Hybrid Architecture For Reversible Watermarking Of Medical Images Using Wavelet Transforms

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Abstract

To overcome the difficulties in the performance analysis of the real time implementation of image processing algorithms; an attempt is made by proposing a hybrid architecture combining CPU and FPGA. FPGA is used as hardware accelerator. The proposed architecture is tested by implementing a real time reversible watermarking system using wavelet transform. Here, Two level Haar wavelet transform based watermarking approach is used. Results have shown that the proposed architecture provides robustness with low computational complexity. Peak Signal to Noise Ratio (PSNR) is used to compare simulation results (MATLAB) with the real time implementation (DE2-115) with respect to signal to PSNR. The experimental analysis shows the improvement in the PSNR when compare to its simulation result.

Keywords*- Discrete Wavelet Transforms (DWT), Haar wavelet, Field Programmable Gate Array, Watermarking.*

Introduction

Transmission of digital data has become unavoidable routine of our daily activities. The work depicted in (Chuan Qin et al., 2019) stresses upon the challenges exists in real-time image watermarking and image forensics such as traditional research methodologies and high computational complexity. Watermarking is embedding digital watermark into cover signal which is used to verify its authenticity. Signal may be image, audio, video or text also. A new combination of dynamic multi watermarking is proposed which has shown a better efficiency compare to its predecessors (Gao et al., 2019). Due to association of most digital transmission with cloud networks, handling the big-data at cloud computation needs algorithms which can handle high computational complexity. Watermarking has many applications like content authentication, copy right protection, source tracing application and traitor tracing.

The main objective of this paper is to propose hybrid architecture for reversible watermarking for enhanced analysis of the algorithm in terms of processing units used, area consumed etc. In this paper, two level Haar wavelet based wavelet transform is used for reversible watermarking algorithm and the electronic patient record (EPR) is embedded in an image along with a secure key. The key used here is the Aadhar number of the patient. At the receiver side, there is a need to recover the medical image without loss, because small distortion or changes lead to wrong diagnosis. This lossless information hiding and retrieving is called as Reversible Watermarking. Reversible watermarking technique should attain,

1) More Imperceptibility - Transparency,
2) More Robustness - Resilient against wide range of intentional and unintentional attacks,
3) Less Payload Capacity - Larger the capacity of watermark, greater the compromise with fidelity of image.
4) Reversibility - Intactness of Region of Interest.
5) Low computational cost.

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Since the emergence of big data and cloud applications involving more images to be analyzed in less time and low computational cost, recently many authors have presented their work in the domain of real time image processing. The work depicted in (Anoop Suraj et al., 2014) proposes to implement two level DWT based image fusion and denoising in FPGA using Daubechies wavelet. His objective is to improvise the algorithm for real time applications. DWT supports acceptable value of tolerable degradation and supports scalability. A three level Haar wavelet based Wavelet Transform is used embed a binary watermark image in selected coefficient blocks (Yahya AL-Nabhani et.al., 2015). A probabilistic neural network is used to extract the watermark image. Experimental results reveal that the proposed watermarking algorithm yields watermarked images with superior imperceptibility and robustness to common attacks, such as JPEG compression, rotation, Gaussian noise, cropping, and median filter.

A architecture is proposed based on discrete wavelet transform stressed on more Transperency (Mohamed Ali Hajjaji et. al., 2019). A blind watermarking system based on Fast Discrete Curvlet Transform (FDCuT) and Discrete Cosine Transforms (DCT) is proposed in (Rohit Thanki et. al., 2017). To get different sub bands such as LF MF and HF, FDCuT is applied on the medical image. FDCuT is used in the proposed system because it represents the image in terms of edges and also provides better imperceptibility. Watermarked image is generated by applying block wise DCT to HF sub band and inserting two White Gaussian Noise sequences to mid band frequencies.

Reversible watermarking (RW) is has introduced with Prediction Error expansion (PEE) that ensures higher embedding capacity with low imperceptibility (Hirak kumar et.al., 2014). As different types of images and region behaves in different ways during embedding. Image is partitioned into smooth, edge and texture using adaptive thresholding. These threshold values are calculated using different fuzzy conditional entropy algorithm. RW scheme works on local characteristics of an image and multiple predictors are used for enhancing the embedding rate. MED predictor is used for edge and texture region, GAP predictor is used for smooth region.

A paper (Jose Juan Garcia-Hernandez et.al., 2016) mainly focuses on the study of Breast Ultrasound (BUS) for the detection of breast cancer in women. Paper deals with the comparison of two watermarking approaches, spread spectrum based on the discrete cosine transform (SS-DCT) and the high-capacity data-hiding (HCDH) algorithm. Medical images are main source of information for detecting and diagnosing diseases. Comparison based on the security, data hiding, quality and authenticity. After the analysis of result HCDH algorithm is recommended for the watermarking of medical images.

An invisible and robust watermarking technique is proposed in (P. Karthigaikumar et.al.,, 2011). Here FPGA is used as a controller for both data and signal operations which allows the capture of image and its processing. External memory module can be saved by using FPGA’s internal memeory, hence making it tamper proof or robust and computationaly fast (344 MHz). An extensive work is done in the field of edge detection for real time image processing using FPGA and other controllers. Disadvantage for this method is the implementation complexity using FPGA as controller is very high. A paper by (Saraju P. Mohanty et.al., 2003) provides the details about development of a hardware system which can insert both robust and fragile invisible watermark. Hardware implementation has advantages over software implementation in terms of low power, high performance and reliability. To develop secure JPEG encoder the hardware module incorporated in JPEG encoder. Watermark module is implemented using 0.13µ CMOS technology.

The remaining part of the paper is organized as follows. Section 2 provides the details of material and methods used for the purpose of experimentation. Section 4 discusses the experimental results and Section 5 gives the conclusion.

Materials and Methods

This section discusses the basics of discrete wavelet transform using two level Haar wavelet and different wavelet operations.

Wavelet Transforms

Wavelets are the little waves used for extracting time and frequency content of a signal. Advantage of wavelets is wide range of wavelets available based on different application. Haar wavelet, Morlet

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wavelet, Daubechies, Coiflets, Bi orthogonal, Mexican Hat, Symplets are few well known wavelets. Fourier transform is a powerful tool for data analysis. But it fails to analyze the abrupt changes present in a signal or image efficiently. Since Fourier transform represent data in sum of sine waves which are not localized in time or space. Discrete wavelet transform is a mathematical tool used to decompose a signal or image into its constituent high and low frequencies. In this paper we concentrate on the compression property of the Haar wavelet which is to be used in the digital reversible watermarking application. Image compression is the representation of image in digital form with less number of bits. The remaining bits can be used to store watermark onto cover image. Let us consider two important wavelet transform concepts involved in application of wavelets to any signal or image,

a) Scaling: Let us consider signal Sci(t). Scaling refers to stretching and shrinking of signal in time *t* with *s* is positive value which corresponds to how much the signal is scales in time *t*.

$$\psi\left(\frac{t}{s}\right); where\ s > 0 \qquad (1)$$

Scale factor is inversely proportional to frequency with Centre frequency as proportionality constant. This is because unlike the sine wave wavelet has band pass character in frequency domain. Mathematically equivalent frequency is defined using the equation (2),

$$F_{eq} = \frac{C_f}{s}\ \delta t \qquad (2)$$

where, C_f is Center Frequency
s is wavelet scale
δt is sampling interval

When you scale a signal by a factor of two it reduces the frequency by an octave. Larger scale factor ($s > 1$) results in a stretched wavelet which represents low frequency. Smaller scale factor ($0 < s < 1$) results to shrunken wavelets which correspond to high frequency. Hence a stretched wavelet helps to capture slowly varying changes in signal and shrunken wavelet to help to capture abrupt changes of the signal or image. Table 1 shows the corresponding scaling value and equivalent frequency reduction,

b) Shifting (Φ): Shifting corresponds to delaying or advancing the wavelets along the length of signal. Shifted wave can be expressed in equation (3)

$$\Phi(\mathrm{t} - \mathrm{k}) \qquad (3)$$

Where *t* depicts time period & *k* indicates translation co-efficient

Scaling and Translation in DWT

The base scale in DWT is set to 2. We can increase the scaling factor by a integer value as shown in equation (4),

$$2^j; where\ j = 1, 2, 3, 4, \ldots \ldots .. \qquad (4)$$

Similarly, Translation can be represented by an integer multiplication as shown in equation (5),

$$2^j m; where\ m = 1, 2, 3, 4, \ldots \ldots .. \qquad (5)$$

This process is called as dyadic scaling and shifting. This kind of sampling eliminates redundancy in coefficients. Output of transforms results in same no of co-efficient as length of input signal. Hence it requires less memory.

DWT of image using Haar Wavelet

Given a signal s, in the first level of decomposition, the signal is first filtered with a high pass and low pass filter to yield high pass and low pass sub bands. Let's refer these as H1 and L1. According to Nyquist criterion half of the sub bands are discarded by filtering operation. Next level of low pass sub band L1 iteratively filtered by same technique to yield narrower sub bands H2 and L2.

Proposed hybrid architecture implementation

In this paper, DWT is applied to cover image and watermark image for the insertion of watermark. For the insertion of secure key in the watermarked image FPGA is used as controller. UART is used as communication protocol for transmission and reception of image. Fig.3. shows Watermarking embedding block diagram. Table 2 shows the different functions in the architecture, their technical specification and target device.

We have applied a two level Haar wavelet based discrete wavelet transform on cover image and watermark image. Watermarking is done using alpha blending technique as given in below,

$$WM = WC1 + WC2 \qquad (6)$$

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Where, $WC1$ & $WC2$ are watermark components given by,
$WC1$ = Scaling factor * low level frequency components of cover image.
$WC2$ = scaling factor * low level frequency of watermark image.
For secure key insertion FPGA is used as ASIC in the hybrid process of watermarking. The same is done using MATLAB in simulation results. UART communication protocol is used to establish communication between FPGA & UART, and to display the resultant images in structured manner we used GUI.

Baud Rate Generator Calculations for UART

Bits per second are termed as Baud rate. Baud rate generator module implemented using Verilog HDL generates a sampling signal whose frequency is 16 times the designated baud rate. Let us consider serial communication with 1,15,200 baud rate, the sampling rate has to be 1,15,200*16 clk/ticks/sec. Since the Altera FPGA has an onboard clock generator with clock rate 50 MHz, the baud rate generator needs a mod-27 counter to generate required baud rate, in which the one-clock-cycle tick is asserted once every 27 clock cycles. The calculation is shown in equation (7).

$$counter = \frac{50MHz}{(16\times115200)} \tag{7}$$

Results and Discussion

To assess the effectiveness of the proposed architecture, a series of experiments are conducted on brain CT images of 256x256 pixel size. This section compares the different results from MATLAB on CPU and Altera FPGA along with CPU.
Steps for watermarked image:

1) Initially the original image is transformed using Haar wavelet transformation.
2) The same process is used for an watermark which contain the Electronic Patient Record.
3) The EPR is collected in the Java applets based forms and then made an water image. We can add the other information such as logo of the hospital, doctor name and credentials etc.
4) The watermark is added to cover image using 2 level Haar wavelet transform.
5) Lastly, IWT is applied on the resultant image of addition of watermark in original image.

Thus we obtained the final watermarked image along with SNR as shown in Fig 4.
Peak Signal to noise ratio (PSNR) of cover image before water embedding is given in comparison with after addition of watermark is shown in Table 3. Comparison shows there is a allowed change in a PSNR of watermarked image. The expected PSNR for the resultant image is 46.078dB but after addition of watermark the PSNR is 44.042 dB.

FPGA based secure key insertion

In this section Aadhar number (16 digit) is inserted as secure key insertion into watermarked image is implemented by sending the watermarked image to FPGA using UART serial communication. As shown in fig. 5, the watermarked medical image which is transformed using Haar wavelet transformation is taken. Then pixels are selected from region of non-interest (RONI) from the watermarked image. The RONI image of the original image is transferred to the FPGA for adding the secret code. After adding the secure key the processed image pixels is returned in watermarked image. Therefore the processed image pixels are attached to the original image. In this order watermarked image is obtained. Signal to noise ratio (SNR) is calculated from original image and watermarked image.
Figure 6. shows the Register Transfer Level of the design implmented in FPGA using Verilog. Different blocks in the RTL design are,
A1: Baud generator module
A2: uart_xx module
A3: d latch module
A4: uart_tx module
All modules are also tested by writing testcases in verilog and observing simulation results and then integrated.
As comparing PSNR of both images from Table 4, there is small change in a PSNR of watermarked image. The expected PSNR for the resultant image is 46.078 dB but after addition of watermark into the image the SNR is 44.054 dB. Corresponding SNR values is also given in the Table 4.

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Conclusions

In this paper, the Aadhar number of 16 digits is inserted in the watermarked image as security key increasing the robustness of the system. Also secure key insertion can be used as Application Specific Integrated Circuit (ASIC) application. We can transmit image via network and separately send the key based on requirement. Since alpha embedding technique uses the low frequency components for watermarking, the watermarked image will be perceptible in nature. The experimental results have shown that the proposed architecture provides robustness with low computational complexity. In Future work, focus will be on enhancing the speed of communication by using fast communication protocols and also reducing the communication overhead.

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Table 1. Scaling value and equivalent frequency

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Wavelet Scale	2	4	8	16
Equivalent Freq (F_{eq})	$F_{eq}/2$	$F_{eq}/4$	$F_{eq}/8$	$F_{eq}/16$

Table 2. Processes and their target device

Functions	Specifications	Target
Storage of medical image	256*256 DICOM image.	CPU
Pre-processing	Get file, resize, typecasting.	CPU
Apply 2 level Haar wavelets based DWT algorithm.	Cover image watermarking using EPR image as watermark.	CPU
Calculate SNR, PSNR	For comparing results	CPU
Communication between FPGA & processor.	Using UART communication protocol.	FPGA
Secure key embedding.	16 bit digit used as security key	FPGA

Table 3. SNR & PSNR after watermark addition

Type of Image	SNR (in dB)	PSNR (in dB)
Cover Image	13.0238	46.078
Watermarked Image	12.8679	44.042

Table 4. SNR & PSNR after addition of secure key

Type of Image	SNR (in dB)	PSNR (in dB)
Watermarked Image	13.0238	46.078
Image after secure key insertion	12.8806	44.054

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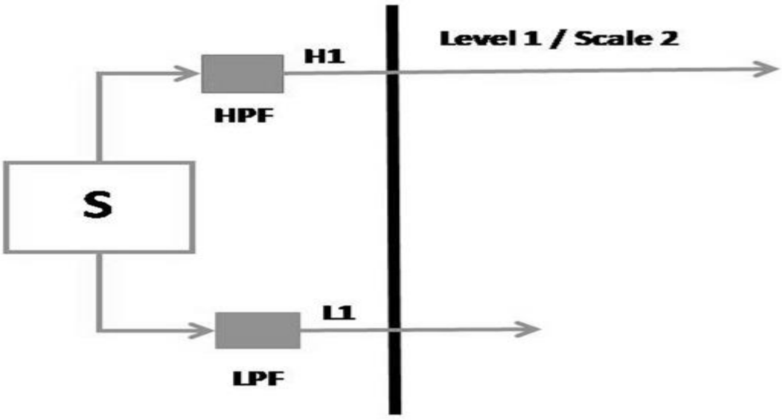

Figure 1. First level of Decomposition

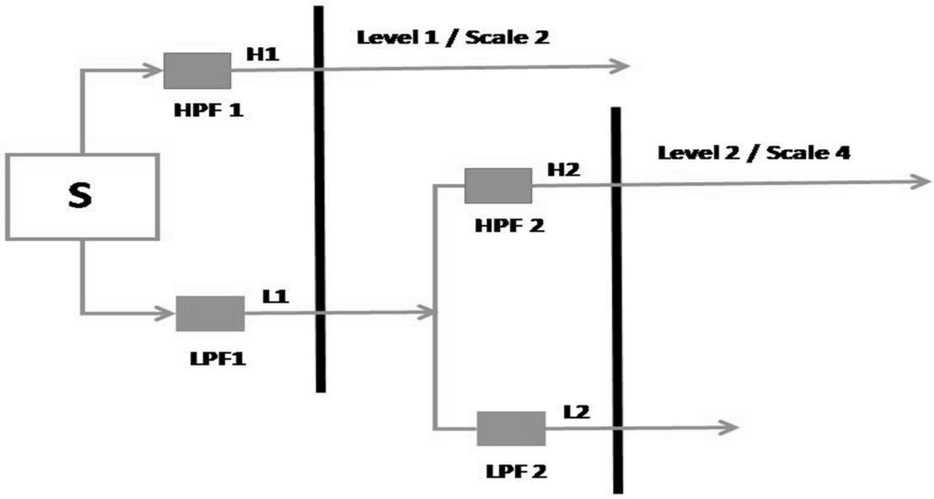

Figure 2. Second level of Decomposition

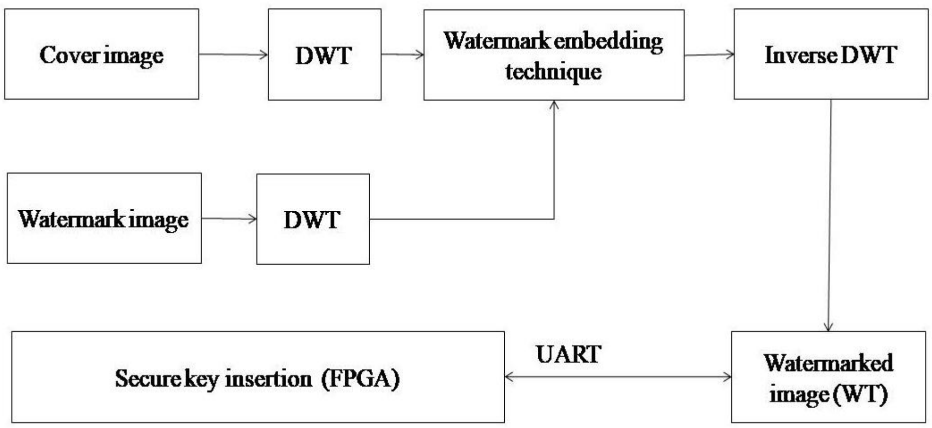

Figure 3. Embedding block diagram

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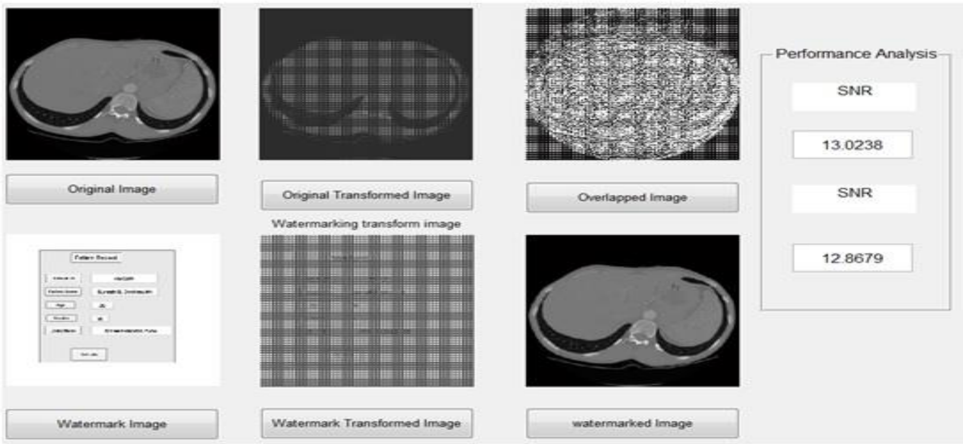

Figure 4. Watermarking using EPR Image

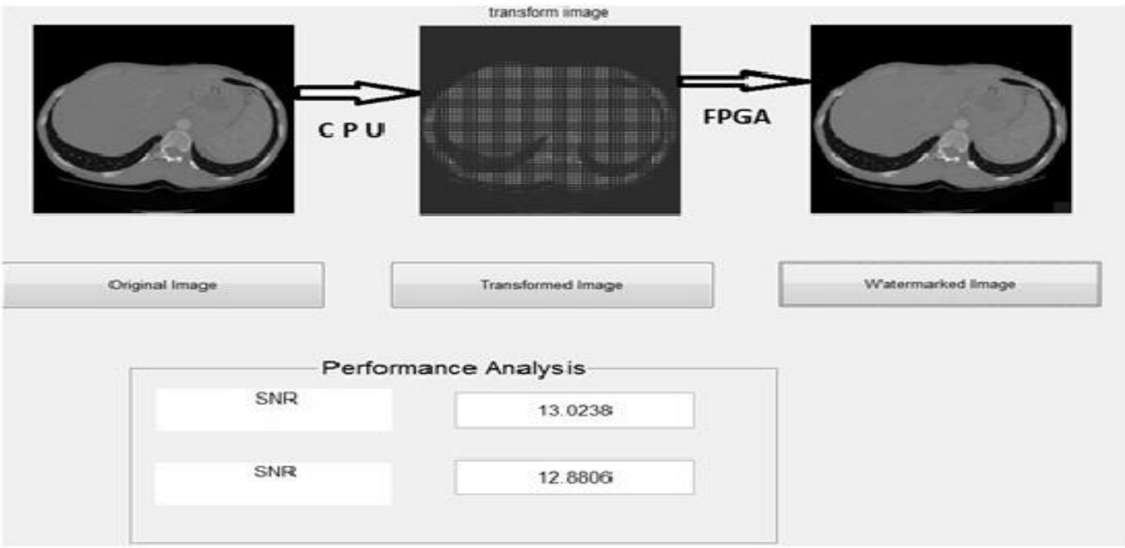

Figure 5. Watermarking implmentation using hybrid architecture

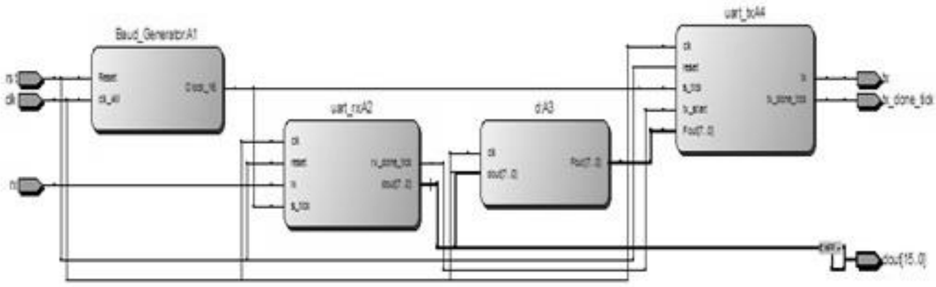

Figure 6. RTL View of secure key insertion module of the Watermarking system

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