depending on gradient values is used to detect the exact positions of the edges, by detecting the edge positions and then applying a class of morphological filtering [4,6,7].

## III.PROPOSED METHOD

The Wavelet Theory is applicable to various problems like in subband coding which leads to efficient data compression, and multiresolution signal processing used for pattern recognition etc. The Wavelet Theory allows to transform signals from the time domain to a time- frequency like domain, the so-called timescale domain. Actually Lifting scheme is worthwhile to merge these steps and design the wavelet filters while performing the wavelet transform.

The idea of lifting scheme also provides the new possibility to construct (bi-)orthogonal haar wavelet basis functions in the spatial domain. It is used to generate second-generation wavelets [8]. Digital signals are usually a sequence of integer numbers, since wavelet transforms result in floating point numbers. For a highly efficient reversible operation, we need a transform algorithm that converts integers to integers. Possibly, a lifting step can be modified to operate on integers, while preserving the reversibility[9,10].

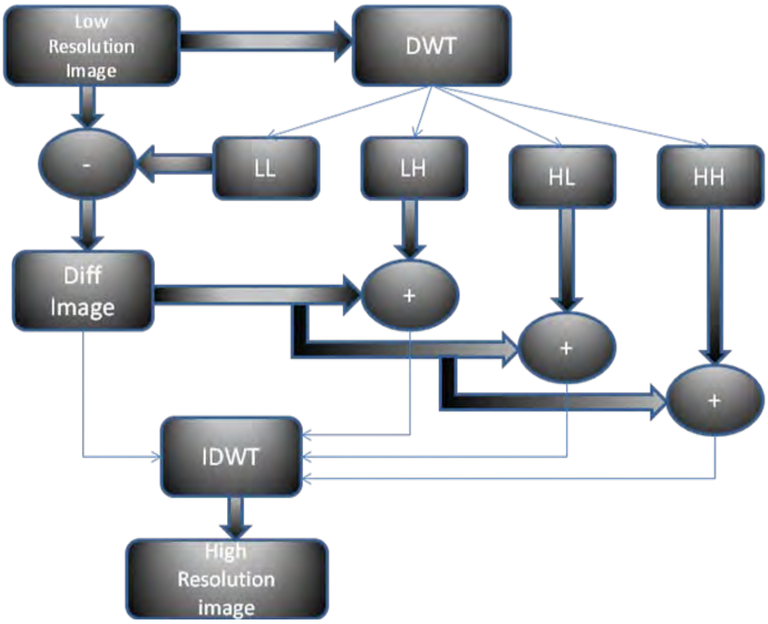


Fig. (7). Proposed Image augmentation Method With Dwt Lifting Scheme

### A. Significance Of Using Lifting scheme:-

In the present world, lifting scheme of WT is commonly used for the digital speech compression because of having the following advantages over conventional wavelet transform technique:-

- Lifting scheme allows us to implement reversible integer wavelet transforms.
- In case of lifting scheme perfect reconstruction is possible for loss-less compression.
- It became easier for storing and processing integer numbers when compared with floating point numbers.
- It can also be applied for irregular sampling process.

### B. Forward wavelet transform:-

Consider the sequence of samples l0,k at some approximation level named as "level0" and same sequence can be transformed into two other sets at "level -1*". First of all, we will divide the sequence into set of odd and even samples. This process is known as lazy wavelet transform. This sequence is transformed into coarser signal l -1,k and detail signal ¡-1,k by predict and update stage of lifting scheme of wavelet transform.

Lifting scheme consists of three steps:

- Split (Lazy wavelet transform)
- Predict (Dual lifting)
- Update (Primal lifting)

In the split stage the input signal or image is separated into even and odd indexed samples. The predict stage actually computes the high pass filter coefficients representing the details of subband. Then update stage gives low pass filter coefficients which will stand for the approximation subband of the DWT process.

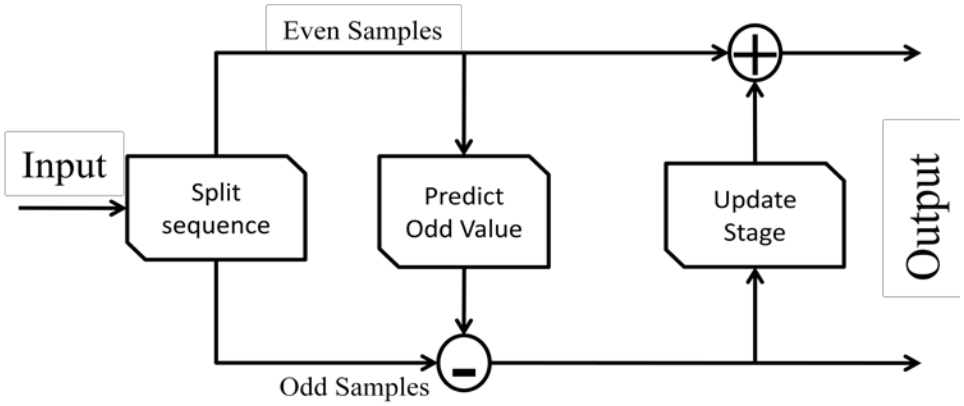


Fig. (8). Forward DWT lifting Scheme

**a. Split (Lazy wavelet transform)**:- This stage splits entire set of signal into two frames. One frame consists of even index samples such as l0,0, l0,2 …….l 0,2k. We will call this frame as l -1,k. Other frame consists of odd samples such as l0,1 , l0,3, …….l0,2k+1. We will call this frame as ¡-1,k. Each group consists of one half samples of the original signal. This kind of dividing a signal into two parts is called lazy wavelets, since we are not performing any of the mathematical operations. If we remove any of the frames, there is a chance of losing signal information.

New sequence can be given as:l*-1,k=l 0,2k.

**b. Predict (Dual lifting):-** If the signal is having locally correlated structure, then even and odd samples are highly connected, then it seems to be easy to predict odd samples from even samples. The prediction can be linear, cubic. Interpolating subdivision is used to find out predictor. We would like to carry data more compactly for reducing storage requirement as well as to reduce transmission rate.

**c. Update (Primal lifting):-** The coarser signal must have same average value that of original signal. To do this, we require lifting the l -1, k with help of wavelet coefficients ¡-1,k. After lifting process, mean value of original and transformed signal remains same. Now we require constructing U as update operator for this lifting process.

**C. Inverse wavelet transform:-**

Inverse DWT is exactly reverse process of forward DWT. From the Inverse DWT we got the exact required output. Inverse wavelet transform consists of following steps:

- Undo Update (Inverse Primal lifting)
- Undo Predict (Inverse Dual lifting)
- Merge

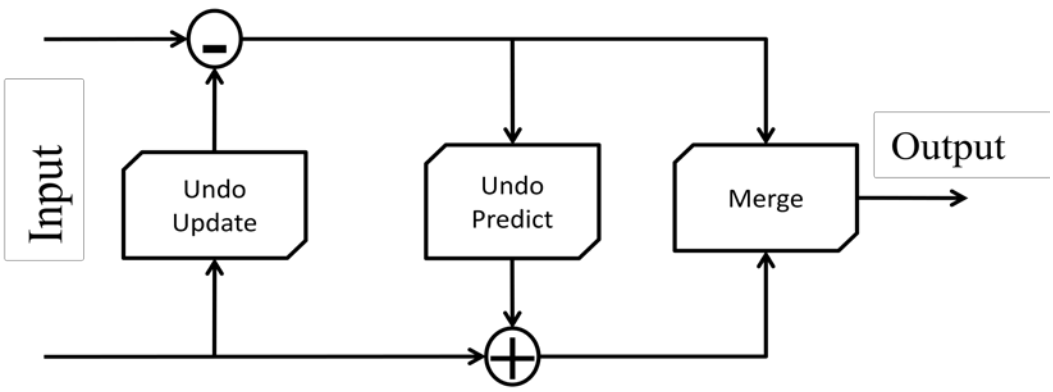


Fig. (9). Inverse DWT Lifting scheme

**a. Undo Update (Inverse Primal Lifting):-** Original even samples are recovered by subtracting the update information.

**b. Undo Predict (Inverse Dual Lifting):-** Odd samples can be recovered by adding prediction information to loss of Information.

**c. Merge:-** After recovering odd and even samples, final job is to merge them together to obtain prior signal. To compress the signal, even samples are scaled by inserting zero values in between the samples and then odd samples are placed in place of zeros.

## IV.THE HARDWARE AND SOFTWARE IMPLEMENTATIONS

Here we are designing the image enhancement using XILINX ISE 10.1 Design suite and Xilinx Platform Studio (XPS), the algorithm is written in VHDL Language interfacing the circuit implemented in FPGA with the PC using the JTAG cable. The proposed design is implemented on the Xilinx (XC3S500E) chip using Spartan 3E FPGA kit. The figure of the proposed hardware kit is shown below:


Figure (10). SPARTAN3 FPGA KIT

The Figure(11) a,b,c are illustrations for the proposed method of image augmentation using the DWT lifting scheme along with Inverse DWT.

Figure (11) a. Input

Figure (11) b. output

Figure (11) c. input

Figure (11) d. output

Figure (11) e. input

Figure (11) f. output

## V. STUDY ON ENTROPY, PSNR AND RMSE VALUES

One of the quantitative measures in digital image processing is Entropy. Claude Shannon introduced the entropy concept in quantification of information content of messages. For an image consists of L number of grey levels, the entropy is defined as:

$$H = \sum_{i=1}^{L} P(i)\log_2 P(i) \dots\dots\dots\dots\dots\dots (5)$$

where P(i) is the probability (here frequency) of each grey scale level. The larger alternations and changes in an image give larger entropy and the sharp and focused images have more changes than blurred and misfocused images. Hence, the entropy is a measure to assess the quality of different aligned images from the same scene.

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{R^2}{\mathrm{MSE}}\right] \dots\dots\dots\dots (6)$$

**PSNR** is an expression for the ratio between the maximum power of a signal and the power of distorting noise that affects the quality of its representation. Since most of the signals have a very wide dynamic range, the PSNR is usually measured in terms of the logarithmic decibel scale(db).

**Mean Squared Error (MSE)** deals with the values obtained by an estimator thus calculating the divergence between estimator values and optimum values of estimated quantity.

$$\mathrm{MSE} = \Sigma_{m,n}[I_{1(m,n)} - I_{2(m,n)}]^2 / (M+N) \dots\dots..(7)$$

**Root Mean Square Error (RMSE)** calculates the root of power two for Standard Deviation, it illustrates the average magnitude of the error.

TABLE1.
CALCULATED MEASURES OF PSNR, MSE & ENTROPY

| Quality Measure | Figure (11)b | Figure (11)d | Figure (11)f |
|---|---|---|---|
| MSE | 3.7043 | 4.6444 | 10.8138 |
| PSNR | 42.4438 | 41.4615 | 37.7910 |
| Entropy | 4.4701 | 6.3614 | 6.7854 |

## VI.CONCLUSION

As from the above discussed sections ,we are illustrating the effective image augmentation technique in areas of contrast, resolution and sharpness in this paper. Also the DWT lifting scheme seems to be an advanced method to reduce the noises and to save the needed data of the image. It gives faster, easier, less demanding, and more effective FPGA solutions. The 12 bits is proved as best word length for DWT coefficients which gave highest PSNR and is suitable for three DWT levels as used and for higher levels also. The quality of the Augmented image can be understand by measuring the PSNR and RMSE using MATLAB programming.

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