Fragile and Blind Reversible Watermarking Method for Color Images using 4-Level DWT

P.Vamshidhar
Department of ECE, JITS,
Narsampet, Warangal-506332,
Andhra Pradesh, India.

Md. Hameed Pasha,
Department of ECE,JITS
Narsampet, Warangal-506332,
Andhra Pradesh, India.

S. Bhargav Kumar, Student,
Department ofECE,SSJEC,
Gandipet, Hyderabad-500075,
Andhra Pradesh, India,

Abstract-- **Digital watermarking algorithms are widely applied to digital color image for ownership protection and tampering detection. Digital watermarking is the process of reversibly or irreversibly embedding information into a digital signal. Blind reversible watermarking has an additional advantage of recovering the image which is same as the original image pixel by pixel, after the image is authenticated. A fragile watermark is distorted in the case of tampering, notifying an investigator upon extraction of potential malicious manipulation in the image. A new algorithm is suggested for reversible watermarking which makes use of difference expansion concept in this paper. In the suggested algorithm, 4-level DWT of the input color image is calculated and the watermark bits are embedded in the transformed coefficients which don't cause any overflow or underflow. The result for embedding up to 8 watermark bits per coefficient is presented. The complete VLSI implementation of watermark embedding and extraction is presented on the FPGA SPARTAN 3E board.**

Index Terms**—reversible watermarking, color image, 4-level DWT, FPGA, SPARTAN 3E.**

I.INTRODUCTION

In recent years a special kind of digital watermarking is discussed widely, called reversible watermarking. It not only provides the protection of the copyright by embedding the assigned watermark into the original image but also can recover the original image from the suspected image. The retrieved watermark can be used to determine the ownership by comparing the retrieved watermark with the assigned one. Similar to conventional watermarking schemes, reversible watermarking schemes have to be robust against the intentional or the unintentional attacks, and should be imperceptible to avoid the attraction of attacks and value lost. Therefore, the reversible watermarking also has to satisfy all requirements of the conventional watermarking such as robustness, imperceptibility, and readily embedding and retrieving.

A. Reversible Watermarking

Reversible watermarking is a subset of fragile watermarking. It has an additional advantage of recovering the image which is same as the original image pixel by pixel, after the image is authenticated.

B. Reversible Watermarking Process

The motivation of reversible data embedding is distortion-free data embedding. In sensitive images such as military and medical image, every bit of information is important. Reversible data embedding will provide the original data when the digital content is authenticated.

Except for these requirements, reversible watermarking has to gratify the additional requirement mainly the reversible watermarking is blind, which means the retrieval process does not need the original image.

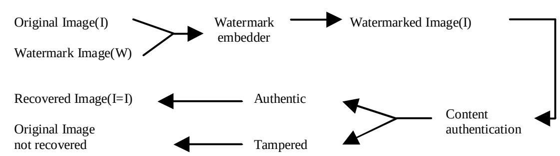

Figure 1. Reversible Watermarking flow diagram

From the flow diagram shown in Figure 1, Let I represent the digital image, W be the watermark then the watermarked image I' is formed after reversibly embedding the watermark in original image. This watermarked image I' is then distributed. The image is finally received at the destination but this received image may or may not be tampered by third party. The received image is then given to the authenticator, if it is authenticated then the recovered image I'' will be exactly same as the original image pixel by pixel otherwise we can say that the image is tampered.

II.WATERMARKING METHOD

The concept of difference expansion in his watermarking algorithm which uses Haar Wavelet transforms to embed watermark bits. This was used as a reference algorithm. In this algorithm, pair of pixels is used to form low pass coefficient (l) and high pass coefficient (h). The high pass coefficient (h) is difference expanded by watermark bit (b) as in Equation (2.1-a)

$$H = (y * h + b)\ (x * h + a), \text{ for all } \quad 0 \le b \le (y-1) \quad (2.1\text{-a})$$
$$0 \le a \le (x-1)$$

Where H is watermarked coefficient and k is the constant which has integer value. For example if y = 2 and x=2 then h will be expanded by one bit either b=0 or 1 and also a=0 or 1.

$$H = 2 * h + b\,(xy + x + y) \qquad (2.1\text{-b})$$

These watermarked high pass coefficients and original low pass coefficients are used to form the watermarked pixels, if there is no overflow or underflow that is the pixel value lies between 0 and 255 for a gray scale image, in these pixel values then the coefficient h is expandable and a watermark can be embedded in this coefficient.

In the watermarking embedding stage, 4-level DWT of the input image is calculated and the watermark is embedded in the high pass coefficients to give the watermark coefficients. The other coding operations are performed on these coefficients to generate coded image.

A. *Implementation*

In this technique, if high pass and low pass filters are complementary, then both high pass and low pass can be factorized into smaller filter coefficients - one with even filter coefficients and the other with the odd filter coefficients delayed by a clock cycle.

In the following methodologies, the input signal is first split into even and odd samples and these odd samples are combined with the predicted even samples to form the high pass output and this high pass output is used to update the even samples to form the low pass output. These high pass and low pass outputs are multiplied by *K* and *1/K* to get the final high pass and low pass coefficients.

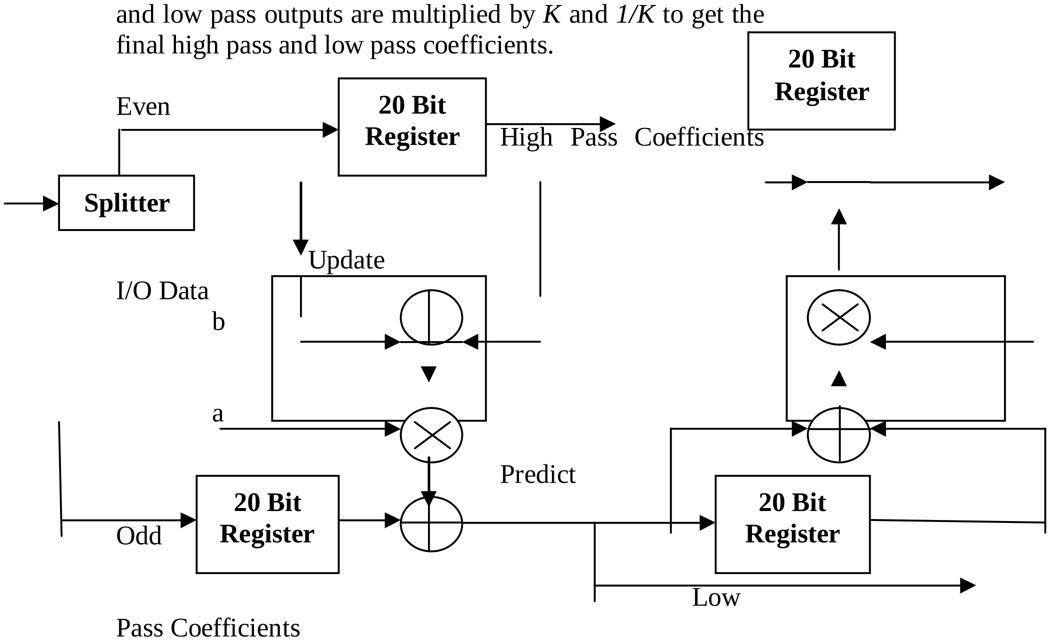

Figure 2.1 Coefficients Extractions

where, K (constant) is a scaling factor and $S_i(z)$ and $t_i(z)$ are smaller filters with reduced number of filter taps.

The reconstruction process just flows in the reverse direction as the decomposition process. First the scaling of the coefficients is done and then the scaled low pass coefficients are used to predict the high pass coefficients. Then the low pass coefficients are updated using these high pass coefficients and merged together to generate the pixels.

B. *Utilization of wavelet analysis properties in watermark problem*

Consider the Figure 2.3, which shows a Lenna image which is smooth. After applying four level decompositions, the image is decomposed into 12 detail sub-bands and one approximate sub-band which is the coarser representation of the original image. From the coefficients distribution, it is evident that smooth image has a more significant peak at the coefficient value 0.

Figure 2.2 Lenna

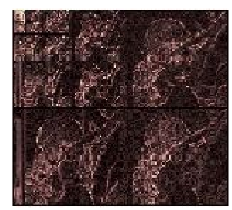

Figure 2.3 Four level decomposition

C. *4-level DWT – Lossless Transformation*

The analysis and the synthesis filter coefficients (both low pass and high pass) for Le Gall 5/3 Integer Wavelet Transform are as shown. Equation 2.3, Equation 2.4, Equation 2.5 and Equation 2.6 shows the lifting steps for the 5/3 le Gall Integer Wavelet Transform. The rational coefficients allow the transform to be invertible with finite precision analysis, hence giving a chance for performing lossless compression. The equations show the lifting steps for 4-level le gall Integer Wavelet Transform.

$$y(2n+1) = x(2n+1) - [(x(2n)+(2n+2))/2] \quad (2.2)$$
$$y(2n)=x(2n)+[(y(2n-1)+y(2n+1))/4] \quad (2.3)$$

An even and odd coefficient equation for 4-level Inverse Integer Wavelet Transform is

$$x(2n)=y(2n)-[(y(2n-1)+y(2n+1))/4] \quad (2.4)$$
$$x(2n+1)=x(2n+1)+[((x(2n)+(2n+2))/2] \quad (2.5)$$

D. Embedding procedure

a) Find the 4-level wavelet transform of the original image, to form low frequency (Y (2n)) and high frequency (Y (2n+1)) coefficients.

b) Do not disturb the low frequency components but check whether the high frequency components are expandable or not i.e., by embedding a bit(b) either 1 or 0 to form (Y (2n+1)) by

$$(Y (2n+1)) = 2 * (Y (2n+1)) + b \quad (2.6)$$

E. Restoring the original image

a) Calculate the 4-level wavelet transform of the received watermarked image. Collect all the LSB's of the high frequency coefficients which have 1 in the location map to form the watermark bits.

b) Use these high frequency coefficients and the original low frequency coefficients and apply 4-level Inverse wavelet transform to get the reconstructed image. Check whether or not the reconstructed watermark is same as the original watermark.

F. Methods to increase the embedding capacity by expanding the coefficients by more than one bit:

For the difference value h and integer average value l, if k = 1 is the largest integer then h can be expanded as H = (y * h + b) (x * h + a), for all $0 \le b \le (y-1)$ (2.7)

$0 \le a \le (x-1)$

Where H is watermarked coefficient

Now get the watermarked image by using this H and l and by applying inverse wavelet transform. If each and every pixel of this image lies in between 0 and 255 then we say the hiding ability of H is $\log_2 k$ bits. For example if k = 2 then H =2*h+b i.e., h is expanded by one bit either b=0 or 1. Similarly we can embed more than one bit into the coefficient, even after the embedding there is no overflow or underflow.

III.DESIGN OF HARDWARE MODEL

Basically 4-level DWT block diagram is developed based on the equations (2). The registers in the top half will operate in even clock where as the ones in bottom half work in odd clock.

The input pixels arrive serially row-wise at one pixel per clock cycle and it will get split into even and odd. So after the manipulation with the coefficients 'a' and 'b' is done, the low pass and high pass coefficients will be given out. Hence for every pair of pixel values, one high pass and one low pass coefficients will be given as output respectively.

A. Watermark embedding stage

The transformed high pass coefficients from the DWT block and the watermark bits were fed to the Difference Expansion and Watermark Embed Block.

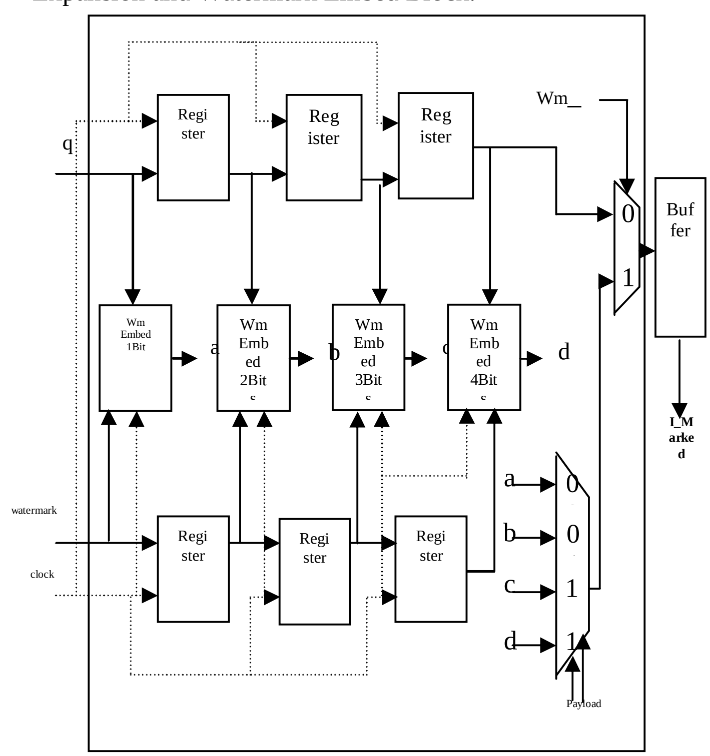

Figure 3.1 Watermark Embed Block

The high pass coefficients and the watermark bits were given to the watermark embed block. In this design, there are four watermark embed blocks are available which will be performing the expansion operation of given high pass coefficients with respect to the number of watermark bits given to the block. Hence the output of the block gives the watermarked coefficients which were represented as "a, b, c and d" in the above block diagram. For Example,

Wm Embed 1Bit – (2 * q) + Watermark Bit (1-Bit)
Wm Embed 2Bit – (4 * q) + Watermark Bits (2-Bits)
Wm Embed 3Bit – (8 * q) + Watermark Bits (3-Bits)
Wm Embed 4Bit – (16 * q) + Watermark Bits (4-Bits)

The payload is the parameter which decides which watermarked coefficients should be given out and watermark enable parameter will decide either plain high pass coefficients or the watermarked coefficients should come out as the final output of the block. This process continues until all the watermark bits are embedded or all the coefficients are traversed.

We can form the watermarked transformed image from these low pass and modified high pass coefficients. We can also see the watermarked image, if these coefficients are given to the Inverse Discrete wavelet transformer block. This is shown in Table 4.1

TABLE 4.1 CONDITIONS FOR NUMBER OF WATERMARK BITS TO BE EMBEDDED

Payload	**Number of Bits to be Embedded**
0,0	One Bit is embedded
0,1	Two bits are embedded
1,0	Three bits are embedded
1,1	Four bits are embedded

These watermarked coefficients and the low pass coefficients from the DWT block will be given to the Inverse DWT and hence the watermarked pixel values will be obtained which represents the watermarked image.

B. Block diagram of Reverse Watermarking

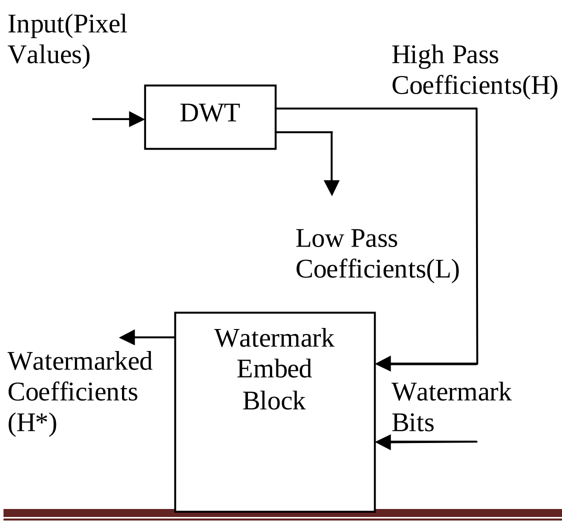

Figure 3.2 Block Diagram of Reversible Watermarking

In this modified algorithm, 2 bits, 3 bits or 4 bits can be embedded in a transformed high pass coefficient without any degradation of the image. Hence the capacity of the information that is to be hidden into the image is more.

IV.RESULTS

The Appropriate test cases have been identified in order to test this modeled reversible watermarking algorithm. Based on the identified values, the simulation results which describes the operation of the algorithm has been achieved. This proves that the modeled design works properly as per the algorithm.

The initial block of the design is that the Discrete Wavelet Transform (DWT) block which is mainly used for the transformation of the image. In this process, the image will be transformed and hence the high pass coefficients and the low pass coefficients were generated. Since the operation of this DWT block has been discussed in the previous chapter, here the snapshots of the simulation results were directly taken in to consideration and discussed.

For this DWT block, the clock and reset were the primary inputs. The pixel values of the image, that is, the input data will be given to this block and hence these values will be split in to even and odd pixel values. In the design, this even and odd were taken as a array which will store its pixel values in it and once all the input pixel values over, then load will be made high which represents that the system is ready for the further process.

The output of the DWT block were High Pass and Low Pass Coefficients in which the high pass coefficients are taken for the watermark embed process and the low pass coefficients are not disturbed.

The internal blocks available inside the design includes DWT top level, watermark Embed block and Buffer which were clearly shown in the above schematic level diagram.

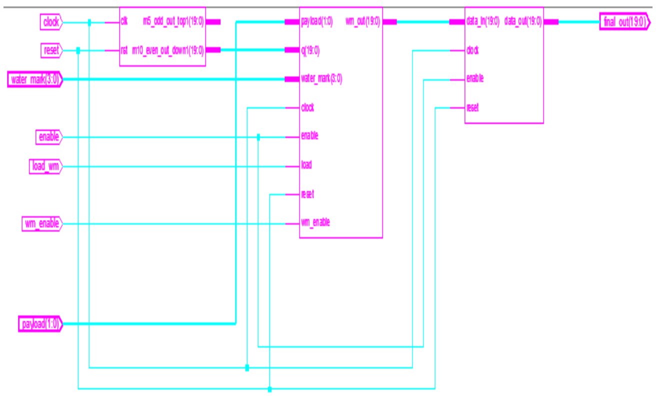

Figure 4.1 Simulation Result of Reversible Watermarking Process

Above Figure 4.1 schematic shows the blocks available inside the top level DWT block. This block includes the Input generator and the DWT design. The input generator is the one which will generate the input pixel values with respect to the clock signal and the DWT block contains the logic. The blocks can be explored still which will shows the generated gate level logic of each block with respect to the modeled Verilog HDL.

The simulation result of the top level block of the Reversible watermarking which includes both the DWT block and the Watermark embed block is shown above. Hence the clear representation of the flow can be seen in the above simulation result and hence the final output of the reversible watermarking is achieved.

V.CONCLUSION

This work is to find a reversible (lossless) watermarking algorithm (which can be used for sensitive applications like medical and military purposes) which can be integrated with the color image standard. Instead of embedding watermark directly in pixels of the image where the distortion is large, watermark bits are embedded in the high frequency coefficients where the embedding capacity is more. Since 4-level discrete wavelet transform is considered as the standard lossless transform for color image standard, this 4-level Integer to Integer transform is used and the watermark is embedded. To increase the embedding capacity, more than two bits at a time are used to embed in the high frequency coefficients and reversibility is confirmed.

The result for embedding up to 8 watermark bits per coefficient is presented. The complete VLSI implementation of watermark embedding is presented.

A. Hardware model

1. Architecture for Reversible Watermarking have been designed in such a way that more than 1bit can be embedded in the high pass coefficients of an image
2. To retain image quality compression is avoided and hence directly embedding the watermark was done.
3. Embedding the watermark in those high pass coefficient, maximum embedding capacity over 85000 bits is achieved for a 256x256 lenna image.

VI.FUTURE WORK

As future work,

1. Maximum payload size that can be embedded in the image can be determined before embedding the watermark.
2. The hardware design for embedding multiple bits in a coefficient can be done.
3. This watermarking block can be integrated with the other blocks of the color image standard.

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