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An Energy Efficient and High Speed Image Compression System Using Stationary Wavelet Transform

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Abstract— Image compression is one of the interesting domains nowadays in all areas of research. Everybody working with huge of amount of data in their daily life. In-order to deal with such huge amount of data, there is a need to store and compress the data. So there is a need to develop a system to compress and store the data. JPEG 2000 is a system to achieve this object. In this paper an area efficient and high speed JPEG2000 architecture has been developed to compress the image data. To implement JPEG2000 system, here a transform called stationary wavelet transform has been used. Stationary wavelet transform reduces the bottlenecks existing in the wavelet transform. Stationary wavelet transform avoids the problem of invariance-translation of the already existing discrete wavelet transform. The proposed stationary wavelet transform based JPEG2000 improves the speed and efficiency of power compared to the discrete wavelet transform based JPEG2000. Many image compression applications such as tele-medicine, satellite imaging, medical imaging require high-speed, low power compression techniques with small chip area. This paper has an analysis on the speed of JPEG2000 using stationary wavelet transform and it will be compared theoretically and practically with the JPEG2000 using discrete wavelet transform. The amount of information missing in the test image usually been very small when compared to the DWT based JPEG2000.The MSE and PSNR values proved to be better when compared to the DWT based JPEG2000. The proposed SWT based JPEG2000 compresses and decompresses the image at a faster rate than the DWT based JPEG2000.Finally the design will be implemented in XILINX Virtex-4 FPGA Kit. .The power consumption of the proposed method proved to be 290mW compared to other types of compression techniques.

***Keywords—**Compression, Stationary wavelet transform, Discrete wavelet transform JPEG2000, MSE,PSNR.*

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I. INTRODUCTION

JPEG2000 is an efficient image compression technique when compared to the JPEG. Image compression plays a vital role in many applications such as tele medicine, satellite images, internet etc. Already existing architectures of JPEG2000 consumes more power and compresses the image at a slower rate. Hence there is a need to develop an architecture which consumes less energy and operates at higher speed. The conventional DWT used in image compression is not shift variant. This means that the DWT translated version of a signal is not same as the original signal. Hence there is a need to use stationary wavelet transform based JPEG2000 image compression system. In stationary wavelet transform(SWT) the high pass filters and low pass filters are applied to the data in the block segments of an image. In SWT modify the filters by padding zeroes. Stationary wavelet transform based JPEG 2000 is slightly computational intensive than discrete wavelet transform based JPEG2000[1][2]. In multi-scale signal processing, wavelet is a time-frequency analysis that has been widely used in the field of image processing such as denoising, compression, and segmentation. For each modification in the circuit the delay and power will be reduced[3][5]. The SWT algorithm isvery simple and close to DWT. To calculate the decimated DWT for a given signal of length by computing approximation and detail coefficients for every possible sequence. The simulation results show the reduction in power and delay. The stationary wavelet decomposition is more tractable than the wavelets.SWT has the advantage of maintaing the same number of coefficients throughout all scales. SWT having 2nk coefficients where n is the length of the signal and k is the number of scales is having high redundancy which is particularly suitable for image compression applications.

The paper is organized as follows: Section I deals with introduction, section II deals with related work, section III covers proposed work, section IV covers results and section V states the conclusion of the work.

II. REVIEW OF PREVIOUS WORK

A) Stationary Wavelet Transform (SWT)

Among the different tools of multi-scale signal processing, wavelet is a time-frequency analysis that has been widely used in the field of image processing such as denoising, compression, and segmentation. Wavelet-based denoising provides multi-scale treatment of noise, down-sampling of sub-band images during decomposition and the thresholding of wavelet coefficients may cause edge distortion and artifacts in the reconstructed images. To improve the limitation of the traditional wavelet transform, a multi-layer stationary wavelet transform (SWT) was adopted in this paper, as illustrated in Figure 1.

In Figure 1, Hj and Lj represent high-pass and low-pass filters at scale j, resulting from the interleaved zero padding of filters Hj-1 and Lj-1 (j>1). LL0 is the original image and

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the output of scale j, LLj, would be the input of scale j+1. LLj+1 denotes the low-frequency (LF) estimation after the stationary wavelet decomposition, while LHj+1, HLj+1 and HHj+1 denote the high frequency (HF) detailed information along the horizontal, vertical and diagonal directions, respectively[4], [5].

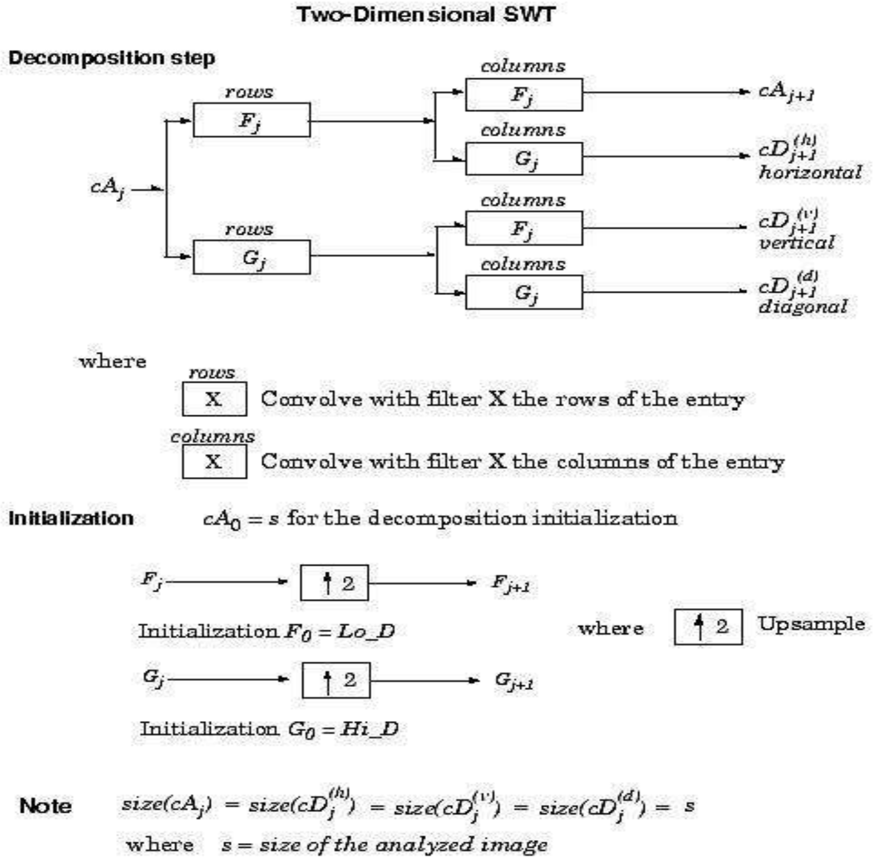

Fig. 1. Schematic Diagram of 2D-SWT

DWT is not a shift invariant transform. Where a SWT is a shift invariant transform. Shift invariance is very much important for applications such as pattern recognition, image denoising etc.In SWT applying low pass and high pass filters at each level but the coefficients are not decimated. Instead of decimation padding zeroes to each coefficient. Using a Trous Algorithm,upsampling the filter coefficients by inserting zeros shown in figure 1.

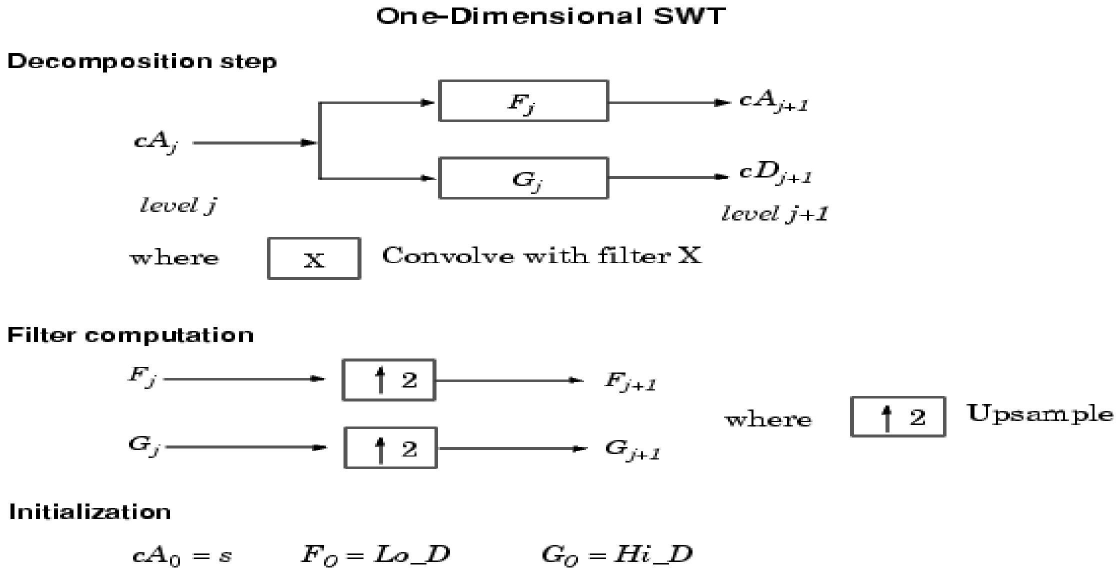

Fig. 2 Block diagram of a stationary wavelet transform

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Sub-band images would have the same size as that of the original image because no down-sampling is performed during the wavelet transform. In this study, the Haar wavelet was applied to perform multi-layer stationary wavelet transform on a 2D image [6].

Mathematically, the wavelet decomposition is defined as:

LLj+1(χ, γ) = L[n] L [m] LLj (2j+1 m- χ, 2j+1 n- γ)

LHj+1(χ, γ) = L[n] H [m] LLj (2j+1 m- χ, 2j+1 n- γ)

HLj+1(χ, γ) = H[n] L [m] LLj (2j+1 m- χ, 2j+1 n- γ)

HHj+1(χ, γ) = H[n] H [m] LLj (2j+1 m- χ, 2j+1 n- γ)

Where L[·] and H[·] represent the low pass and high pass filters respectively, and LL0(X,Y)=F(X,Y)

III. PROPOSED WORK

A) COMPRESSION

THE FOLLOWING STEPS SUMMARIZE THE PROPOSED METHOD:

1. Load the individual blocks of an image in a order.
2. Perform a stationary wavelet decomposition of the elements in a block. SWT is implemented to obtain non decimated-wavelet coefficients.
3. Construct approximations coefficients and details coefficients from the previous step.
4. Show the approximation and detail coefficients at level 1.
5. Successive separation of the coefficients and up sampling of the decomposition filters is repeated until the best tree structure at a predefined decomposition level is obtained.
6. For each wavelet decomposition level , a level dependent soft threshold is determined.
7. Soft thresholding is applied on the wavelet coefficients.
8. The reconstructed image can be obtained from the approximation and detail coefficients

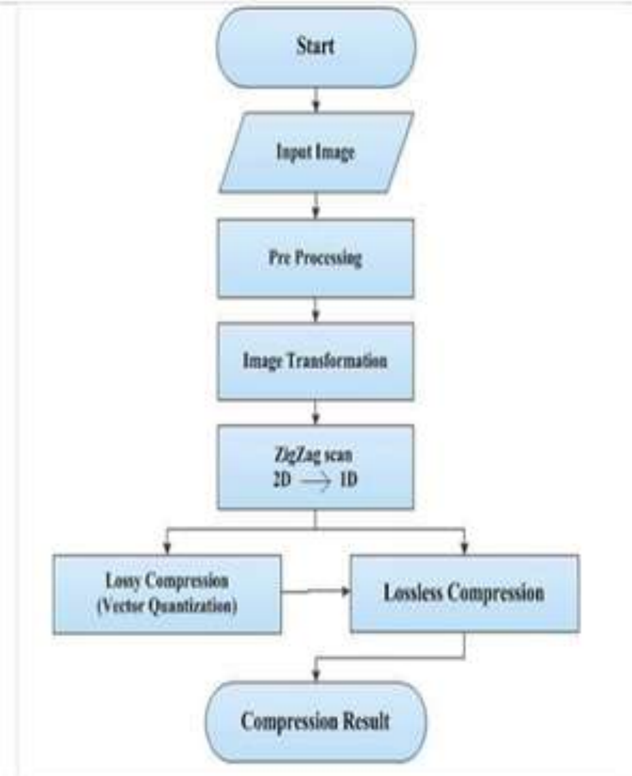

Fig.3.Architecture of proposed algorithm

SWT offers better denoising and compression capability than the existing wavelet transforms. The main advantage of SWT is it is shift invariant transform. The SWT algorithm is very close to DWT but in SWT the down sampling operation after filter convolution is suppressed. The division obtained is then a redundant representation of the input data. The advantage of this redundant representation over the memory-efficient decimated DWT is the reduction of problems at discontinuities and irregularities in reconstructed image. These problems are caused by unpredictable changes in coefficients with different time shifts. Preprocessing phase receives images as input, so that the proposed approach resize the image in accordance with the measured rate of different sizes to (8 × 8) and then converted from RGB to gray scale.

B) FPGA Implementation

The flexibility offered by FPGA makes the FPGA is suitable for modifications in the design. Moreover FPGA offers less consumption, less cost, high speed and high reliability. In this work image compression system has been implemented by using stationary wavelet transform. The newely developed methods for image compression system has been mentioned in[4],[5].The system has been implemented in software using the soft processor Vertex from Xilinx, which facilitates interaction with peripherals.

IV. RESULTS

MATLAB simulations have been run to test the proposed algorithm. The performance of the compression algorithm is assessed in terms of compression ratio, mean square error etc.

Table 1 shows the comparison of results among various types of compression techniques. The proposed work proved to be

Better compression time and compression ratio compared to other compression techniques.

Table 1: Comparison of Results

Compression Technique	Image	Compression time(Sec)	Compression ratio
2D-SWT	Cameraman	0.0315	4.35
2D-DWT	Lena	0.412	5.12
2D-DCT	Peppers	1.21	5.74

Table 2 shows that the synthesis report of the proposed method has been implemented on Vertex 4 FPGA device. The proposed architecture consumes less power and operates at higher speed.

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Table 2: Synthesis report

Hardware utilization	Used	Available	% of utilization
LUTs	125	1214	10.29
Muxs	252	2560	9.84
IOBS	122	520	23.46
Power Consumption	290mW	---	----
Delay	20ns	----	-----

V. CONCLUSION

The image compression system using stationary wavelet transform has been proved to be an efficient method for compressing and decompressing an image than Discrete wavelet transform based image compression system. The compression system has been verified using reconfigurable field programmable gate arrays to achieve better performance at low bit rates. The power consumption proved to be less than the existing methods using discrete wavelet transform. The system compresses and decompresses the image at a faster rate with less critical path delay. The proposed image compression system performs with more accuracy. The reconstructed image is appears to be same as the input image by losing few redundant data. If this concept is applied to 3-D stationary wavelet transform it will give some interesting results in image compression systems.

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