# Digital Image Watermarking Algorithm Based on Wavelet Packet

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**Abstract**

In this paper, a method for Digital Image Watermarking based on the modification of certain subband of the wavelet packet decomposition was presented. A key is used for wavelet bases selection, watermark generation and selection of blocks for embedding the watermark bits. To efficiently embed the watermark within the images and provide the robustness for the watermark detection under attacks, watermark is embedded by quantizing the mean of the wavelet coefficient block. A method for exploiting human visual system (HVS) characteristics in wavelet packet domain is presented. In this method original image is not needed and only secret key is required for extracting the watermark. Experimental results show that proposed method is robust to different types of attacks.

**Keywords:** *WaveletPacket, HVS, Weight Factor, Quantization, Robustness, Geometric Attacks.*

## 1. Introduction

Doing business on the Internet has become an important business model at present time. Since every transmitted data is digitized and can be easily duplicated, the problem of the copyright protection for commercial or sensitive data grows to an unavoidable situation for many businesses. Digital watermarking emerged as a tool for protecting the multimedia data from copyright infringement. In digital watermarking an imperceptible signal “mark” is embedded into host image, which uniquely identifies the ownership. The main requirements of the watermarking are imperceptibility and robustness to intentional and unintentional attacks.

In DCT based embedding scheme which uses random number as the watermark. Similar approach can be applied to other transform like the DWT.The drawback of this approach is that it is necessary to refer to the original image in order to extract the watermark which makes the authentication process difficult. Transform domain methods are more robust than spatial domain methods because when image is inverse transformed watermark is distributed irregularly over the image, making the attacker difficult to read or modify. Among the transform domain techniques wavelet based watermarking methods are gaining more popularity because of superior modeling of HVS. Another important issue in watermarking is access to original image. In many applications it is difficult to have access to original image, so it is desirable that the watermarks should be extracted without using original image.

Watermarking methods are also classified into two categories based on embedding mechanism. In the first method, watermark bits are added directly to the host data by encoding or modulating. Example of this type of method is spread spectrum watermarking [4]. In the second method, single coefficients or group of coefficients are mapped to represent one bit of watermark information. These methods are free from host interference. Example of this type is quantization based watermarking [3], [10].The methods discussed above have not properly exploited HVS characteristics in embedding the watermark and hence these methods are not much robust against intentional and unintentional attacks.

To embed watermark more robustly by exploiting HVS characteristics, in this paper, a novel wavelet packet based watermarking method is presented. Watermark is embedded by quantizing the mean of wavelet coefficient block. For extraction of the watermark only secret key is required and original image is not needed. Robustness of the proposed method is tested with different types of attacks and results are compared with the existing methods. From the results it is be observed that proposed method is much better than the existing methods.

The rest of the paper is organized as follows. Exploitation of HVS characteristics is explained in section 2. In section 3 mean quantization, watermark embedding and extracting algorithms are explained. Experimental results are given in section 4. Finally, the conclusions are given in section 5.

## 2. HVS Characteristics

Number of factors affects the noise sensitivity of the human eye like luminance, frequency and texture. Human eye is less sensitive to areas of the image where brightness is high or low. The human eye is less sensitive to noise in high frequency bands and bands having orientation of 45 degrees. Sensitivity of human eye to noise in textured area is less and it is more near the edges. In [8], these observations are exploited for finding weight factors to quantize wavelet coefficients for image compression. With some modification, Barni et al. [2], used these weight factor in embedding the watermark. With some modifications a method for exploiting HVS characteristics in wavelet packet domain was presented.

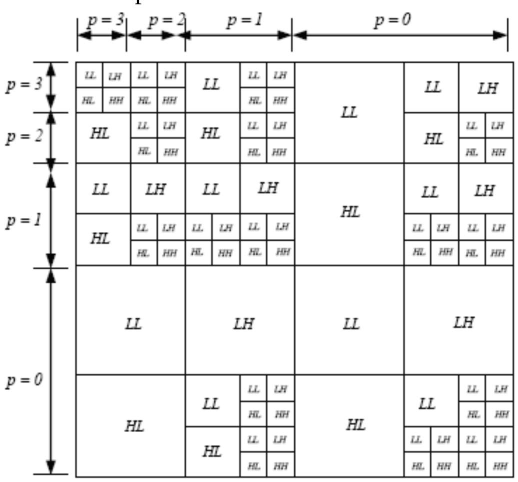


**Figure 1. 4-level wavelet packet bases representation.**

The wavelet packet basis representation of a 4-level transformed image is shown in figure 1. Let us represent the subbands of image size $M \times N$. Let as $Sm$ where $m = 1,2,3......Nm$ and $Nm$ is the total number of subbands. Let $\theta m$ be the orientation of the $m\ th$ subband where $\theta \in \{LL,LH,HL,HH\}$. $lm$ represents the level of $mth$ subband and $pm$ represents position as shown in figure 1. Let $n_p$ be the total number of subbands in $p\ th$ position. For the sake of convenience let us represent the $l$th level approximate band in pyramidal structure decomposition by $Gl$ . Weight factors for wavelet coefficients can be found by using three terms, namely, luminance L, frequency and orientation F, and texture activity T as given in equation (1) [2].

$$w_m(i,j) = F(l,\theta)L(l,i,j)T(l,p,i,j)^{0.2} \qquad (1)$$

As per the results given in [8], first term in equation can be handled as follows

$$F(l,\theta) = \begin{Bmatrix} \sqrt{2} & if\ \theta = HH \\ 1 & otherwise \end{Bmatrix} * \begin{Bmatrix} 1.00, & if\ l=0 \\ 0.32, & if\ l=1 \\ 0.16, & if\ l=2 \\ 0.10, & if\ l=3 \end{Bmatrix} \qquad (2)$$

As per the observations give by Barni [2], human eye is less sensitive to noise in bright or dark background regions. They calculated the effect of luminance by considering the $LL$ band of highest level as given below

$$L(l,i,j) = 1 + B'(l,i,j) \qquad (3)$$

Where,

$$B'(l,i,j) = \begin{cases} 1 - B(l,i,j) & if\ B(l,i,j) < 0.5 \\ B(l,i,j) & otherwise \end{cases} \qquad (4)$$

$$B(l,i,j) = \frac{1}{256} G_l(i,j) \qquad (5)$$

Sensitivity to noise in texture areas can be found by finding the product of the local mean square value of the wavelet coefficients in all detail bands and local variance of the approximate band. These two terms are found in 2*2 neighborhood corresponding to the location (i,j). Mathematically, it can be represented as,

$$T(l,p,i,j) = \sum_{k=p}^{3} \sum_{z=t_p}^{t_p+n_p} \frac{1}{16^{(k-l)}} \sum_{x=0}^{1} \sum_{y=0}^{1} \left[ S_Z\left(x + \frac{i}{2^{(k-l)}}, y + \frac{j}{2^{(k-l)}}\right) \right] * Var\left\{ G_l\left(x+i,\ y+j\right) \right\}_{x=0,1;y=0,1} \qquad (6)$$

Here $t_p$ be the number of first subband in $p^{th}$ position.

## 3. Proposed Watermarking Method

3.1. Mean quantization

For quantizing the mean of the wavelet coefficients block,a quantization table is used. This quantization table is determined by considering the tradeoff between the watermarking strength and quality of watermarked image. For large value of quantization interval, coefficients are quantized heavily, which increases watermarking strength but decreases the quality of the image, $q$. Let $l \times m$ is size of the block chosen for embedding the watermark bit. $x_n$ is the mean of the $n^{th}$ block of wavelet coefficients $x(i,j)$ and is calculated as given in equation (7)

$$x_n = (1/(l*m)) \sum_{i=1}^{l} \sum_{j=1}^{m} x(i,j) \qquad (7)$$

Depending on watermark bit, mean value is quantized to nearest quantization interval. If the mean value is to be quantized from one quantization interval to another interval then $\Delta min$ and $\Delta max$ are calculated. $\Delta min$ is the minimum updating required so that the mean value will be within the required quantization interval. The maximum value of $\Delta min$ is $q/2$. Therefore quantization interval value $q$ is chosen such that $q/2$ should not give any perceptual degradation. $\Delta max$ is the maximum updating that can be applied so that the mean will be mapped to middle of the required quantization interval. Based on the value of $\Delta min$ and $\Delta max$ each wavelet coefficient in the block are updated using equation (8).

$$x'(i, j)=x(i, j)+\Delta min+w(i, j)*(\Delta max - \Delta min) \qquad (8)$$

where $x'(i, j)$ is updated wavelet coefficient and $w(i, j)$ is weight factor of the coefficient , which ranges between 0 and 1.
If the mean value of the block is within the required quantization level then calculate $x(i, j)$ $\Delta$ such that it will map the mean to the middle of the same quantization interval. Quantization of coefficients is done by equation (9).

$$\mathbf{x'(i,j)=x(i,j)+w(i,j)*\Delta} \qquad (9)$$

3.2. Watermark Embedding
Step 1: Generate binary watermark bits of $\pm 1$ using the secret key. Let us represent watermark bit with $bi$ $i=1....N_b$ where , $N_b$ is the length of the watermark.
Step 2: Decompose the host image using the key and DWPT into required number of levels .
Step 3: Find the weight factor $w$ of each coefficient in these subbands For $i=1....N_b$ do step 4 and step 5.
Step 4: Find the wavelet coefficients block using secret key and the mean using equation (7).
Step 5: Based on the watermark bit $bi$ and using quantization table quantize each coefficient in the block to desire value. If the mean is within the required quantization interval then calculate $\Delta$ and update coefficient using equation (9). Otherwise find $\Delta min$ and $\Delta max$ , and update each coefficient using equation (8).
Step 6: After embedding the watermark take IDWPT of the image to get the watermarked image.

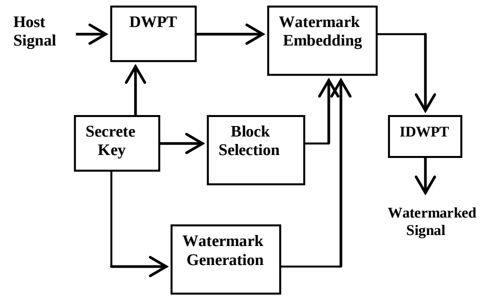


**Figure 1 Block diagram of watermark embedding**

3.4. Watermark Extraction
Step 1: Decompose the doubtful image using secret key and DWPT and select the middle frequency bands.
For $i=1....N_b$ do step 2 and step 3
Step 2: Find the wavelet coefficient block using key and the mean.
Step 3: Using quantization table determine the watermark bit $b_i'$ by finding to which quantization interval this mean belongs.
Step 4: After extracting all watermark bits find the correlation between the given and extracted watermark.

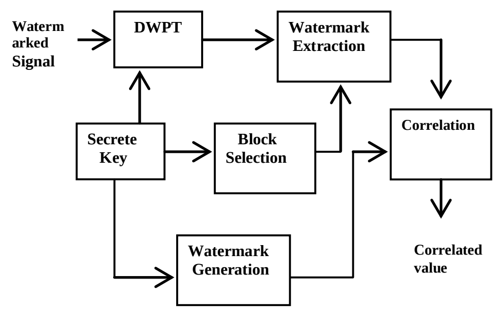


**Figure 2 Block diagram of watermark extraction**

## 4. Experimental Results

Here the results are presented for grayscale 8-bit Lena image of size $512\times 512$ shown in figure 4. Daubechies 9/7 filter coefficients are used for DWPT of the image. Block size of $2 \times 2$ is used for embedding the watermark bit. The quantization interval $q$ equal to 2.5 is used for generating the quantization table. To evaluate the quality of the watermarked image we have used the peak signal-to-noise ratio(PSNR) as a measure. PSNR value of the watermarked Lena image is 49.55. To test the robustness of the proposed algorithm. watermarked Lena image is tested with different types of geometrical and non-geometrical attacks.

**Figure 3 Original Lena image of size 512× 512**

**Figure 4 Watermarked Lena image**


Figure 6 Extracted Watermark

To verify the robustness of the algorithm Lena image is tested for average, median and Gaussian filtering. Results are shown in table I for Average, Median and Gaussian filtering.

Salt and pepper noise with median filtering

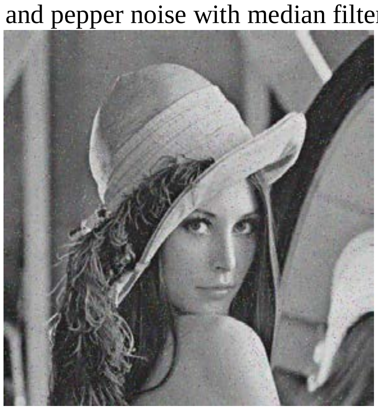

Figure 7 Noisy image

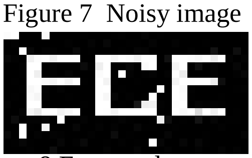


Figure 8 Extracted watermark (filter size 3*3)

Table-I. Correlation ρ at different filter size of Average, Median and Gaussian filters

| Filter Dimensions | correlation in (%) | | |
|---|---|---|---|
| | Average filtering | Median filtering | Gaussian filtering |
| *3× 3* | 80.46 | 96.6797 | 97.6563 |
| 5× 5 | 80.2734 | 92.3828 | 95.1172 |
| 7× 7 | 80.2730 | 87.8906 | 99.992 |
| 9× 9 | 80.2728 | 83.3984 | 89.0625 |

To show the robustness of proposed method to geometrical attack we verified with JPEG Compression, resizing and cropping attacks Results are shown in table II for JPEG Compression & table III for resizing and cropping attacks.

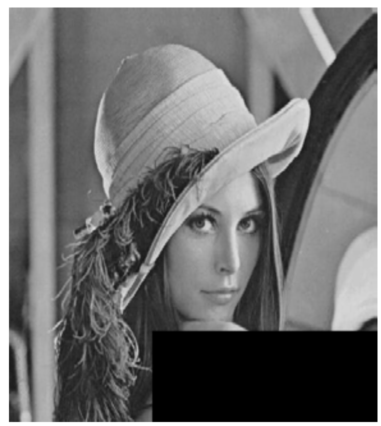

Figure 9 Cropped image

Figure 10 Extracted Watermark

Table-II.Correlation ρ at resizing factor and cropping attacks.

| | Resizing (scale factor) | | Cropping |
|---|---|---|---|
| | 2 | 3 | |
| ρ (%) | 92.18 | 91.40 | 94.72 |

Figure 11 Compressed image

Figure 12 Extracted watermark

Table-III. Correlation ρ with JPEG Compression.

| | JPEG Compression (Q factor) | | |
|---|---|---|---|
| | 70 | 30 | 10 |
| ρ (%) | 99.4141 | 97.0703 | 88.6719 |

In order to verify the quality and robustness of the watermarked image of the proposed method, it is tested on different type of images. The first test on this algorithm is the robustness to noise. Two kinds of noise are tested. One is a Gaussian noise and the other is a salt-and-pepper noise. The results are given in Table IV and demonstrate that this algorithm is robust to noise.

Table-IV. Correlation ρ with Gaussian and salt and pepper noises for various images.

| IMAGE | Correlation in (%) for Gaussian noise | Correlation in(%) for S.& P.noise | |
|---|---|---|---|
| | | Average filtering | Median filtering |
| Cameraman | 97.0703 | 83.9844 | 95.7031 |
| Rice | 96.6797 | 75.9766 | 99.6797 |
| Knee | 98.432 | 74.376 | 98.940 |

## 5. Conclusion

In this paper, a novel wavelet packet based watermarking method for copyright protection is presented. Wavelet packets are used to gain the advantage of better frequency resolution representation. A method for exploiting the HVS characteristics is also presented. Watermark is embedded by quantizing the mean of the wavelet coefficient block. Original image is not required for extracting the watermark. The proposed method is more secure as the security lies in secret key, which is used for selecting the bases, watermark generation and selecting the watermark embedding blocks. This method is tested with different type of geometric and non-geometric attacks.

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