Digital Image Watermarking Algorithm in Discrete Wavelet Transform Domain Using HVS Characteristics

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Abstract:

   Protection of digital multimedia content has become an increasingly important issue for content owners and service providers. Watermarking is identified as a major means to achieve copyright protection.

   This watermarking algorithm is based on the Discrete Wavelet Transform (DWT). Watermark components are added to a high frequency subband by considering the human visual system (HVS) characteristics. HVS characteristics are used in this scheme to develop a robust watermarking scheme with a better tradeoff between robustness and imperceptibility. A visual mask based on HVS characteristics is used for calculating the weight factor for each wavelet coefficient of the host image.

   The proposed scheme was tested against mostly known threats and it proves to give good robustness. Also it still gives a high quality watermarked image. MATLAB Program was used to perform the watermarking task.

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المستخلص:

تكتسب حماية المحتوى للوسائط الرقمية المتعددة اهمية متزايدة لاصحاب الملكية لهذه الوسائط ولمزودي الخدمة. تعد اضافة الصورة المائية احدى الوسائل الاساسية للحصول على حماية حقوق التصرف. الخوارزمية المعتمدة هنا لاضافة الصورة المائية تعتمد على التحويل المويجي المتقطع (الرقمي) DWT. مكونات الصورة المائية اضيفت الى احدى الحزم الفرعية عالية التردد الناتجة عن التحويل المويجي المتقطع بالاستفادة من خصائص نظام الرؤية البشري (HVS). هذه الخصائص تم توظيفها للحصول على وسيلة لاضافة الصورة المائية بشكل مقاوم للتهديدات مع جعلها مخفية داخل الصورة بشكل غير ملحوظ . يعتمد مبدأ العمل على اختيار معاملات الحزمة الفرعية باستخدام خصائص نظام الرؤية البشري واستخلاص معامل وزن مناسب على اساسه تضاف مكونات العلامة المائية مع الحفاظ على المواصفات المذكورة انفا. اختيرت هذه الطريقة بتعريض الصورة المحمية لمختلف التهديدات المتعارف عليها واعطت مقاومة جيدة لها مع التمتع بجودة عالية دون اثر للصورة المائية . استخدم برنامج MATLAB وسيلة لادخال العلامة المائية واسترجاعها.

Keywords: DWT, blind watermarking, HVS.

1. Introduction:

Digital watermark is a kind of technology that embeds copyright information into multimedia data (Cox, Miller, and Bloom, 2002). Each watermark method consists of an embedding algorithm and an extracting algorithm. The embedding algorithm inserts the watermark information in the data and the extracting algorithm decodes the watermark information. Some methods extract the whole watermark information (decoder) and others determine only its existence (detector), the detection process decides (yes) if the watermark is found and decides (no) if the watermark is absent (Seitz, 2005). Watermark embedding can be done in either spatial domain or frequency domain. The spatial domain watermark embedding manipulates host image pixels, especially on least significant bits that have less perceptual effect on the image (Chan and Cheng, 2004). Although the spatial domain watermark embedding is simple and easy to implement, it is less robust than frequency domain watermark embedding at various attacks and noise (Pan, Huang, and Jain, 2004).

There are a number of desirable characteristics that a watermarking technique should exhibit. That is, a watermarking technique should at least include the following requirements (Seitz, 2005): **robustness**:

means the resistance ability of the watermarking information to changes and modifications made to the original file. Modifications could be resizing, rotation, linear and nonlinear filters, lossy compression, contrast adjustment...etc. **Imperceptibility**: It refers to the perceptual similarity between the original and watermarked versions of the cover image (Chan and Cheng, 2004). The imperceptibility is based on the idea and properties of the human visual system (HVS). **Security**: It is assumed that the attackers have full knowledge about the applied watermark procedure. So, an attacker will try to manipulate the data to destroy the watermark. **Complexity**: describes the expenditure to detect and encode the watermark information. It is recommended to design the watermarking procedure and algorithm as complex as possible so that different watermarks can be integrated. **Capacity**: refers to the amount of information that can be stored in a data source.

1.1 watermarking verification:

One commonly employed measure to evaluate the imperceptibility of the watermarked image is the peak signal-to-noise ratio (PSNR). Assuming that the original image *X* and the watermarked image *X'* both have image sizes *M* x *N*. The mean square error (MSE) between the original and the watermarked images can be represented by (Pan, Huang, and Jain, 2004):

$$\text{MSE} = \frac{1}{M.N} \sum_{i=1}^{M} \sum_{j=1}^{N} (X(i,j) - X'(i,j))^2 \tag{1}$$

Consequently, the PSNR in decibel (dB) can be calculated by (Pan, Huang, and Jain, 2004):

$$\textbf{PSNR in dB} = 10 . \log_{10}(\frac{\textbf{MAX}^2}{\textbf{MSE}}) \quad \textbf{(dB)} \tag{2}$$

Where MAX is the maximum possible pixel value of the image, here the image is 8-bits grayscale image then MAX=255; Higher PSNR values indicate better imperceptibility.

Classification of watermarks can be made as, visible and invisible embedded watermarks; visible watermarks are used in authenticity applications. An example of visible watermarking is provided by television channels, whose logo is visibly superimposed at the corner of the TV picture. Invisible watermarking, on the other hand, is a far more complex concept. It is most often used to identify copyright data, and other applications (Lu, 2005).

In order to detect the watermark information, blind, Semi-blind and non-blind techniques are used. When the cover work is not required but the secret key is required at the detector, the system is called blind or oblivious. When the decoder requires both the original image and the secret key, the system is called non-blind watermarking. Semi-blind schemes require the secret key(s) and the watermark bit sequence (Sverdlov, Dexter, and Eskicioglu, 2005).

Watermarks can also be divided into fragile watermarks, semi-fragile watermarks and robust watermarks. Fragile watermarks are very sensitive to any transforms or processing (compression, rescaling, etc.). Semi-fragile watermarks are robust against some special image processing operations while not robust to other operations. Fragile / semi-fragile watermarks are used in authentication. Robust watermarks are robust to various popular image processing operations and are designed for the copyright protection (Yu, Lu, Luo, and Wang, 2010).

The performance of the blind or non-blind watermark extraction result is evaluated in terms of Normalized Correlation Coefficient (NCC), for the extracted watermark W' and the original watermark W as:

$$NC(W, W') = \frac{\sum_{i=1}^{n} W(i) W'(i)}{\sqrt{\sum_{i=1}^{n} W(i)^2} \sqrt{\sum_{i=1}^{n} W'(i)^2}} \qquad (3)$$

Where (n×n) are the watermark dimensions. The magnitude range of NC varies between [-1 and 1], the unity value is given exact matching between the extracted watermark logo and the original watermark logo (Pan, Huang, and Jain, 2004).

1.2 Literature survey:

(Barni, Bartolini, and Piva, 2001) proposed a method to embed the watermark according to the characteristics of the Human Visual System (HVS). In contrast to conventional methods operating in the wavelet domain, masking was accomplished pixel by pixel by taking into account the texture and the luminance contents of all the image subbands. The watermark was detected by computing the correlation between the watermarked coefficients and the watermarking code. This method embedded the watermark image in HH sub-band of the first level, and

this subband was not robust to some attacks like JPEG compression, and low passes filtering. (McKinnon and Qi, 2006) proposed a wavelet-based watermarking technique by adaptively quantizing a pair of family trees. The family trees were created by a group of wavelet coefficients of the different decomposition levels along the same spatial directions. Each watermark bit was embedded in various frequency bands and therefore was spread among large spatial regions. (Zolghadrasli and Rezazadeh, 2007) proposed a multi-resolution discrete wavelet transform watermarking method for copyright protection of digital image. Watermark components were added to the significant coefficients of each selected sub-band by considering the Human Visual System (HVS) characteristics. (Reddy and Varadarajan, 2009) proposed a watermarking method in wavelet domain by means of Haar wavelet transform with lifting scheme. The incorporation of HVS model into the proposed scheme has resulted in an efficient watermarking scheme.

1.3 aim of the work:

In this paper, a blind image watermarking scheme is introduced since only a secret key is required in the extraction algorithm. This scheme is suitable for Internet applications where the original cover is not available for the receivers. This scheme makes use of a binary logo as watermark data for protecting the copyrights of images. The requirements were met by the proposed algorithm exploiting the attractive properties of the Discrete Wavelet Transform (DWT). The high frequency subband of the second level Wavelet decomposition (HH2) was selected to embed the logo image. The remainder of this paper is organized as follows. Section II describes the background of DWT and HVS and their properties, section III describes the details of the proposed scheme, in section IV the experimental results are provided to demonstrate the effectiveness of the proposed scheme, and in section V the conclusions are given.

2. Preliminaries

2.1 Discrete Wavelet domain techniques:

It is the method used here to transform the image from spatial domain to frequency domain. It furnishes remarkable localization in time and frequency for the image data. The DWT processes the image by dividing it into four non overlapping multi-resolution subbands LL, LH, HL and HH. The sub band LL represents the coarse-scale DWT coefficients (the approximation) while the subbands LH, HL and HH represent the fine-scale of DWT coefficients (the details), figure 1

illustrates this concept. To obtain the next coarser scaled wavelet coefficients, the subband LL is further decomposed and dividing into four non overlapping multi-resolution sub bands is accomplished. This process is repeated several times, which is determined by the application at hand. Each level has various bands information such as low–low, low–high, high–low, and high–high frequency bands. Furthermore, from these DWT coefficients, the original image can be reconstructed. This reconstruction process is called the inverse DWT (IDWT). If C[m,n] represents an image, the DWT and IDWT for C[m,n] can similarly be defined by implementing the DWT and IDWT on each dimension and separately (Perumal, Kumar ,Sumalatha, and Kumar, 2009). More details about wavelet transform can be found in (Acharya, and Tsai, 2005).
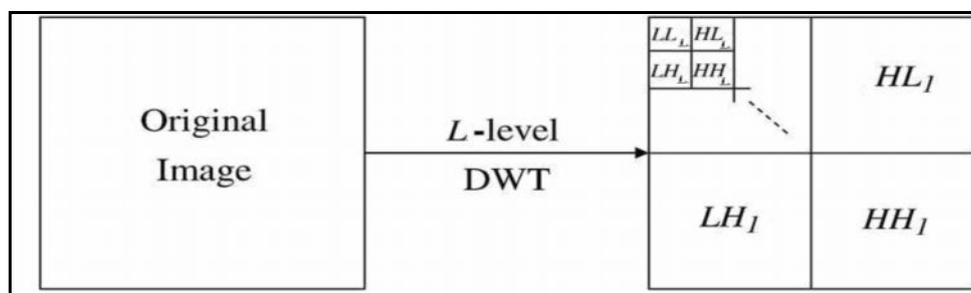

Figure 1: Representation of L-Levels of DWT Transform

Advantages of embedding a watermark in a Wavelet Transformed image:
1. It performs an analysis similar to that of the HVS. The HVS splits an image into several frequency bands and processes each band independently (Barni, Bartolini, and Piva, 2001).
2. Watermarking in the wavelet domain is compatible with the JPEG 2000 compression standards (Xia, Boncelet, and Arce, 1997).
3. With DWT, the edges and textures are usually exploited very well in high frequency subbands (HH, HL, and LH). Therefore, adding a watermark to these large numbers of coefficients is difficult for the human eyes to perceive (Xia, Boncelet, and Arce, 1997), (Lumini, and Maio, 2011).
4. Wavelet processes data at different scales or resolutions, highlighting both large and small features (Lumini, and Maio, 2011).

2.2 Basics of Human Visual System

The human visual system which is introduced in (Barni, Bartolini, and Piva, 2001) is used. To describe better the model, the wavelet representation of 4-1evels transformed image is shown in Figure 2. Each subband is represented with I_l^θ (i, j) where (i, j) is the indices of pixels, $\theta \in$ {0, 1, 2, 3} is the orientation (i.e. θ =0 denotes horizontal subband, θ =1 denotes diagonal subband, θ =2 denotes vertical subband, and θ =3 denotes approximation subband) and $l \in$ {0, 1, 2, 3) gives decomposition level of the image. This model takes into account a number of factors like luminance, frequency band, texture and proximity to an edge. These factors are based on the following observations.

- The eyes are less sensitive to noise in high resolution bands and in those bands having orientation of 45° (i.e., j=3 in our illustration).
- The eyes are less sensitive to noise in the areas where brightness is high or low.
- The eyes are less sensitive to noise in highly textured areas but, among these, more sensitive near the edges.
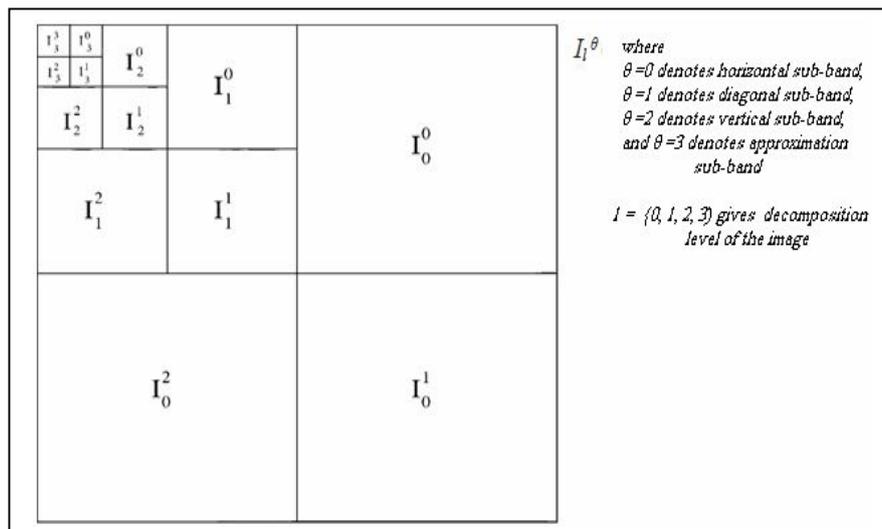

Figure 2: the 4-1evel DWT representation.

The weighting function S_l^θ (i, j) can be computed as a product of three terms:

$$S_l^\theta (i, j) = (\Theta(l , \theta) . \Lambda(l, i, j) . E (l, i , j)^{0.2}) / 2$$
(4)

Where the above three terms represent the sensitivity to noise changes in the bands, the local brightness and the local texture activities, respectively.

- $\Theta(l, \theta)$ denotes the sensitivity of the human eyes to noise changes and is computed as:

$$\Theta\,(l\,,\,\theta) = \left\{ \begin{array}{ll} \sqrt{2} & \text{If } \theta = 1 \\ 1 & \text{Otherwise} \end{array} \right\} \cdot \left\{ \begin{array}{lll} 1.00 & \text{If} & l = 0 \\ 0.32 & \text{If} & l = 1 \\ \text{f th } 0.16 & \text{If} & l = 2 \end{array} \right\} \tag{5}$$

- brightness or darkness and is computed as:

$$\Lambda\,(l,\,i,\,j) = 1 + L^{'}\,(l,\,i,\,j) \tag{6}$$

Where

$$L^{'}\,(l\,,\,i\,,\,j) = \left\{ \begin{array}{ll} 1 - L\,(l,\,i,\,j), & \text{If } L\,(l,\,i,\,j) < 0.5 \\ L\,(l,\,i,\,j), & \text{otherwise} \end{array} \right\} \tag{7}$$

$$L(l\,,\,i\,,\,j) = \frac{1}{256}\,I_3^3\,\left(1 + \left\lfloor \frac{i}{2^{3-l}} \right\rfloor,\,1 + \left\lfloor \frac{j}{2^{3-l}} \right\rfloor\right) \tag{8}$$

- $E\,(l\,,\,i\,,\,j)$ denotes the sensitivity of the human eyes to the texture activity in the neighborhood of a pixel.:

$$E\,(l,i,j) = \sum_{k=0}^{3-l} \frac{1}{16^k} \sum_{\theta=0}^{2} \sum_{x=0}^{1} \sum_{y=0}^{1} \left[I_{k+l}^{\theta}\left(y + \frac{i}{2^k},\,x + \frac{j}{2^k}\right) \right]^2 \cdot$$
$$var\,\left\{ I_3^3\left(1 + y + \frac{i}{2^{3-l}},\,1 + x + \frac{j}{2^{3-l}}\right) \right\}_{\substack{x=0,1 \\ y=0,1}} \tag{9}$$

3. The Proposed Algorithm:

The proposed method embeds watermark by decomposing the host image using discrete wavelet transform. A visual mask based on HVS characteristics is used for calculating the weight factor for each wavelet coefficient of the host image. The algorithm is described in this section by outlining the major steps in its two procedures; the watermark embedding procedure and the watermark extraction procedure. The host

is a 512×512 bit gray scale image and the logo is a 32×32 binary image having either black color (0) or white color (1) pixels.

3.1 Watermark Embedding Procedure:

To furnish its embedment, after performing a four level DWT decomposition upon the original image, it selects coefficients of the HH2 subband to embede the watermark, and to compute the weight factors S_l^θ (i, j) for wavelet coefficients. Both the watermark logo and the HH2 subband are converted from two dimensional to one dimensional, after converting the HH2 subband to a vector, the HH2 subband vector is divided into small blocks each having a size of eight pixels.

Only one pixel from each block is used to embed one pixel of the watermark logo, the selecting method of these blocks is random by pseudo random key; this pseudo random key is generated by Random permutation function in matlab. The size of key is equal to the total number of blocks, while the pixel location for embedding is fixed through the program. Figure (3) gives the embedding procedure, and figure (4) gives the embedding algorithm.
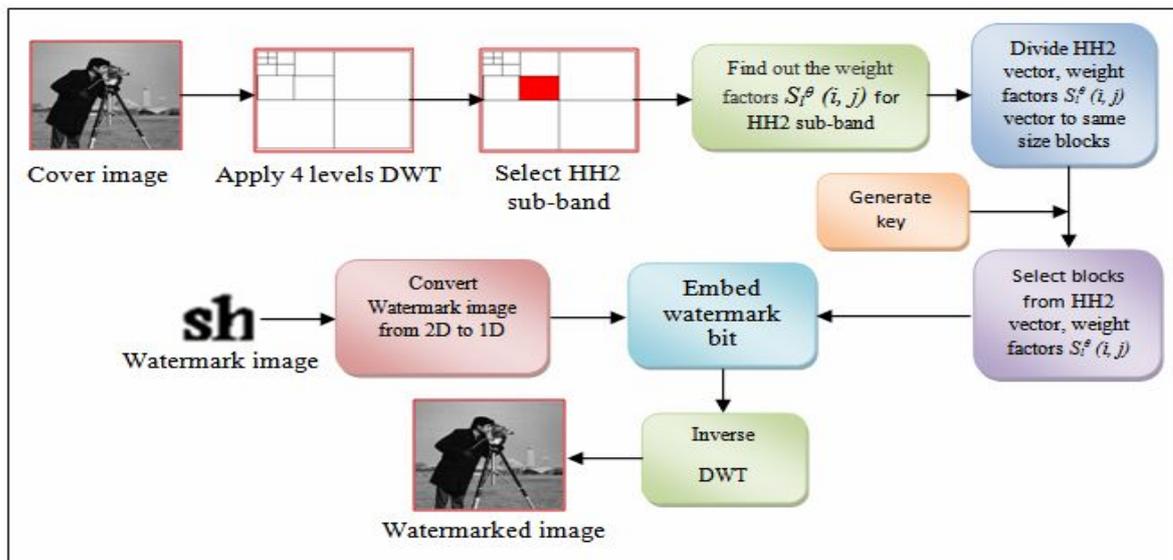

Figure 3: block diagram for the embedding algorithm's procedures.

The embedding method is performed after selecting a certain pixel from each block, the average value for each block is computed, and this average is beneficial for the embedding and extracting procedure. This mean of block is consolidating watermark strength, and it increases the watermark robustness against threats. After calculating this average, calculate the modulus for this average as divided by 2. Watermark

strength factor modulation is accomplished through a mask giving a pixel by pixel measure of the sensibility of the human eye to local image perturbations. The strength factor of watermark embedding is computed to be:

$$Strength \quad factor \quad = \quad \beta \quad + \quad S_l^{\theta} \quad (i, \quad j) \quad * \quad \alpha \quad (10)$$

Where α, and β are the parameters which determine watermark strength factor.

Start

Read cover image, Read watermark logo.

Implement the DWT (4-level) by Daubechies-4 wavelet filter for cover image, and Select *HH2* subband for embedding the logo image.

Compute the weight factors for *HH2* wavelet coefficients using the weighting function $S_l^\theta (i, j)$.
$$S_l^\theta (i, j) = (\Theta (l, \theta) * \Lambda (l, i, j) * E (l, i, j)^{0.2}) / 2$$
Where the above three terms represent the sensitivity to noise changes in the bands, the local brightness and the local texture activities, respectively.

Convert *HH2* sub-band from two dimensions to one dimension $HH2_{vec}$, and convert the weight factors $S_l^\theta (i, j)$ from two dimensions to one dimension $S_{l\ vec}^\theta$. Where vec = 1 to 16384.
Convert watermark logo image from two dimensions to one dimension Wi. Where i = 1 to 1024 for 32x32 logo

Partition the $HH2_{vec}$ into non-overlapping blocks B_{sub}, and Partition the $S_{l\ vec}^\theta$ into non-overlapping blocks B_w,
The total number of blocks B_{sub} is similar to the total number of blocks B_w.
w, sub = 1 to 8, and the total number of blocks = 2048.

Generate pseudo random key1 with size equal to the total number of blocks, where key1 represent indices location of both blocks (B_{sub}, and B_w).

Select the non-overlapping blocks (B_{sub}, and B_w) by key1 for embedding.
$$B1_i = B_{sub} (key1).$$
$$B2_i = B_w (key1).$$
Where i =1 to k, k = total number of blocks

Compute the average value of each block $B1_i$ for wavelet coefficients $B1_{avg}$, then Compute the modulus (mod) for the $B1_{avg}$ as divided by 2.
$$m = mod (B1_{avg}, 2)$$

Select the pixel location from each block $B1_i$ for embedding.
Embedding rule for ($B1_i$) block is:
If (watermark logo bit) Wi =1 $B1_i (n)' = m + (\beta + abs (B2_i (n) * \alpha))$,
If   *Wi =0* $B1_i (n)' = m - (\beta + abs (B2_i (n) * \alpha))$.
Where *n* represent location of the pixel for embedding, and the mark (') means after embedding.

Reconstruct the modified blocks ($B1_i'$) into vector $HH2_{vec}'$, then convert $HH2_{vec}'$ from one dimension to two dimensions. Apply the inverse DWT on the modified coefficient matrix HH2 '.
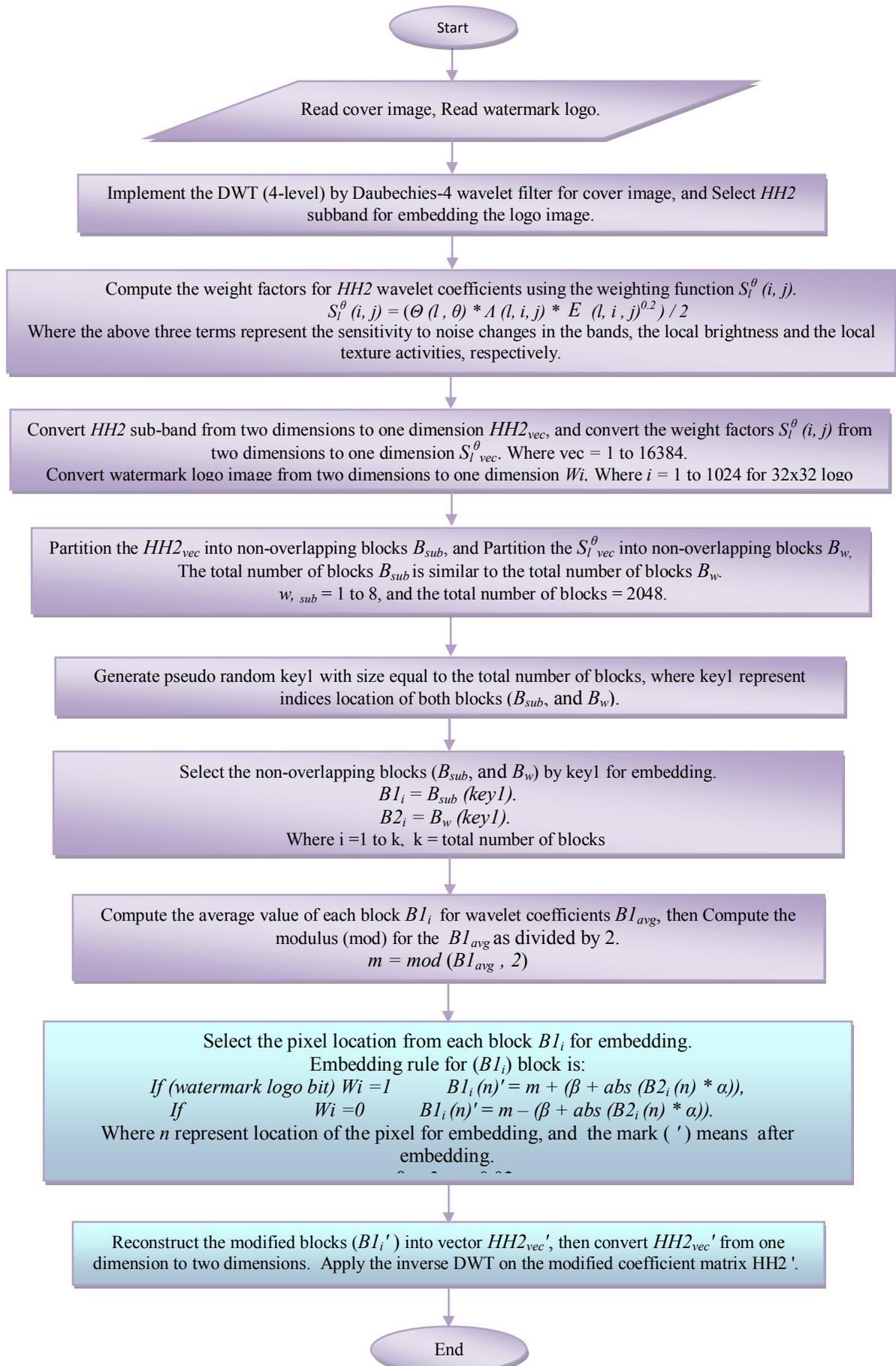
End

Figure 4: Flow diagram of embedding digital image watermark algorithm.

3.3 Watermark Extraction Procedure:

The proposed multi-level DWT algorithm is blind in the sense that watermark extraction is accomplished without referring to the original image. As depicted in the block diagram in figure (5), and the flow chart shown in Figure (6).In the watermark extraction scheme, the user can extract the watermark logo without re computing the weighting function S_l^{θ} (i, j), and then use it to extract the logo. Also the watermark strengths (α, and β) that have been used in the embedding procedure are not required to extract the watermark image. Therefore the extraction procedure will be faster. After selecting HH2 subband for extracting the watermark, convert HH2 subband from two dimensions to one dimension, then divide the vector HH2 into non-overlapping blocks with size equal to eight pixels as mentioned in the embedding procedure. The same key that was used for embedding scheme is generated to select the same non-overlap blocks. Afterwards compute the average value of each block, then calculate the modulus for this average as divided by 2. This modulus is used for logo bits extraction.
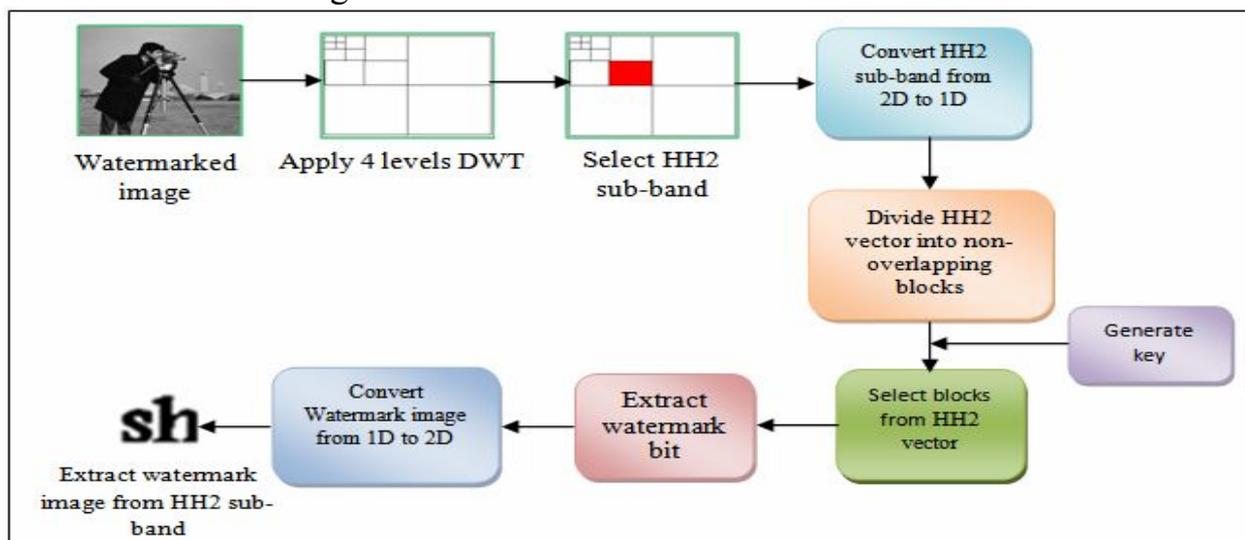
Figure 5: block diagram of extracting digital logo watermark.

In order to extract the watermark logo from watermarked image, the user must know the following requirements:-

Size of watermark logo, type of wavelet filter to decompose the watermarked image into 4-levels DWT, the locations of the non-overlapping blocks to extract from HH2 where the watermark image was embedded. Location of the pixel in each block, where the watermark logo

bit is embedded, is fixed in both embedding, and extracting. It is chosen to be the 4th pixel in each block.
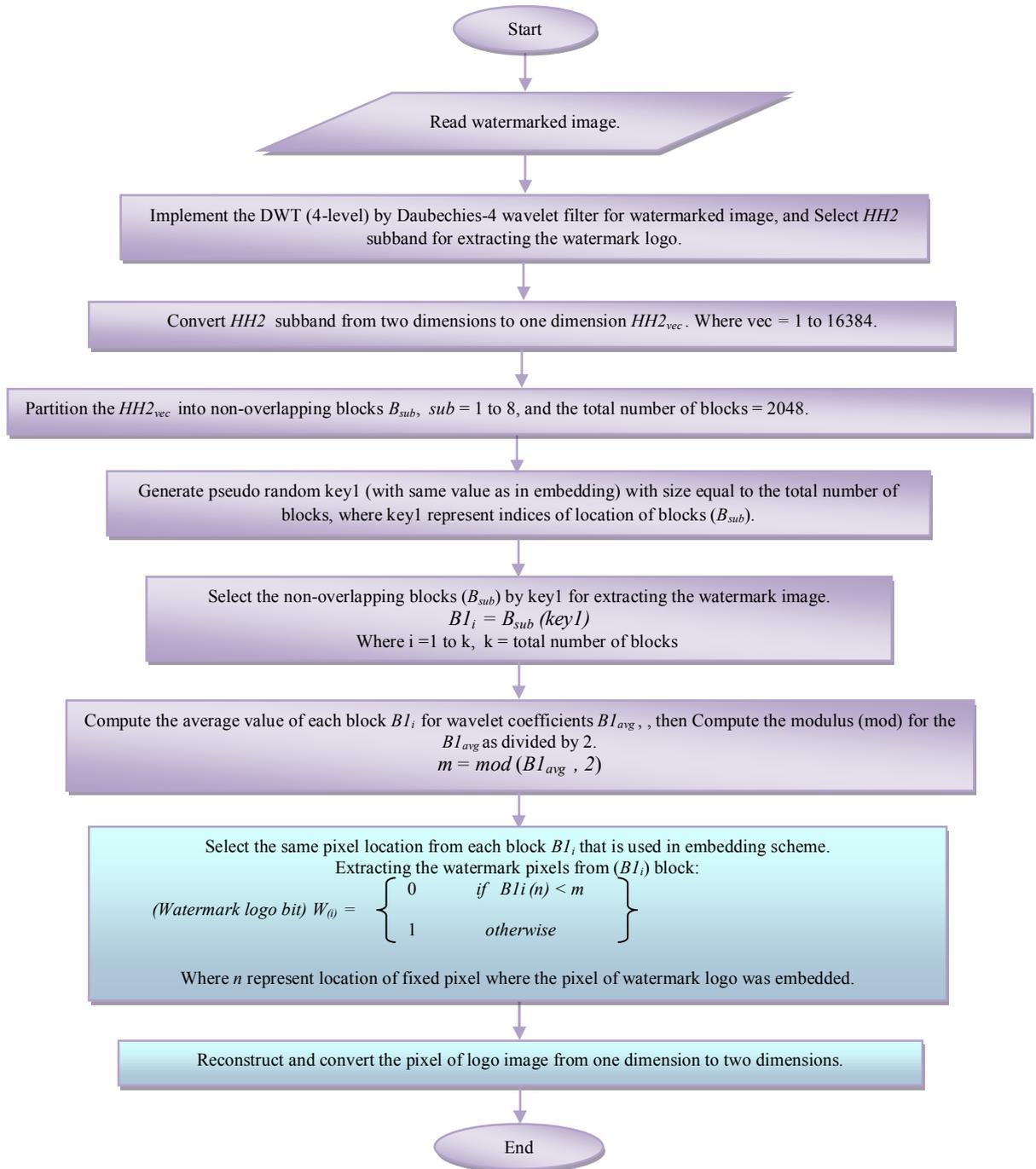
Start

Read watermarked image.

Implement the DWT (4-level) by Daubechies-4 wavelet filter for watermarked image, and Select *HH2* subband for extracting the watermark logo.

Convert *HH2* subband from two dimensions to one dimension $HH2_{vec}$. Where vec = 1 to 16384.

Partition the $HH2_{vec}$ into non-overlapping blocks B_{sub}, sub = 1 to 8, and the total number of blocks = 2048.

Generate pseudo random key1 (with same value as in embedding) with size equal to the total number of blocks, where key1 represent indices of location of blocks (B_{sub}).

Select the non-overlapping blocks (B_{sub}) by key1 for extracting the watermark image.
$$B1_i = B_{sub} \, (key1)$$
Where i =1 to k, k = total number of blocks

Compute the average value of each block $B1_i$ for wavelet coefficients $B1_{avg}$, , then Compute the modulus (mod) for the $B1_{avg}$ as divided by 2.
$$m = mod \, (B1_{avg} \, , 2)$$

Select the same pixel location from each block $B1_i$ that is used in embedding scheme.
Extracting the watermark pixels from ($B1_i$) block:

(Watermark logo bit) $W_{(i)} =$ $\begin{cases} 0 & if \ \ B1i \, (n) < m \\ 1 & otherwise \end{cases}$

Where *n* represent location of fixed pixel where the pixel of watermark logo was embedded.

Reconstruct and convert the pixel of logo image from one dimension to two dimensions.

End

Figure 6: Flow diagram of extracting digital image

4. Experimental Results:

The cover image used is an 512×512 gray scale image and the watermark logo is an 32×32 binary logo. For extracting the binary watermark logo, each pixel of the watermark logo needs one block in the host to furnish its embededment, where any change due to attacks on the block, only one pixel of the host image is affected, also one pixel of the watermark logo is affected. Figure 7 shows the 512×512 bit gray scale cover image Barbara, and mandrill, the 32×32 binary visual watermark, the watermarked cover image and the watermark constructed from HH2 subband. The Normalized Correlation (NC) is used to measure similarities of extracted watermarks. The DWT was performed using the Daubechies-4 wavelet filter. Table (1) shows (size of cover images, size of logo image) which is used for testing the proposed scheme, and Measure the quality of watermarked image similarity of extracted logo to evaluate the (imperceptibility ,robustness) of the proposed method.

| Original image (Barbara). 512×512 | Watermark logo (32x32) | Watermarked image with PSNR = 42.87 dB | Extracted watermark logo from HH2 given NC =1 |
| Original image (mandrill). 512×512 | Watermark logo (32x32) | Watermarked image with PSNR = 42.30 dB | Extracted watermark logo from HH2 given NC =1 |
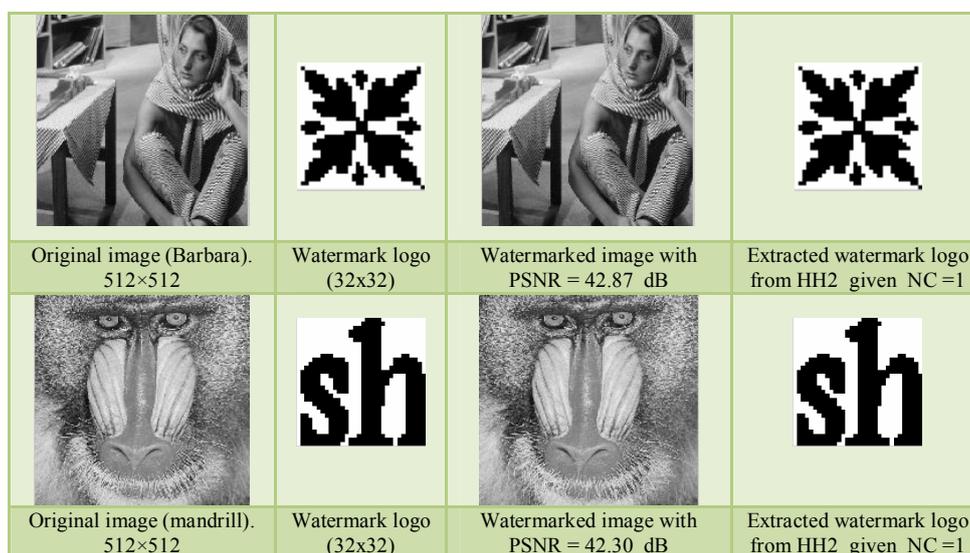
Figure 7 shows the two standard gray scale cover image with 32×32 watermark logo, watermarked image, and extracted logo.
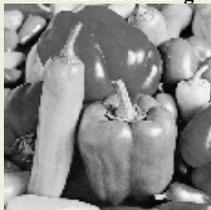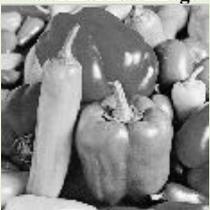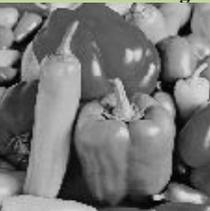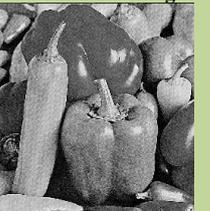
Table (1) includes the size of (cover, logo), and measure the quality of two images.

Size of cover image (gray scale)	512×512
Size of logo image (binary)	32×32
Measure the quality of watermarked image	MSE, PSNR
measure the similarity of extracted logo	NC

Various attacks are used to test the robustness of the watermark. All the attacks except image tampering and JPEG2000 attack were tested using MATLAB 7.10. JPEG2000 attack is tested using MORGAN JPEG2000 tool box, and image tampering is applied with PAINTBRUSH. Table (2) shows watermarking logo extracted from peppers 512×512 watermarked images, after exposing the watermarked image to different attacks. The Normalized Correlation (NC) is used to express quality of the reconstructed logo for each of the attacks.

Table (2) includes the constructed 32x32 watermarks from the HH2 subband by using (Daubechies-4) wavelet filter.

No attack		Wiener filtering 3x3		Gaussian Noise mean=0, variance=0.0005	
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR = 46.10 dB	NC = 1	PSNR = 36.19 dB	NC= 0.85	PSNR = 32.81 dB	NC = 0.82
Intensity adjustment From [0.2 0.8]to[0 1]		Crop image (100:400,150:450)		Crop 1/4 [th] image	
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR = 18.98 dB	NC= 0.93	PSNR = 10.26 dB	NC= 0.85	PSNR = 9.35 dB	NC= 0.8
Image tampering		Histogram Equalization		Resizing 512x512 ➔ 256x256 ➔512x512	
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR=23.89 dB	NC= 0.97	PSNR = 20.57 dB	NC= 0.94	PSNR = 31.6 dB	NC= 0.90
Row-Column blanking 10,70,100, 160,190, 230,400,450,500		Row-Column Copying 10-30,40-70, 100-120,50-160, 250-200, 330-300, 470-400 rows and columns are copied		Gaussian low pass filter 9x9, sigma 0.5	
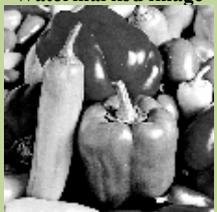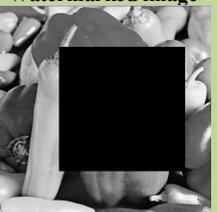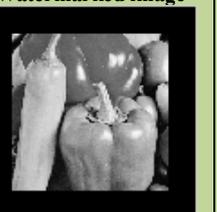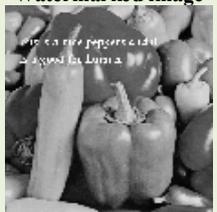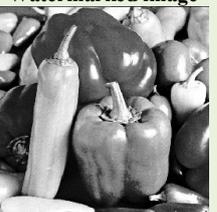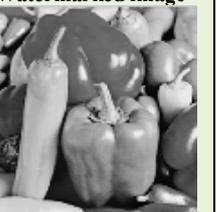
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR = 20.15 dB	NC= 0.98	PSNR = 27.56 dB	NC= 0.98	PSNR = 39.31 dB	NC= 0.99

JPEG 2000 compression 50%		JPEG 2000 compression 30%		Bit Plane Removal 3th	
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR = 45.51 dB	NC= 1	PSNR = 42.49 dB	NC= 0.97	PSNR = 36.80 dB	NC= 0.97

Salt & pepper noise 1%		Salt & pepper noise 5% and insert to median filter with size 3x3		Sharping filter 3x3 , alpha = 0.2	
Watermarked image	Watermark extracted	Watermarked image	Watermark extracted	Watermarked image	Watermark extracted
PSNR = 25.17 dB	NC= 0.77	PSNR = 33.97 dB	NC= 0.77	PSNR= 22.51 dB	NC= 0.97

5. Conclusion:

1. The proposed technique of blind digital image watermarking has been performed in multi-level DWT. The incorporation of HVS model into the proposed scheme has resulted in an efficient watermarking scheme for effective copyright protection of images.

2. The quality of the watermarked image is good in terms of perceptibility and PSNR. Which happens to be (46.20 dB) for Lena image, (46.38 dB) for boat image, (44.84 dB) for cameraman image, (42.30 dB) for mandrill image, and (46.34 dB) for goldhill image. It can be noticed that all PSNR values are higher than 40 dB which is quite acceptable for the human eye, with almost no sign of watermark existence.

3. The proposed scheme can extract the logo without need to the original logo which is embedded in the host image and this scheme can be used in any grayscale image as a host image.

4. All attacks that may alter or affect the high frequency components of the watermarked image cause deterioration for the retrieved logo. This results from the fact that embedding has been accomplished by modifying the values of some coefficients in the HH2, high frequency subband in the 2nd DWT level, as shown in table (2) for the following attacks: Gaussian Noise, salt and pepper noise, and cropping attacks.

5. The proposed scheme has satisfied both the requirements of effective copyright protection scheme: imperceptibility and robustness.

References:

[1] Alexander Sverdlov, Scott Dexter, and Ahmet M. Eskicioglu, 2005, "Robust DCT-SVD domain image watermarking for copyright protection: Embedding data in all frequencies," Proceedings of the 13th European Signal Processing Conference, submitted to Multimedia Computing and Networking Conference.

[2] Alessandra Lumini, and Dario Maio, 2011, "A Wavelet-Based Image Watermarking Scheme," in Proceedings of the IEEE International Conference on Information Technology: Coding and Computing, pp. 122-127, March.

[3] A. Zolghadrasli., S. Rezazadeh ,2007, " EVALUATION OF SPREAD SPECTRUM WA TERMARKING SCHEMES IN THE WAVELET DOMAIN USING HVS CHARACTERISTICS ", International Journal of Information Science & Technology, Volume S, Number 2.

[4] Boyd McKinnon and Xiaojun Qi, 2006,"Adaptive Wavelet-Based Family Tree Quantization for Digital Image Watermarking", Proc. of the 8th IASTED International Conference on Signal and Image Processing (SIP'06), Honolulu, Hawaii, August 14-16.

[5] Chi-Kwong Chan, and L.M. Cheng, 2004, "Hiding Data in Images by Simple LSB Substitution", Pattern Recognit, 237 (3): 469-474.

[6] Chun-Shien Lu, 2005," Multimedia security: steganography and digital watermarking techniques for protection of intellectual property", Idea Group.

[7] Faxin Yu, Zheming Lu, Hao Luo, and Pinghui Wang, 2010,"Three-Dimensional Model Analysis and Processing", Springer-Verlag GmbH.

[8] Ingemar J. Cox, Matthew L. Miller, and Jeffrey A. Bloom, 2002, "Digital Watermarking". San Francisco: Morgan Kaufmann Publishers.

[9] Jeng-Shyang Pan, Hsiang-Cheh Huang, and Lakhmi C. Jain, 2004,"Intelligent Watermarking Techniques", World Scientific Publishing Co. Pte. Ltd.

[10] Juergen Seitz , 2005 ,"Digital watermarking for digital media", Edition, Idea Group, Inc.

[11] Mauro Barni, Franco Bartolini, and Alessandro Piva, 2001, "Improved Wavelet-Based Watermarking Through Pixel-Wise Masking", IEEE Trans. Image Processing, vol. 10, pp. 783-791.

[12] S. Maruthu Perumal, B. Vijaya Kumar , L. Sumalatha and V. Vijaya Kumar, 2009, "Wavelet based Watermarking Technique using Simple Preprocessing Methods", (IJCNS) International Journal of Computer and Network Security,Vol. 1, No. 2, November.

[13] Tinku Acharya, Ping-Sing Tsai, 2005 ,"JPEG2000 Standard for Image Compression", John Wiley & Sons, Inc.

[14] V. Padmanabha Reddy, and S. Varadarajan, 2009, "Human Visual System Sentient Imperceptible and Efficient Wavelet-Based Watermarking Scheme for Copyright Protection of Digital Images", IJCSNS International Journal of Computer Science and Network Security, VOL.9 No.4.

[15] Xiang-Gen Xia, Charles G. Boncelet, Gonzalo R. Arce, 1997, "A Multi-Resolution Watermark for Digital Images," in Proceedings of the IEEE International Conference on Image Processing, vol. 1, pp. 548-551, October.