A FUZZY LOGIC APPROACH TO ENCRYPTED WATERMARKING FOR STILL IMAGES IN WAVELET DOMAIN ON FPGA

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Abstract

In this paper a fuzzy logic approach is introduced to embed the encrypted watermark in the wavelet domain. The multi-resolution representation based on DWT incorporates a model of Human Visual System (HVS). Encryption and digital watermarking techniques need to be incorporated in digital right management. It is clear that these two technologies are complimenting each other, and the complete security of the digital contains depends on both. Encryption transforms the original contain into unreadable format and watermarking leaves the digital object intact and recognizable. The objective is to develop simple, real time and robust secure watermarking system, which can be achieved through the hardware implementation. To meet a real time constrain we have proposed parallel computing architecture for wavelet transform. The experimental results demonstrate the high robustness of the proposed algorithm to various attacks like noise additions etc

Keywords: DWT, Digital Watermarking, HVS, Fuzzy Logic, PN, FSM

1. Introduction

Digital right management is the collection of technologies and techniques that enables the licensing of the digital information. This includes the multimedia property like image, video, music etc.

The success in the digital revolution and internet introduces the new set of problems regarding security. The digital content providers are unwilling to distribute their multimedia content such as images over internet due to lack of security. Digital revolution provides tool to unlimited copying without fidelity loss [1].

Digital watermarking is defined as a process of informed signal (watermark) into multimedia content such as image to protect the owner's right to that content. Later watermark extracted from suspected image verified for the ownership identification [2].

For still digital images there are three primary methods for insertion and extraction of watermark. These are spatial domain methods, transform domain and color space methods. Spatial domain method [3] provides algorithm that directly operate on the pixel values of the of the host image. In the transform domain the pixel values are transformed into another domain by applying appropriate transform like DCT [4][5][6], DWT [7][8] etc. and then embedded a watermark by modifying these coefficients. But it is seen that the spatial domain watermarks are weaker than the frequency domain.

Human visual system (HVS) has been characterized with several phenomenon that permits to adjust the pixel values to elude perception. These phenomenon are luminance sensitivity, frequency sensitivity and texture sensitivity. The distortion visibility is very low if the back ground is with the high texture. In a high texture block, energy is more distributed among the pixel block. Therefore if the block having a stronger texture can be embed a signal with the larger gain and the block having low texture can be embedded with the less gain. This technique gives the benefits when host image is attacks such as by the JPEG compression.

The human visual model suggested in [9] and [10] are used to embed the watermark. This model describes the three properties of the human visual system like luminance sensitivity, texture sensitivity and frequency sensitivity. In the proposed scheme only texture sensitivity is considered which is very simple to calculate. The algorithm embeds the binary logo into host image as watermark. Fuzzy logic approach is used to estimate the optimal gain with a proper scaling factor so that the watermark remains imperceptible.

We have divided this paper in three sections first section is introduction and the background of watermarking. In the second section we have described the proposed scheme of watermarking and the hardware architecture for the same. Last section discusses the results of proposed watermarking algorithm and a conclusion.

2. Proposed Scheme for Watermarking

2.1. Algorithm for Watermark Insertion:-

In this section we described the invisible algorithm that is implemented in hardware**.** The following notations we are going to use throughout the paper

I -cover image, **BXB** – block size
$\mathbf{I_N}$ – nearest neighborhood, **w -** Original watermark
w*- encrypted watermark, **α** - Gain
β - Scaling factor, **K**-key to generate PN sequence

The original image **I** is divided into **BXB** non-overlapping blocks. Then wavelet transform is calculated by two parallel averaging and difference filter banks. The nearest neighborhood $\mathbf{I_N}$ is calculated for each wavelet transformed block by using equation (1). Simultaneously from original block the variance is calculated and the value of variance is feed to FIS block to calculate the gain.

$$I_{N,k}(i,j)=\frac{\frac{I_k(i+1,j)+I_k(i+1,j+1)}{2}+I_k(i,j+1)}{2} \qquad (1)$$

The binary image is used as watermark **w** for image. This binary watermark is encrypted using PN sequence generated by a known key **C.** This encrypted watermark is **w*** is actually embedded into the block by modifying the nearest neighborhood with the proper gain factor equation (2).

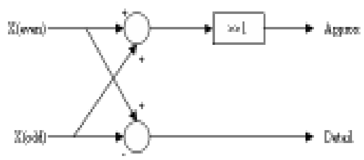
The I_N is modified by using the scaling function equation (3) and gain for the particular block is set by using the equation (4).

$$I_k*(i,j)=\begin{cases} I_k(i,j) & \text{if } W*(i,j)=1 \\ S(I_k(i,j),I_{N,k}(i,j)) & \text{if } W*(i,j)=0 \end{cases} \qquad (2)$$

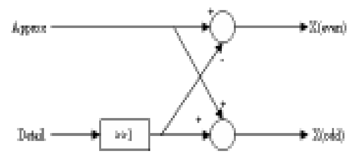
The encoding function 'S' define as follows

$$S(I_k, I_{N,k}) = (1-\alpha) I_{N,k}(i,j) + \alpha(I_k(i,j)) \quad (3)$$

Whe



$$D \times \beta \quad (4)$$



2.2. Architectural Design for Proposed Algorithm

In this section, hardware architecture for the watermarking encoder algorithm described. This encoder consists of watermark generation, control unit, FIS and block processing unit.

2.3. Block processing unit

Block processing unit consist of DWT calculation block, watermark embedding unit and IDWT calculation block.

2.2. DWT and IDWT Processor

The discrete wavelet transform is popular being a very effective signal analysis tool for many practical applications like image watermarking. DWT can analyze the data in different scales and resolutions this principal is called as multi-resolution analysis [11].

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 standards like JPEG2000 [13] and MPEG-4[12].

The DWT decomposes a signal into a lowpass and a highpass signals by using a pair of QMF filters and having mirror symmetry to Π/2 [14]. The lowpass signal is called as approximations and the highpass signal is called as details. The approximation sub signal shows the general trend of pixel values and other three detail sub signals show the vertical, horizontal and diagonal details or changes in the image.

In this algorithm we have used Haar wavelet which is the simplest type of wavelet [15]. Haar scaling function is given in equation_(5)

$$W_f(n) = \begin{cases} 1 & 0 \leq t \leq 1 \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

The advantages of Haar wavelet being used are less complexity of calculation which requires less hardware, memory efficient, fast and it is exactly reversible.

Haar transform performs an average and difference on a pair of values. Then the algorithm shifts over by two values and calculates another average and difference on the next pair. To meet the real-time constraint we have implemented such two filters pairs so that they act in parallel to calculate forward as well as inverse wavelet transform. To calculate the 2D wavelet these filters calculate the coefficients first row wise and then column wise similarly the inverse transform is calculated. The intermediate results are stored in temporary memory.

Figure 1. FDWT Processor

Figure 2. IDWT Processor

2.2.2. Watermark Generation

Watermark generation unit generates the necessary encryption watermarking bit. This block has two input key **C** and the watermarking bit. Block generates the PN sequence by using LFSR (Linear Feedback Shift Register) with known key **C.** The generated PN sequence and watermark bit is XOR sequentially to generate the encrypted bit. Watermark generation unit is shown in figure 3

2.2.3. Watermarking Insertion Unit

The figure 4 shows the watermark insertion unit. This unit calculates the NN of the LL band in a given block and inset the watermark by modifying the NN. Two adders and two right shift operations are used to calculate the NN. To modify the NN of the block the calculated NN and the I(i, j) is multiplied by scaling factor. These two quantities are added together to get modified value of I (i,j). According to equation (6) if the watermark bit is to select the modified value or not to change the value this operation is performed by 2:1 multiplexer.

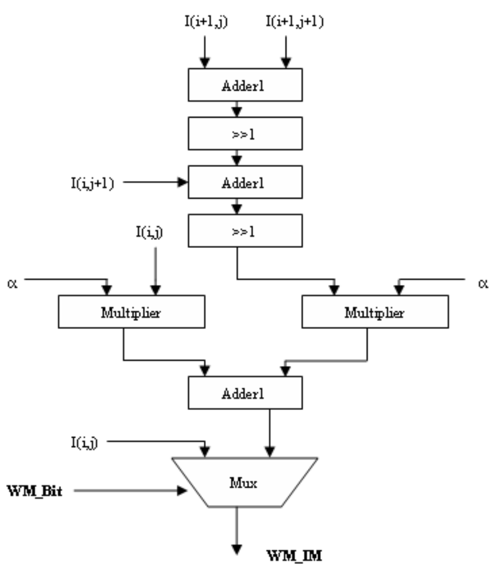


Figure 4. Watermark insertion unit

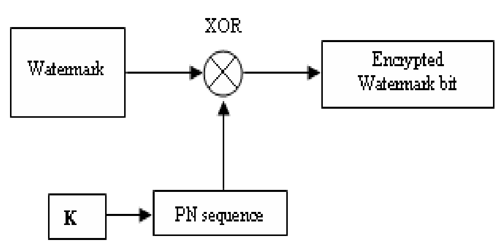


Figure 3. Encrypted Watermark Generation

2.2.4. FUZZY Interface System (FIS)

The human visual model used in his paper was suggested by in [7] and [8] and it employees the general form and break up into three different properties and these properties are luminance sensitivity, frequency sensitivity and texture sensitivity. In the proposed scheme we are considering texture sensitivity.

It is important to realize that this approach enables the texture sensitivity membership function to be adjusted in such a manner to best fit the image's properties. Each input is composed of three membership function based on the variance distributed among smooth, slightly rough and rough. The output of the FIS is gain factor for the particular block is based on the three membership function minimum, medium and maximum.

This block calculates the mean and the variance of the image block. The calculated variance is feed to the FIS. The fuzzy rules and the membership function were developed using intuitive logic and the characteristics of human visual system. These rules calculated corrected the amount of gain for the particular block. The following simple fuzzy rules illustrated are as follows

1. If the image block is smooth (low variance) then gain is minimum.
2. If the image block is slightly rough (medium variance) then gain is medium.
3. If the image block is rough (high variance) then gain is maximum.

The defuzzified output D, is calculated for the composite output set, using a volume defuzzification method by using equitation (8)

$$D = \frac{\sum_j Z_j V_j C_j}{\sum_j Z_j V_j} \qquad (6)$$

Where Vj and Cj are respectively volume and center of the consequent set of rules j, and Zj is the extent to which rule

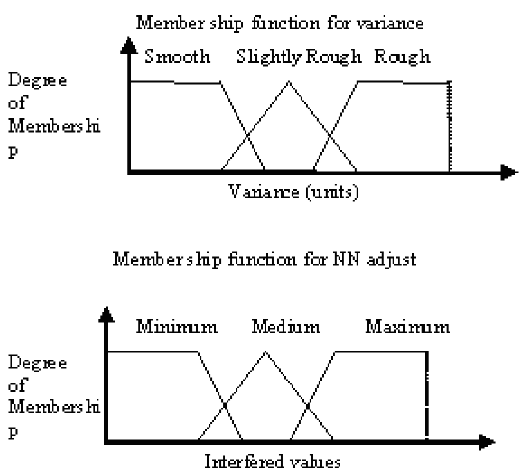


Figure 5. Membership Function

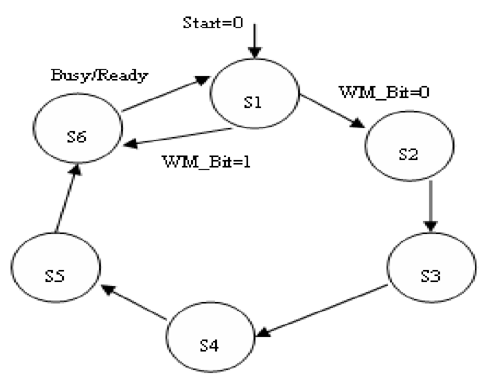


Figure 6. Control Unit

2.2.5. Control Unit

The control block generates the necessary control signals for the entire block during the watermarking process.

Figure 6 shows the control unit as FSM. Following are the control signal are given to the control block: start signal to start the watermarking processes block by block, **β** is a user defined gain control for watermarking process, key **C** is key is used to generate the PN sequence and the watermarking bit to watermark the block. Following are the output signals: Ready when the watermarking processes is in a progress the ready signal goes to low and when it is completed it goes to high.

Slices	2%
Slice Flip- flop	1%
4 input LUT	2%
Bounded IOB 's	22%
GCLK	4%
DSP48	19%

This unit has six states in each state the particular task is done and the FSM moves to the next step.

S1: It reads the block and check the watermark bit 1/0
S2: The computation of the DWT of the block is performed
S3: It computes the variance
S4: In this state the α is calculated by using FIS
S5: The NN is computed from the LL band of DWT transformed block
S6: In this state NN is modified according to α
S7: this state, the ready signal is rest to 0 if the process is finished

2.2.6. Watermark Detection

The watermark detection algorithm is implemented in MatLab software. Original and suspected image both are required detect a watermark. The watermarked image and original image are tiled in to BXB blocks and NN is calculated of DWT coefficients for both images. This algorithm also generates the PN sequence from known for decryption of watermark.

$$W^*(i,j) = \begin{cases} 1 \ \text{ if } I^*_{NN_k}(i,j) - I_{NN_k}(i,j) > 0 \\ 0 \ \text{ other wise} \end{cases} \qquad (7)$$

By comparing the NN of the suspected image and original image we can recover the encrypted watermark. To get an original watermark the PN sequence generated by key 'K' is then XOR with the recovered watermark W*.

3. Experimental Result

3.1. Synthesis and Implementation

The chip was modeled using a Verilog HDL and the functional simulation was performed. The code was synthesized on XC3SD1800A-4FGG676C device using AccelDSP tool from Xilinx. The results are verified using the hardware co-simulation using AccelDSP. The hardware co-simulation run at 33.3 MHz clock frequency and samples are fed to the target device at the rate of 448.76KSPS through JTAG USB cable. The design utilizes the 204 startup clock cycles and 203 clock cycles for per function call. The device utilization summary is given in Table 1.

Table 1. Hardware Utilization

The experimental results show the robustness of the technique to the intentional and unintentional attacks.

3.2. Imperceptibility

Figure 7.(a) shows the original image with 512×512 and 8 bits per pixels. The watermarked image with gain β=2 and block size B (4×4) is shown in figure 7 (b). It can be seen from figures that the watermark is not perceptible, but at the same time it could be extracted without any error.

Figure 7. (a) Original Image

Figure 7. (b)Watermarked Image

3.2. Image Performance Evaluation on Various Attacks

The experiment was performed on more than 50 different images with different textures. In [16] 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 as the distortion introduced due to watermarking is less.

The various performance evaluations metrics, like Image Fidelity (IF), Normalized cross correlation(NC) and correlation quality(CQ) calculated from watermarked image for few popular images is given in Table 2.

Image	NC	CQ	IF
Lena	0.99	1	1
Mandrial	0.99	1	1
Woman	0.99	1	1

Attacks	BER
Gaussian Noise	3.7%
Median filter 7X7	5.6 %
Salt and Pepper Noise	5.6 %

Table 2. Quality Metrics

Table 3. Performance on Various Attacks

The watermarked image is tested with various types of attacks. The measured results on above image are tabulated in Table 3. It is observed that the watermark with stands after image preprocessing attacks like median filtering (7×7). The proposed scheme also tolerates noise attacks such as addition of Gaussian noise, salt and pepper noise. The results shows that proposed scheme can withstand the attacks if they are done intentionally or unintentionally.

4. Conclusion:

The experimental results show that the proposed scheme of wavelet based watermarking is imperceptible and robust against various attacks like different noise additions and filtering. This is achieved because of space and frequency localizing property of discrete wavelet transform, embedding the watermark based modifying NN is appropriate wavelet domain. The importance of gain factor with respect to texture sensitivity of image is also proved. The proposed scheme outperforms many present algorithm [17], [18] in terms of various attacks and calculation of gain factor.

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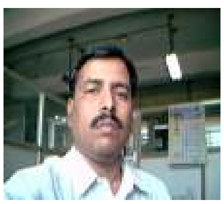

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