FPGA Implementation of 4-D DWT and BPS based Digital Image Watermarking

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***Abstract*--- In order to protect copyrighted material from illegal duplication, two typical technologies have been developed they are key-based cryptographic techniques and digital watermarks which enable the appropriate security during the transmission process. A digital image watermark consists of signing an image with a signature or copyright message and the message is secretly embedded in the image by using a computer algorithm, using the signature the watermarked image will be detected and extracted. In our paper, we propose a new technique of watermarking, combining both Discrete Wavelet Transform (DWT) and Bit-Plane Slicing (BPS) techniques. In the first unit, we decomposed the image to be watermarked in to four dimensional modified DWT coefficients, by adding pseudo-random codes at the high and middle frequency bands of the DWT of an image. In the second unit, a key has been generated from LHLH frequency bands of the 4-Level DWT image and this key is watermarked in to the original gray image. In the third unit, for data compression we used bit plane slicing technique where the original gray image is sliced in to 8 planes and we used bit plane 3 to embed in to the key watermarked image. The embedded key watermarked image is transmitted and the key watermarks are extracted with robustness. Using our technique, the processing time of the extraction of the watermark has been reduced and the peak signal-to-noise ratio (PSNR) value is improved. We implemented our technique using MATLAB and these units are simulated, synthesized and optimized for Spartan-3EDB FPGA chips using Active-HDL Version 7.2SE design tools.**

***Keywords*--- copyrighted material, cryptographic techniques, digital watermarks, signature, DWT, BPS, PSNR, Spartan-3EDB FPGA, Active-HDL.**

I. INTRODUCTION

Because of the widespread of the Internet, Digital Image watermarking became popular for Proof of Ownership (copyrights and IP protection), Copying Prevention, Broadcast Monitoring, Authentication and Data Hiding. Digital Image watermarking technique involves, adding undetectable copyright information or data or message to the original image, which identifies the ownership. After adding the watermark in the original image, there should be no image degradation, watermark should not be removable and should be robust against different types of attacks. Different watermarking techniques have already been evolved in the field of digital image processing. Because of copyright protection, watermarking techniques are often evaluated based on their robustness, recoverability, and invisibility [2].

Watermark Insertion involves the process of adding the watermark message. Watermark message $W_M(x, y)$ may be a Random or pseudo random signal, a Binary {-1, +1} or {-1, 0, +1} signal which are added linearly.

Watermarking techniques can be broadly classified into different categories based on two criteria's, they are transform domain techniques involves Discrete Fourier Transform (DFT) Domain, Discrete Cosine Transform (DCT) Domain and Discrete Wavelet Transform Domain (DWT) and spatial domain techniques. Comparatively transform domain watermarking techniques are more robust than spatial domain techniques; our paper will include only transform domain watermarking techniques.

Among all the transform domain watermarking techniques, DWT technique provides more invisibility, fragile and robustness to the retrieved watermark image for copyright protection and data hiding.

In DWT each image frequency bands may have property of redundancy but they are redundant in different manner [1]. To remove the redundancy in the image we are going for image compression algorithms, lossy and lossless. In our paper we are going for lossy compression algorithm for compressing redundancy by removing irrelevancy.

There are several image compression algorithms for both gray images and color images. In our paper, a bit-plane slicing technique (BPS) involving the bit-level image compression algorithm, to compress gray level image by taking a gray scale image, separating into bit plane then compressing by bit-level image.

Our paper deals with the implementation of these two techniques DWT and BPS to evaluate their susceptibility to retrieve the watermarked image under different attacks by various image processing techniques. To implement our proposed watermarking technique, we created a GUI as well as to evaluate their respective watermarks based on several image attacks.

We implemented our technique using MATLAB GUI feature to add and extract the watermark image in to the original image and the watermarked image has been synthesized in Active-HDL Version 7.2SE design tools which was optimized for Spartan-3EDB FPGA chips.

The rest of the paper is organized as follows. In the next section, we are explaining the details about the 4-D DWT and BPS. In section 3, we present the proposed method for Digital Image Watermarking. In section 4, experiments performed on Lena image is presented and compared with the other image using PSNR value. Conclusion and proposed method remarks are given in section 5.

II. IMPLEMETED TECHNIQUES

For invisible and robust watermarking, DWT of 4-Level decomposition [1, 2] is proposed. And for image data redundancy a bit-plane slicing lossy compression technique is utilized in our technique. In our paper, we are proposing a technique using both DWT and BPS techniques and comparatively PSNR value is improved in our proposed technique than the DWT & BPS.

A. DWT Based Watermarking Technique

This section gives the overview of wavelet based watermarking technique proposed in our paper. Wavelet transform decomposes a signal into a set of basic functions. These basis functions are called wavelets. Wavelets are obtained from a single prototype wavelet called mother wavelet by dilations and shifting. The wavelet transform is computed separately for different segments of the time-domain signal at different frequencies.

Multi-resolution analysis (MRA) analyzes the signal at different frequencies giving different resolutions. MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. Good for signal having high frequency components for short durations and low frequency components for long duration. e.g. images and video frames.

The DWT transformations are classified based on the levels of wavelet transformation [5], they are 1-D wavelet transform, 2-D wavelet transform [3], 3-D wavelet transform, 4-D wavelet transform, 5-D wavelet transform and more.

In 1-D wavelet transform the levels are L and H. In 2-D wavelet transform the levels are LL, LH, HL and HH.In our paper we are implementing a 4-Level decomposed Discrete Wavelet Transform technique, where the original message image is decomposed in to 16 high and low frequency sub bands of coefficients. They are LLLL, LLLH, LLHL, LLHH, LHLL, LHLH, LHHL, LHHH, HLLL, HLLH, HLHL, HLHH, HHLL, HHLH, HHHL and HHHH.

Using lifting scheme, first split the original image into two sets (split phase) i.e., odd samples and even samples, which are composed of high-pass and low-pass filters that perform a convolution of filter coefficients and input pixels. After a one-level of 4-D discrete wavelet transform, the volume of image is decomposed into 16 levels of signals as shown in the figure 1.

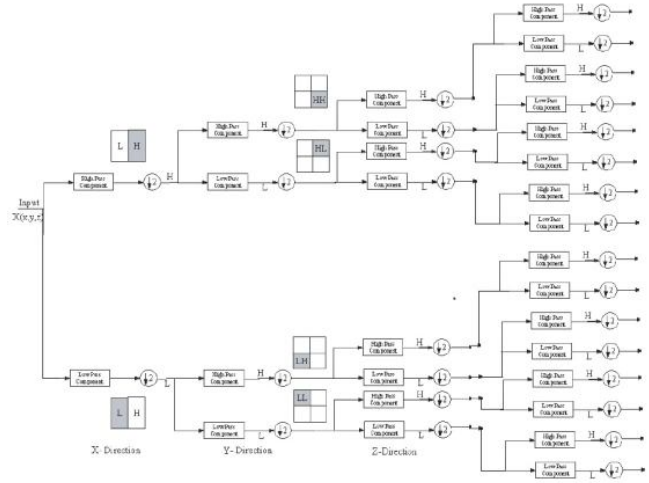

Figure 1: 4-D wavelet transforms

B. BPS Based Compression Technique

Bit plane slicing [6] is new way of looking at an image. In bit plane slicing the image is considered to be a stack of binary images. The images closes to the bottom are least significant and the images on top are most significant. Instead of highlighting intensity ranges, highlighting the contribution made to the total image appearance by specific bit might be desired.

Imagine that the image is composed of eight 1-bit planes, ranging from plane 0 for least significant bit to plane 7 for the most significant bit. Bit-plane slicing reveals that only the five highest order bits contain visually significant data. Also, note that plane 7, corresponds exactly with an image threshold at gray-level 128.

Given an 8-bit per pixel image, slicing the image at different planes (bit-planes) [7] plays an important role in image processing. In general, 8-bit per pixel images are processed. We can slice an image into the following bit-planes. Zero is the least significant bit (LSB) and 7 is the most significant bit (MSB):

1. 0 which results in a binary image, i.e, odd and even pixels are displayed
2. 1 which displays all pixels with bit 1 set: 0000.0010
3. 2 which displays all pixels with bit 2 set: 0000.0100
4. 3 which displays all pixels with bit 3 set: 0000.1000
5. 4 which displays all pixels with bit 4 set: 0001.0000
6. 5 which displays all pixels with bit 5 set: 0010.0000
7. 6 which displays all pixels with bit 6 set: 0100.0000
8. 7 which displays all pixels with bit 7 set: 1000.0000

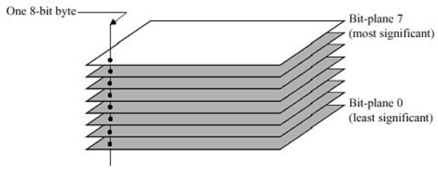

Figure 2: 8-bit plane slicing method.

III. PROPOSED 4-D DWT AND BPS BASED WATERMARKING METHOD

In our paper, we are proposing a method using both 4-D DWT method and 8-bit plane slicing method. In our method, we had taken a Lena color image [4] and converted into gray level for our implementation. This gray level image is transformed in to 4-D DWT, where we had taken only LHLH frequency sub band coefficient.

Using a key generation algorithm, a key image has been generated from the original gray Lena image. The key image is embedded in to the LHLH coefficient image as a watermark.

The process of key watermark image includes adding LHLH image and key image of the original gray image. The algorithm for adding LHLH and key images is:

Step 1: Check whether the Original image is a gray scale image or not. If it is a color image, then convert it to a gray scale image.

Step 2: Extract the 4-D DWT from the original gray image and process only the LHLH frequency sub band coefficients.

Step 3: Generate key image from the original gray image using key generation algorithm.

Step 4: Now embedded the key image and LHLH frequency sub band coefficients.

Next the original Lena image is converted in to 8-bit planes using BPS technique [6], in which only 3rd bit plane is considered in our implementation. The key watermarked image from 4-D DWT is embedded in to the 3rd bit plane.

The steps involved in Bit-Plane Slicing procedure is as follows:

Step 1: Convert the input original color image into gray image.

Step 2: Isolate the various bit planes by generate random numbers ranging from the size of the original gray image.

Step 3: Get the 3rd level of Bit-Plane from the bit planes.

Step 4: Watermark the key watermarked image in 4D-DWT procedure with the 3rd bit plane slicing image using the proposed watermarking technique.

Above procedure is implemented in MATLAB GUI interface and the images are scaled properly to increase the image processing time. The embedded watermark image is transmitted using the MATLAB GUI interface and retrieved using the Visual Basic (VB) tool.

Using Active-HDL Version 7.2SE design tool, the original gray image, key image, LHLH coefficient image, key watermarked image and 3rd bit plane slice image is stored in the memory of the Spartan-3EDB FPGA chip.

In our technique, the key watermarked image and 3rd bit plane slice image is embedded in the chip through the memory control logic. The key watermarked embedded image is stored in the internal memory of Spartan-3EDB FPGA chip. The key watermarked embedded image is extracted using memory control logic through VB tool through pixel by pixel in VB window.

Using the program control logic in our proposed technique, the original gray image will be extracted from key watermarked embedded image. The original image will be extracted using the same VB window.

PSNR value is calculated with the original gray image and the retrieved images, results found satisfactory.

IV. EXPERIMANTAL RESULTS

In our paper, we performed our technique on Lena image of 256 x 256 sized images. Firstly, the process of 4D-DWT implementation [3, 5] is done and extracted only LHLH coefficient.

Then a key is generated from the original gray image. Secondly, the LHLH and key is watermarked and converted into a key watermarked image. The following images of figure 3 shows the key watermarked image generation.

Fig 3(a) Color image Fig 3(b) Gray image

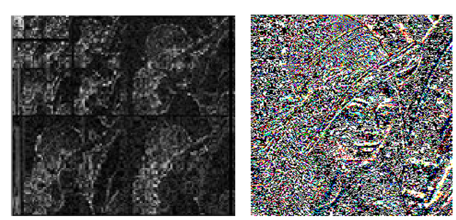

Fig 3 (c) 4 D-DWTimage Fig 3(d) LHLH image

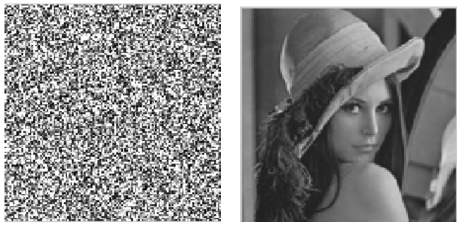

Fig 3(e) Key image Fig 3(f) Key watermarked image

Figure 3: Results of conversion of gray images in to key watermarked image.

Thirdly, using BPS technique [6,7] the original gray image is converted into 8-bit plane slices. In these slices only 3rd bit-plane is embedded in to key watermarked image. The following images of figure 4 show the embedding technique.

Fig 4(a) Gray image Fig 4(b) 0-bit plane image

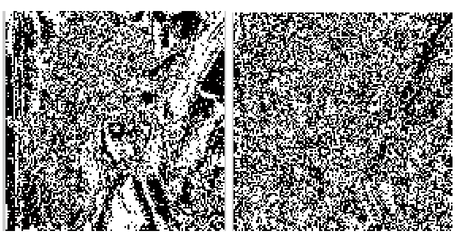

Fig 4(e) 3-bit plane image Fig 4(f) 4-bit plane image

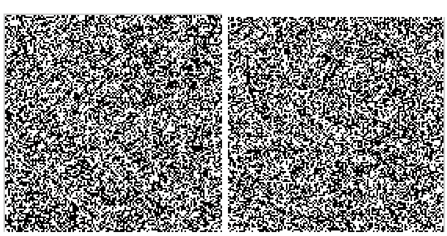

Fig 4(g) 5-bit plane image Fig 4(h) 6-bit plane image

Fig 4(c) 1-bit plane image Fig 4(d) 2-bit plane image

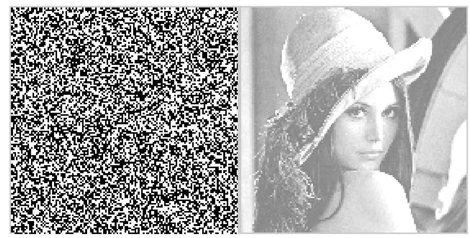

Fig 4(i) 7-bit plane image Fig 4(j) 3rd bit plane and key embedded image

Figure 4: Results of embedding of 3rd bit plane and key watermarked image.

Figure 5 Extracted image from the watermarked image

There is no perceptual distortion in the original and watermarked image, which means that proposed technique has satisfied the criteria that an efficient watermark should be unobtrusive, discreet and easily extracted.

Figure 5 shows the extracted image. The images are processed and their running time is calculated. The running time of the algorithm for one image can range from 45 to 60 seconds on a Pentium IV CPU using MATLAB code and Active VHDL tool.

Execution time will vary from one image to another, depending on the size of the image. The Lena image which is taken as an analysis in our paper, as shown in the Figure. 3, 4 and 5 took a running time of 47 seconds depending on the source and reference Image.

For robustness [4], the obtained PSNRs between host image and watermarked images for different images were calculated, respectively as shown in Table I.

TABLE I
PSNR VALUE OF DIFFERENT IMAGES

Image	**PSNR value between the images**			
	Gray & Key watermarked image	**Key watermarked & embedded image**	**Embedded & extracted image**	**Extracted & gray image**
Lena	54.56	57.62	69.22	72.12
Camera Man	43.21	31.55	35.45	56.88
Peppers	50.26	49.56	49.44	53.22
Faces	56.25	60.11	60.59	62.32

From the experimental results and PSNR values we can say that there is no perceptual distortion in the original and watermarked image, which means that proposed technique has satisfied the criteria that our watermarking technique is more invisibility, fragile and robustness for copyright protection, data hiding, discreet and easily extracted.

V. CONCLUSION

In our paper, we combined the 4D-DWT technique for image segmentation and BPS for image compression. Combining these two techniques, a new technique as developed which increased the robustness and invisibility of the watermarked image.

Using our proposed method any image of the given dimensions can be watermarked in to bit plane slices and retrieved without any attacks.

Our proposed technique was synthesized and optimized for Spartan-3EDB FPGA chips using Active-HDL Version 7.2SE design tools. Synthesized report clearly shows that the running time of our proposed technique is 47 seconds which is very less comparative with the other techniques.

This concludes that using our proposed technique, there is an increase in the robustness and invisibility of the watermarked image, also the PSNR value is improved and the running time is reduced.

VI. FUTUREWORK

The proposed method can be further extended to Digital Video Image Processing. Effect of noise attacks on these images can be further studied. Correlation coefficients between the images can be further calculated. And this paper can be extended further for the Gaussian, salt and pepper, Speckle and JPEG images.

VII. REFERENCES

[1] Hitesh Patel, Jignesh Patoliya, Pradip Panchal,R. N. Patel, "*Digital Robust Video Watermarking Using 4-Level DWT*," IJAET/Vol.I/ Issue III/Oct.-Dec.,2010/101-113.

[2] Chetan K.R, Raghavendra K, "*DWT Based Blind Digital Video Watermarking Scheme For Video Authentication*", International Journal Of Computer Applications (0975 – 8887) Volume 4– No.10, August 2010/19-26.

[3] Nikita Kashyap and Sinha G.R. " *Image Watermarking Using 2-Level DWT* ",Advances In Computational Research, ISSN: 0975-3273 & E-ISSN: 0975-9085, Volume 4, Issue 1, 2012, pp.-42-45.

[4] Baisa L. Gunjal, "Wavelet *Based Color Image Watremarking Scheme Giving High Robustness And Exact Corelation* ", International Journal Of Emerging Trends In Engineering And Technology (IJETET), Vol. I No. 1, 2011, Issn 2248-9592,pp.-21-30.

[5] Mauro Barni, Franco Bartolini, Alessandro Piva, "*Improved Wavelet-Based Watermarking Through Pixel-Wise Masking*", IEEE Transactions On Image Processing, Vol. 10, No. 5, May 2001, pp.- 783-791.

[6] M. Jasmine Pemeena Priyadarsini, K. Murugesan, "*Efficient Face Recognition In Video By Bit Planes Slicing*", Journal Of Computer Science 8 (1): 26-30, 2012, ISSN 1549-3636.

[7] Barghavi Govindarajan1, Karen Panetta1,Sos Agaian, " *Progressive Edge Detection On Multi-Bit Images Using Polynomial-Based Binarization* ".