FPGA PROTOTYPE OF ROBUST WATERMARKING JPEG2000 ENCODER

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Abstract**—** In this paper we have presented a novel hardware for watermarking which can be used with the loss less JPEG2000 compression standard. The aim of hardware assisted watermarking is to achieve low power usage, real-time performance, reliability, and ease of integration with existing consumer electronic devices. We have implemented CDF5/3 wavelet filters with lifting scheme which requires less hardware and they are also the basis of lossless JPEG2000. The experimental result shows that the proposed scheme of watermarking is robust against most of the geometric attacks scaling and rotation.

Keywords**—** Watermarking, FPGA, CDF 5/3, JPEG2000

I. INTRODUCTION

The fast development of the internet and rapid emergence of multimedia applications in the past decade gave rise to the new set of problems like *digital piracy*: illegal copying, use, and distribution of copyrighted digital data. The digital form of audio, images, and video has become the commercial standard in the past decade. Digitalized multimedia can be easily created, copied, processed, stored, and distributed using freely available software [1].

This needs the gives rise to the new technology of hiding the information in the digital content which is called as watermarking. Watermarking technique for paper manufacturing have been in use since the middle ages, same concept was adopted by digital world and extended this concept for digital images, video and music. Watermarking is the process that embeds the informed signal called as watermark into multimedia object such as image for authentication and protecting ownership rights [3].

Watermarking techniques can be divided into various categories in numerous ways. According to human perception, the digital watermarking can divided into visible [2] and invisible watermarking [6][7].On the basis of performance against various attacks watermarking techniques can be divided into invisible fragile[16] or robust watermarking [7].

The watermarking methods can be divided into three primary methods depending on the insertion and extraction domain used for watermarking. These are spatial domain, transform domain and color space methods. The spatial domain method [4] involves an algorithm that directly operates on the pixel values of the host image. It is been observed that the spatial domain watermarks are weaker than the frequency domain watermarking methods [5]. However the spatial domain watermarking scheme requires less computations compared to frequency domain scheme.

In the transform domain method the pixel values are transformed into another domain by applying appropriate transform technique like discrete cosine transform (DCT) [6][8][9],discrete wavelet transform (DWT) [7] and discrete Hadamard transform(DHT) [11]. A watermark is then embedded by modifying these coefficients. A DCT based watermarking algorithms described in many literatures; however DWT based watermarking algorithms are more effective for several reasons [12].

Wavelet is a small wave whose energy is concentrated in time and still possesses the periodic characteristics. An arbitrary signal can be analyzed in terms of scaling and translation of a single mother wavelet function. Properties of wavelet allows both time and frequency analysis of signals simultaneously. They offer excellent space-frequency localization of salient image features such as textures and edges. DWT can analyze the data in different scales and resolutions this principal is called as multi-resolution analysis [13]. Its characteristics well suited for image watermarking which includes the ability to take into account of human visual system's (HVS) characteristics. It is also a basis of a compression standard JPEG2000 [15] and MPEG-4[14].

The new still compression image standard, JPEG2000 has emerged with a number of significant features that would allow it to be used efficiently over a wide variety of images. The JPEG2000 standard exhibits a lot of features, the most significant being the possibility to define regions of interest in an image, the spatial and SNR scalability, the error resilience and the possibility of intellectual property rights protection. Interestingly enough, all these features are incorporated within a unified algorithm. This compression standard uses the Cohen-Daubechies-Favreau (CDF) 5/3 and CDF 9/7 DWT for lossless and lossy image compression respectively. Since JPEG2000 (1) is the newest version of one of the most popular

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image formats and it includes the DWT, efficient VLSI implementations of DWT processors became more and more important.

II. Related work

There are several software based watermarking scheme are available in literatures [6][7][8]. The image is capture and watermark is embedded in image offline; but there is gap between the capturing image and inserting the watermark. In opposite to software solutions, hardware implementations offer an optimized specific design to incorporate small, fast and potentially cheap watermarking solutions. A hardware based watermarking unit can be easily integrated with digital cameras and graphics processing units. Watermarking unit consumes lesser power than software, which requires a general purpose processor. Hardware based watermarking unit are ideal for battery operated applications. The hardware based watermarking scheme has been presented in following literatures.

Basu and Das presented a spatial domain watermarking scheme is proposed in [17]. The watermarking algorithm uses binary image as the watermark. The watermark is inserted in gray scale image using least significant bit (LSB) modulation. Performance evaluation against various attacks of the watermarking scheme is not discussed. The algorithm was implemented on Xilinx Virtex II technology.

In [18] ASIC is implemented using 0.13µm technology for watermarking. The scheme describes invisible-fragile watermarking in spatial domain. The differential error is encrypted and interleaved along the first sample. The watermark can be extracted by accumulating the consecutive LSBs of pixels and then decrypting. The extracted watermark is then compared with the original watermark for image authentication.

Mohanty et al. [19] have proposed two visible watermarking scheme and their hardware architectures. Both watermarking schemes embed visible watermarks in images in the spatial domain. In the first algorithm the watermarked image is obtained by adding a scaled gray value of the watermark image to the host image. In the second algorithm the pixel gray values are modified based on local and global statistics. This architecture can insert either of the two watermarks depending on the requirements of the user. The ASIC is implemented on 0.35µm technology operated at 3.3V and 292.27MHz.

An FPGA prototype of biometric watermarking or security scheme is described in [20]. In this scheme the original image is divided into 8×8 blocks and DCT is performed for each block. The biometric image (watermark) is divided into blocks and embedded into perceptually significant regions; original image is requires for watermark detection. This prototype was implemented in VHDL and synthesized using Xilinx Virtex II technology.

Mohanty [21] proposed a novel algorithm for encrypted watermarking based on block-wise DCT. This algorithm converts RGB color space into YCbCr color space; the Y component is used for watermarking. The architecture was modeled using VHDL and synthesized using Virtex II technology.

In this paper we have presented a watermarking scheme using the CDF 5/3 wavelet filter which can be incorporated with JPEG2000 lossless image compression. Hardware architecture was implemented on FPGA. The proposed scheme is an invisible robust wavelet domain watermarking method. The scheme described in [22] is used for implementing CDF5/3 filters. The proposed architecture uses the lifting scheme technique and provides advantages that include small memory requirements, fixed-point arithmetic implementation, and a small number of arithmetic computations. The chip was modeled using Verilog and a function simulation was performed. This chip was tested using AccelDSP in a hardware in the loop (HIL) arrangement. The proposed scheme is robust against several geometric attacks. We have tested our watermarking scheme using standard benchmark such as StirMark software.

III. CDF 5/3 Filters

The lifting scheme calculates the DWT using spatial domain analysis, and consists of a series of *Split*, *Predict* and *Update* steps. The split step separates odd and even samples, and the predict step predicts values in the odd set, as follows: where α= -0.5 as the predict step coefficient. The Update step uses the new wavelet coefficients in the odd set to update the even set producing “smooth” or “scaling” coefficients: where β=0.25 as the update step coefficient. Lifting operation for the CDF 5/3 synthesis filter is shown in Figure 1. The inverse DWT using the lifting scheme is symmetrical and therefore performed by reversing the lifting steps in the forward DWT. In predict step multiplication by 0.5 is replaced by single right-shift operation and a subtractor. In update step multiplication by 0.25 is replaced two right-shift operation and addition. The number of multiplications and additions compared to the filter-bank implementation are reduced resulting in more efficient use of power and chip area. Its modular structure is well suitable for hardware implementation.

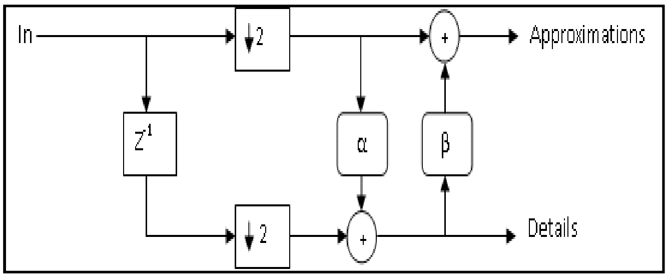

Figure1.CDF 5/3 filter with lifting scheme

IV. Proposed Watermarking Scheme and Hardware Architecture

In this section we have described a simple invisible watermarking scheme and its hardware. The following notations are used. The watermarking algorithm implements same multiple watermarks in image. The original image I is divided into non-overlapping blocks of size B×B. Wavelet transform is calculated for block separately. A binary watermark is embedded into cover image using equation (1).

$$I_{W,N}\ (x,y)= I_N\ (x,y)+K \times W(x,y) \quad (1)$$

$I_{W,N}$ is the N[th] block of the watermarked image ;K is gain, W is a binary watermark logo. x and y are index numbers. In each block of B×B one watermark is implemented. The watermarking chip mainly consists of a block processing unit and control.

A. Block Processing Unit

The block processing unit considers the original image block as input. Image block is wavelet transformed and the watermark is embedded using equation (1). consists of CDF5/3 wavelet filters and watermarking unit. To meet the real time constrain, we have used two filters in parallel to calculate forward and inverse transform. In order to calculate the 2D wavelet, these filters first calculate the coefficients first row-wise and then column-wise. The intermediate results are stored in the memory. Inverse wavelet is calculated in similar manner.

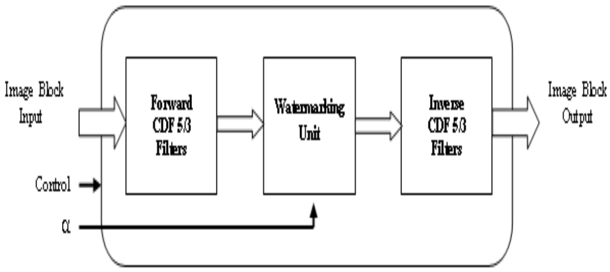

Figure2. Block diagram of block processing unit

B. Watermarking Unit

The watermarking unit consists of a multiplier and adder. The watermark is embedded using equation (1). Because a multiplier requires more hardware, only one multiplier is implemented. The wavelet transformed block is fed serially to the watermarking unit. The gain is multiplied by watermark and added to the wavelet transformed coefficients. The intermediate results are stored in the memory. The control unit generates the necessary control signals for the entire system during the watermarking process. The control unit generates four main signals and these signal are as follows

C. Control Unit

The control unit generates the necessary control signals for the entire system during the watermarking process. The control unit generates four main signals and these signal are as follows

INPUT_AVIL: Image block is available at input.
OUTPUT_AVIL: Watermarked image block is available at output
CLOCK : Clock signal for chip
CLOCK_ENABLE: When clock enable is high chip is in a active mode for processing

This unit undergoes seven states in each state; the particular task is performed in each state and the finite state machine (FSM) begins to the next state. Figure (3) shows the state diagram of FSM.

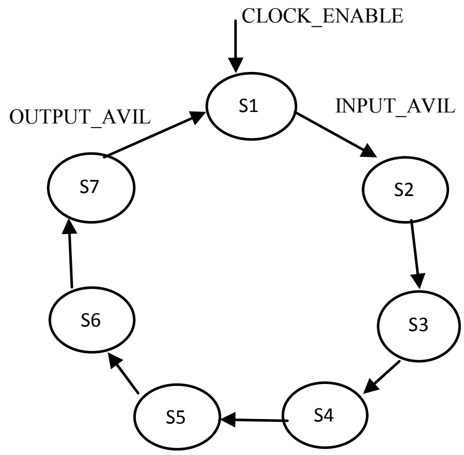

Figure3. Watermarking unit

D. Watermark Detection

The watermark detection algorithm is implemented using MatLab. The watermark can be detected using two methods blind and non-blind. Original and watermarked image both are required to detect a watermark. The suspected image and original image are divided into B×B blocks, and DWT coefficients are calculated for both images. The watermark is recovered using equation (4).

$$W(i,j)=\begin{cases}1 & \text{if } I_{W,N}(x,y)-I_N(x,y) > \tau \\ 0 & \text{other wise}\end{cases} \quad (4)$$

τ represents threshold for blind detection
In the blind watermark detection method the suspected image is divided into B×B blocks, and DWT coefficients are calculated. The correlation between encrypted watermark and wavelet transformed block is calculated using equation (5)

(5)

If γ> ρ then the watermark is detected. ρ is threshold for blind detection

V. Experimental Results

A. Synthesis and Implementation

The chip was modeled using a Verilog and functional simulation was performed. The code was synthesized on Xilinx Spartan-3A technology on XC3SD1800A-4FGG676C device using the AccelDSP. The results are verified by the hardware in the loop configuration using AccelDSP. The HIL was run at 33.3 MHz clock frequency, and the samples were fed to the target device at a rate of 319.585 Ksps through a JTAG USB cable. The design utilizes 2 startup clock cycles and single clock cycles per function call. The device utilization summary is given in Table 1.

Logic	Used	Available
Number of Slices	628	16640
Number of Slice Flip Flops	290	33280
Number of 4 input LUTs	1077	33280
Number of bonded IOBs	293	309
Number of GCLKs	1	24

Table 1. Device utilization summary

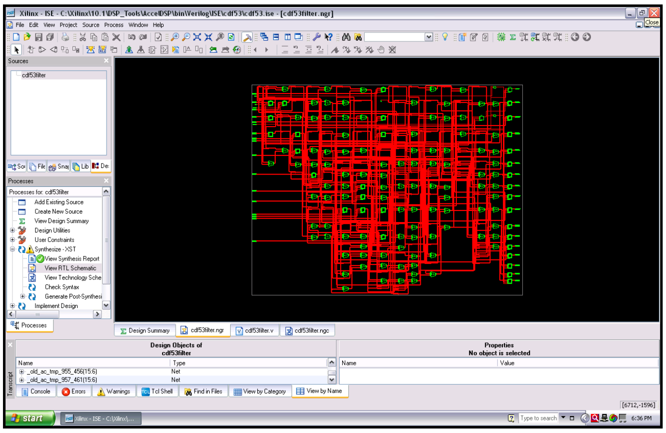

Figure 4. RTL of watermarking chip

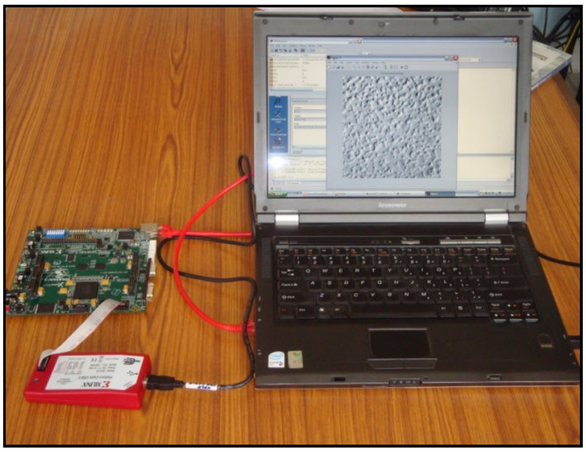

Figure 5. Hardware in the loop test

B. Image Performance Evaluations on Various Attacks

In this section, we evaluate the performance of the watermarking algorithm against various attacks using standard bench mark software. StirMark is the one of the earliest benchmark software. The StirMark software includes several attacks such as compression geometric transformation, noise addition etc. The geometric attacks includes rotation, cropping, scaling and geometric transformation with medium compression. Some of the results of these evaluations are summarized in Table 2. These results indicate that the proposed watermarking scheme is robust against the geometric attacks.

The proposed scheme of watermarking embeds multiple watermarks in cover image. The objective was, at least a single watermark will survive after attacks. In detection algorithm all the watermarks are detected, and the watermark which is having highest correlation with the original watermark is treated as the recovered watermark. As scheme implements several watermark in the cover image, due to which scheme is robust against various geometric attacks.

C. Image Quality Measures

In [25] Kutter and Petitcolas have discussed various parameters to estimate any watermarking scheme. For fair benchmarking and performance evaluation, the visual degradation due to embedding is an important issue. Most distortion measure (quality metrics) used in visual information processing belongs to a group of difference distortion measures. The watermark images are acceptable to the human visual system if the distortion introduced due to watermarking is less.

The various performance evaluations metrics such as PSNR (dB), Image Fidelity (IF), Normalized cross correlation, correlation quality etc. are calculated. Results for few popular images are given in Table 2.

Quality Measures	Lena	Wood	Grass
Mean square error	1.74	1.73	1.70
PSNR	45.70	45.70	45.70
Normalized cross correlation	1	1	1
Average Difference	-0.50	-0.49	-0.50
Structural content	0.99	0.99	0.99
Maximum difference	1	1	1
Normalized absolute error	0.01	0.007	0.01
Image Fidelity	1	1	1
correlation quality	1	1	1

VI. Conclusion

In this paper, we proposed a novel image adaptive invisible watermarking algorithm and developed efficient the hardware architecture which can be used with lossless JPEG2000. The watermarking scheme utilizes minimal hardware resources as it can be seen from the device utilization summary table. Because of the lifting scheme is used in CDF 5/3 filters it requires minimum hardware and it requires less clock cycles. The experimental results showed that the proposed scheme of watermarking scheme is imperceptible and robust against geometric attacks. The proposed algorithm outperforms than the watermarking scheme described[17][21.]This was achieved because of space and frequency localizing property that is the characteristics of the discrete wavelet transform.

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