Design and Implementation of Effective Architecture for Reversible Watermarking using FPGA

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***Abstract*—The expansion of the Internet has frequently increased the availability of digital data such as images, audio and videos to the public & it is effortlessly duplicated & even manipulated. Digital watermarking is a technology being developed to ensure and facilitate data authentication, security and copyright protection of digital media. This paper focuses on the design and implementation of a fast FPGA (Field Programmable Gate Array) based architecture using discrete cosine transform (DCT) based image watermarking algorithm. The schematic based design and implementation of the VLSI architecture is done with Xilinx on Spartan 3E FPGA family. Security level offered by the watermarking techniques based on hardware is higher than the software based watermarking techniques. In hardware watermarking implementation, the data is untouched by an external party. The results show the viability of less Area, high speed & improve the clarity of the watermarked image.**

***Index terms*- VLSI Architecture, Watermarking, FPGA, DCT.**

I. INTRODUCTION

The use of internet growing faster day to day and the need to display multimedia contents on the internet become necessary. Intellectual property right; documents are not fast information but property. YouTube, face book, Torrents, pirate bay such other video, audio, image, documents resource websites are now became water and food for youngsters across the globe so it is necessary to protect the rights of authors. So, digital protection is necessary and in-evitable. There are many popular techniques for this such as Steganography, Digital signature, Fingerprinting, cryptography and Digital watermarking but Digital watermarking is proved best out of them. The protection of intellectual property has become a major problem in the digital age.

The ease of copying digital information without any loss of quality violates the conservation of mass property of traditional media, which inhibited wide global distribution in the past. On the Internet today, it is possible to duplicate digital information a million-fold and distribute it over the entire world in seconds. [1] These issues worry creators of intellectual property to the point that they do not even consider to publish on the Internet. More information is transmitted in a digital format now than ever, and the growth in this trend cannot be estimated in the future. Digital information is susceptible to be copied at the same quality as the original. [2]

Digital watermarking is that technology that provides and ensures security, data authentication and copyright protection to the digital media. “Digital watermarking” is the embedding of signal, secret information (i.e. Watermark) into the digital media such as image, audio and video. Later the embedded information is detected and extracted out to reveal the real owner/identity of the digital media. For some critical applications such as the law enforcement, medical and military image system, it is crucial to restore the original image without any distortions. The watermarking techniques satisfying those requirements are referred to as ‘reversible watermarking’. [1] It is designed so that it can be removed to completely restore the original image.

II. WATERMARKING TECHNIQUES

Digital image watermarking schemes mainly fall into two broad categories:
(1) Spatial Domain Watermarking Techniques
(2) Frequency Domain Watermarking Techniques

(1) Spatial Domain Watermarking Techniques:

A spatial domain technique slightly modifies the pixels.[9] However, there must be trade-offs b/w invisibility & robustness, and it is hard to resist common image processing and noise. Some of the spatial domain modulation techniques are:

(a) Least Significant Bit (LSB):

Old popular technique embeds the watermark in the LSB of pixels. This method is easy to implement and does not generate serious distortion to the image; however, it is not very robust against attacks. The embedding of the watermark is performed choosing a subset of image pixels and substituting the least significant bit of each of the chosen pixels with watermark bits. [9] But these primitive techniques are vulnerable to attacks and the watermark can be easily destroyed. Such an approach is very sensitive to noise and common signal processing and cannot be used in practical applications.

(b) Spread Spectrum Method (SSM):

Spread-spectrum techniques are methods in which energy generated at one or more discrete frequencies is deliberately spread or distributed in time.[9] SSM based watermarking algorithms embed information by linearly combining the host image with a small pseudo noise signal that is modulated by the embedded watermark.

(2) Frequency Domain Watermarking Techniques:

Compared to spatial domain methods, frequency domain methods are more widely applied. In frequency domain, the characteristics of the HVS are better captured by the spectral coefficients. To obtain a balance between imperceptibility and robustness, most watermark algorithms are embedded in the midrange frequencies. The most commonly used transforms are:

(a) Discrete cosine transforms (DCT):

DCT like a Fourier Transform, it represents data in terms of frequency space rather than an amplitude space. This is useful because that corresponds more to the way humans perceive light, so that the part that are not perceived can be identified and thrown away. DCT based watermarking techniques are robust compared to spatial domain techniques. Such algorithms are robust against simple image processing operations like low pass filtering, brightness and contrast adjustment, blurring etc. However, they are difficult to implement and are computationally more expensive. [10] At the same time they are weak against geometric attacks like rotation, scaling, cropping etc. DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. Embedding in the perceptually significant portion of the image has its own advantages because most compression schemes remove the perceptually insignificant portion of the image.

(b) Discrete Wavelet Transforms (DWT):

Wavelet Transform is a modern technique frequently used in digital image processing, compression, watermarking etc. The transforms are based on small waves, called wavelet, of varying frequency and limited duration. The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal. Hence wavelets reflect the anisotropic properties of HVS more precisely. Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, and HL). The Discrete Wavelet Transform (DWT) is currently used in a wide variety of signal processing applications, such as in audio and video compression, removal of noise in audio, and the simulation of wireless antenna distribution.[3] Wavelets have their energy concentrated in time and are well suited for the analysis of transient, time-varying signals. Since most of the real life signals encountered are time varying in nature, the Wavelet Transform suits many applications very well. One of the main challenges of the watermarking problem is to achieve a better trade-off between robustness and perceptivity.

III. PROPOSED ALGORITHM

The classic and still most popular domain for image processing is that of the Discrete-Cosine-transform, or DCT. The DCT allows an image to be broken up into different frequency bands, making it much easier to embed watermarking information into the middle frequency bands of an image. The middle frequency bands are chosen such that they have minimize they avoid the most visual important parts of the image (low frequencies) without over-exposing themselves to removal through compression and noise attacks (high frequencies).

The 1D_DCT transformation is given by the following equation:

$$C(u) = \mathrm{a(u)} \sum_{x=0}^{N-1} \mathrm{f(x)} \cos\left(\frac{\pi(2x+1)u}{2\mathrm{N}} \right) \qquad x = 0, 1, 2 \ldots N-1 \quad (1)$$

Similarly, the inverse transformation is defined as,

$$f(x) = \sum_{x=0}^{N-1} \mathrm{a(u)\ c(u)} \cos\left(\frac{\pi(2x+1)u}{2\mathrm{N}} \right) \qquad x = 0, 1, 2 \ldots N-1 \quad (2)$$

In both equations 1 and 2 a (u) is defined as, $\mathrm{a\ (u)} = \frac{\sqrt{x}}{N}$ for $u \neq 0$ and

$\mathrm{a\ (u)} = \frac{\sqrt{1}}{N}$ for u=0

It is clear that for u=0, $c(u = 0) = \frac{\sqrt{1}}{N} \sum_{x=0}^{N-1} \mathrm{f(x)}$

The first transform coefficient is the average value of the sample sequence.

The 2D_DCT transformation is given by the following equation:
This necessitates the extension of ideas presented in the last section to a two dimensional space. The 2-D DCT is a direct extension of the 1-D case and is given by

$$C(u,v) = \mathrm{a(u)a(v)} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} \mathrm{f(x,y)cos}\left(\frac{\pi(2x+1)u}{2\mathrm{N}}\right) \cos\left(\frac{\pi(2y+1)v}{2\mathrm{N}}\right) \quad (3)$$

Here, a (u) and a (v) are same as defined earlier part in equation 3. All other transform coefficients are called the AC Coefficients.

Inverse DCT is also defined as,

$$f(x,y) = \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} \mathrm{a(u)a(v)c(u,v)cos}\left(\frac{\pi(2x+1)u}{2\mathrm{N}}\right) \cos\left(\frac{\pi(2y+1)v}{2\mathrm{N}}\right) \quad (4)$$

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub bands) of differing importance (with respect to the image's visual quality).[9] The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain. A discrete cosine transform (DCT) expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of audio (e.g. MP3) and images (e.g. JPEG) (where small high-frequency components can be discarded), to spectral for the numerical solution of partial differential equations.[11] The use of cosine rather than sine functions is critical in these applications: for compression, it turns out that cosine functions are much more efficient (as described below, fewer are needed to approximate a typical signal), whereas for differential equations the cosines express a particular choice of boundary conditions. In this DCT algorithm we also use CSA adder instead of full adder to achieve reduced area and improved speed and Otsu's thresholding for the clarity of the input image.

Watermark embedding:

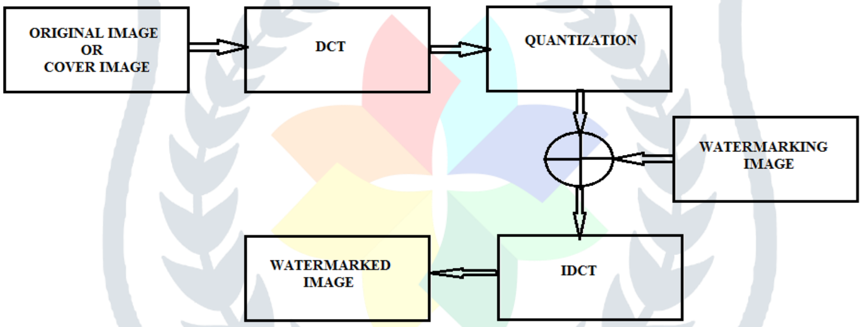

Fig. 1 Block diagram of watermark extraction

The Watermark embedding steps using this technique are following:
1. Read colour host image, 2. Convert RGB to YCbCr components, 3. Apply DCT, 4. Embed the watermark components in to the frequency subcomponents, 5. Apply IDCT, 6. Convert YCbCr to RGB, 7. Get watermarked image and 8. Check Authentication.

Watermark extraction:

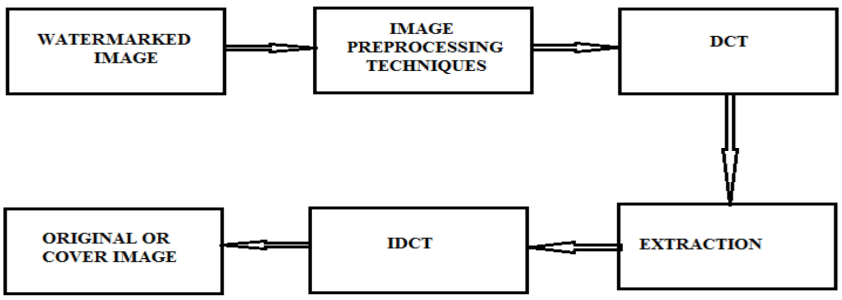

Fig. 2 Block diagram of watermark extraction

The Watermark extraction steps using this technique are following:
1. Read Watermarked image, 2. Convert RGB to YCbCr components, 3. Apply DCT, 4. Extract the watermark components from frequency subcomponents, 5. Convert YCbCr to RGB, 6. Get watermark image and 7. Check Authentication.

IV. ANALYSIS AND EXPERIMENTAL RESULTS

The watermark embedding block of watermarking system is simulated using Verilog language in Xilinx software. The simulation waveforms is shown in figure.

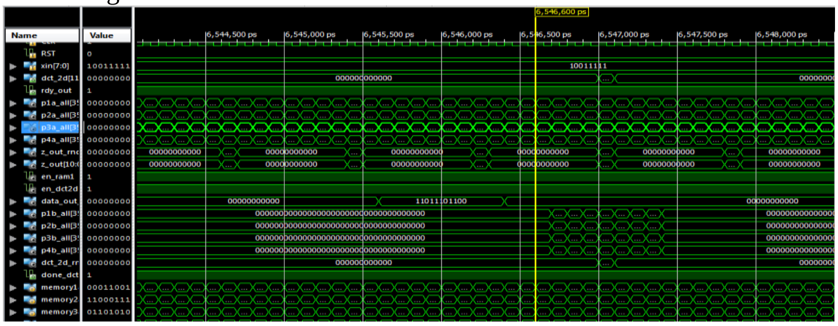

Fig. 3 waveforms of watermarking embedding

Synthesis report: device utilization comparison of DCT based proposed algorithm and RCM based technique [1].

TABLE 1: Device Utilization Summary

Logic Utilization	RCM technique[1]	Proposed algorithm(DCT)
No. of 4 input LUTs	528	392
No. of occupied slices	303	207
No. of bonded IOBs	230	17

V. CONCLUSION

This model is developed to reduce the computational complexity for the calculation of embedding and scaling factors which are used to improve the quality of the resultant image with respect to original image. A DCT module is used to calculate the DCT coefficient values of the host image and the watermark image, in order to minimize the resource utilization and power consumption in terms of area. The hardware implementation of this algorithm has numerous advantages such as reduced area and speed. The performance of the architecture is studied by implementing in Xilinx technology. In future we can also implement and design for reversible watermarking for getting original image.

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