Image Watermarking Using DWT_DCT

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Abstract

Digital watermarking has been developed to protect digital images from illegal manipulation. Discrete wavelet Transform (DWT) and Discrete Cosine Transform (DCT) are techniques used for digital watermarking. A combination of DWT and DCT techniques are used in this paper to meet imperceptibility, robustness and security requirements.

Peak Signal to Noise Ratio (PSNR) and Bit Correct Ratio (BCR) measurements are used to study the effect of parameters: gain factor, threshold value, sub band, and image size on the watermark image. Many images are used to embed the watermark image and the effects of parameters on the extracted watermark image are studied. Then the optimal parameter values has been specified.

Keywords: Digital watermarking, DWT, DCT.

تضمين العلامة المائية الصورية بأستخدام DWT-DCT

الخلاصة

لقد تم تطوير تقنيات تضمين العلامة المائية الرقمية من اجل حماية الصور الرقمية من التلاعب الغير شرعي. ومن الطرق المستخدمة في عملية التضمين الرقمي هي تقنية DCT و DWT. في هذه المقالة تم استخدام طريقة تجمع بين هاتين التقنيتين حتى يتم تحقيق متطلبـــات الشفافية والمتانة والامنية. وتم استخدام كل من PSNR و BCR في دراسة تأثير كل من عامل الربح وقيمة العتبة والحزمة الجزئية وسعة الصورة على الصورة المضمنة. وعليه اســتخدمت عدة صور في اخفاء العلامة المائية لدراسة مدى تأثير المعاملات على الصورة المضمنة وتــم تحديد القيم المثالية لها.

1. Introduction

The tremendous growth in computer networks and the exponential increase of computer performance facilitate the distribution of multimedia data such as images, publishers, artists, and photographers. Pictures may be unwilling to distribute over the internet due to the lack of security.

Digital watermarks have been proposed as a way to tackle this tough issue. The digital signature could discourage copyright violation, and may help determine the authenticity and ownership of an image.

Watermarking is a technique used to hide data or identifying information within digital multimedia. The use of watermarking techniques are often evaluated based on their invisibility, recoverability, and robustness [1].

In the following, a brief description for certain related work is presented :
Elham Shahinfard and Shohreh Kasaei 2001 [2], introduced a robust multiresolution watermarking

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algorithm for copyright protection of digital images.

Serkan EMEK , Melih PAZARC 2002 [3] , described an imperceptible and a robust combined DWT-DCT digital image watermarking algorithm, this technique is used to introduce the proposed algorithm but our algorithm embed a different watermark in the DCT coafficients of H2 or V2 sub band of the image for imperceptibility and robustness consideration .

Ersin Elbasi and Ahmet M.Eskicioglu 2000 [4], proposed a DWT image watermarking algorithm that embedded a PRN sequence as a watermark.

Tahani Al-Khatib, Ali Al-Haj, 2008 [5] , proposed an effective, robust and imperceptible video watermarking algorithm based on a cascade of two transforms: Discrete Wavelets Transform (DWT) and Singular Value Decomposition (SVD).

Ali Al-Haj and Aymen Abu-Errub 2008 [6], proposed a DWT-based image watermarking that can be achieved by Genetic algorithm.

2. Principles Of DWT

The transform of a signal does not change the information content present in the signal. It is just another form to represent the signal. The wavelet transform provides time-frequency representation of the signal. It uses multi-resolution technique by which different frequencies are analyzed with different resolutions .

The Discrete Wavelet Transform (DWT) separates an image into a lower resolution approximation image (A) as well as horizontal (H), vertical (V) and diagonal (D) detail components. The process can then be repeated to compute multiple "scale" wavelet decomposition [7].

One of the many advantages over the wavelet transform is that it is believed to be more accurately model aspects of the Human Visual System (HVS) as compared to the Discrete Cosine Transform (DCT). This allows to use higher energy watermarks in regions that the HVS is known to be less sensitive , such as the high resolution detail bands {H, V}. Embedding watermarks in these regions allows to increase the robustness of the watermark, at little to no additional impact on image quality [8].

The wavelet transform gives good time resolution and poor frequency resolution at high frequencies. While at low frequencies, the wavelet transform gives good frequency resolution and poor time resolution[9].

The DWT is used to transform a sampled data into wavelet coefficients. While the IDWT (Inverse DWT) converts the wavelet coefficients into the original sampled data.

2.1 Decomposition Process [9]

Let have an image R by S, the image is high and low-pass filtered along the rows and the results of each filter are down- sampled by two. Those two sub-signals correspond to the high and low frequency components along the rows and are each of size R by S/2. Each of those sub-signals is then again high and low-pass filtered, but this time along the column data. The results are again down-sampled by two [9].

In this way the original data is split into four sub-images each of size R/2 by S/2 containing information from different frequency components. Figure (1) shows the one decomposition step of the two dimensional grayscale image. Figure (2) shows the four subbands in the typical arrangement.

The LL subband is the result of low-pass filtering both the rows and columns and contains a rough description of the image. Therefore the LL subband is also called the approximation subband. The HH subband was high-pass filtered in both directions and contains the high-frequency components along the diagonals. The HL and LH images are the result of low-pass filtering in one direction and high-pass filtering in the other direction. LH contains mostly the vertical detail information, which corresponds to horizontal edges. HL represents the horizontal detail information from the vertical edges. All three subbands HL, LH and HH are called the detail subbands, because they add the high-frequency detail to the approximation image.

2.2 Composition Process [9]

The inverse process is shown in figure (3), the information from the four sub-images is up-sampled and then filtered with the corresponding inverse filters along the columns. The two results that belong together are added and then again up-sampled and filtered with the corresponding inverse filters. The result of the last step is added together and the original image is reconstructed again.

3. PSNR and BCR measurements

An important way of evaluating watermarking algorithms is to compare the amount of distortion introduced into a host image by a watermarking algorithm. The widely used peak signal-to-noise ratio (PSNR) measurement, which measures the maximum signal to noise ratio found on an image. It has been used as an objective measure for the distortions introduced by the watermarking system. The *PSNR* is given by [10] :

$$PSNR(I, I_{WD}) = 10 \times \log\left(\frac{MAX^2}{MSE(I, I_{WD})}\right) \quad ....(1)$$

Where *MSE* is mean square error between the original image I and the watermarked image I_{WD}. The *MSE* is defined as :

$$MSE(I, I_{WD}) = \frac{1}{RxS} \sum_{x=0}^{R-1}\sum_{y=0}^{S-1}(I(x,y) - I_{WD}(x,y))^2 \quad ....(2)$$

Where R and S are the image dimensions and (MAX=255) is the maximum value of luminance . Some of the early literature considered a binary robustness metric that only allows for two different states (the watermark is either robust or not). However, it makes sense to use a metric that allows for different levels of robustness. The use of the Bit-Correct Ratio (BCR) has become common recently, as it allows for a more detailed scale of values. The bit correct ratio extracted bits to the total number of embedded bits and can be expresses using the formula in [10] :

$$BCR = \frac{100}{l}\sum_{n=0}^{l-1}\begin{cases} 1, & I'_{Wn} = I_{Wn} \\ 0, & I'_{Wn} \neq I_{Wn} \end{cases} \quad ....(3)$$

where l is the watermark length, I_{Wn} corresponds to the n^{th} bit of the embedded watermark and I'_{Wn} corresponds to the n^{th} bit of the recovered watermark .

4. DWT_DCT Technique

The DWT_ DCT technique is used which is mentioned in [3]. It combines DWT and DCT to provide watermarking system with high imperceptibility and robustness. This technique will be used to proposed DWT_DCT technique but by using different watermark encrypted with AES and the embedding process will be only in the *H*2 or *V*2 sub band to achieve higher imperceptibility, security and robustness, the introduced technique can survive attacks like JPEG compression, noise. The watermark image is encrypted with AES and then it will be embedded in H2 or V2 sub band to achieve higher imperceptibility security and robustness. This technique can be explained by the embedding and extracting processes.

4.1 Embedding Process :

The embedding process is explained in the following steps :

Step 1: A DWT is applied to the image *I(x,y)* by using the Daubechies filters (which is filter used apply DWT to the image), but the two level DWT decomposition is applied to H subband as in Figure (4).

Step 2: Apply the DCT to the particular horizontal or vertical (*H*2 or *V*2) subband in order to increase robustness against attacks like compression or cropping. Order the DCT coefficients into a zig-zag order, such as in the JPEG compression algorithm. In order to obtain a tradeoff between perceptual invisibility and robustness to image processing techniques, the lowest *L* coefficients are skipped and the watermark is embedded in the next *L*+*M* DCT coefficients (where *M* is the middle frequency coefficients).

Step 3: Re-formulate the grey-scale watermark image into a vector of zeros and ones. Generate two uncorrelated pseudo random sequences (PN). One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is used to embed the watermark bit 1 (PN_1) . Embed the two pseudorandom sequences, PN_0 and PN_1, with a gain factor (*K*=2), in the DCT transformed coefficients (*B*) of the select DWT sub bands of the host image. Embedding is not applied to all coefficients of the DCT block, but only to the mid-band DCT coefficients.

Step 4: The process can be made image dependent by modulating the DWT coefficients of *V* or *H* bands to increase the efficiency of the watermark embedding as follows :

$$I_{WD(V,H)}(x,y) = I_{V,H}(x,y) + K.B.I_W(x,y) \quad .(4)$$

Step 5: Apply inverse DCT (IDCT) to each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step.

Step 6: Apply the inverse DWT (IDWT) on the DWT transformed image, including the modified subband, to produce the watermarked host image.

4.2 Extraction Process In the extraction process the watermark is extracted and the watermarked image is submitted to several attacks to judge the performance of the algorithm according to the survival of the watermark or not. The following steps describe the extraction process:

Step1&3: As in the embedding process 1 and 2 steps.

Step 3: Regenerate the two pseudorandom sequences (PN_0 and PN_1) using the same seed used in the watermark embedding procedure. For each block in the subband HL2 (or HH2), calculate the correlation between the mid-band coefficients and the two generated pseudo random sequences (PN_0 and PN_1). If the correlation with the PN_0 was higher than the correlation with PN_1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1. Reconstruct the watermark using the extracted watermark bits, and the similarity measurement (*sm*) is calculated for each 8x8 DCT block of *V* and *H* sub bands , as follows :

$$I_{V,H}(x,y) = DCT\{J(x,y), J \in (V_n, H_n), 1 \le n \le 4\}$$

$$I_{WD(V,H)}(x,y)^* = I_{WD(V,H)}(x,y)\, I_W(x,y)$$

$$E\left[I_{WD(V,H)}(x,y) I_{WD(V,H)}(x,y)^*\right] = E\left[\left(I_{V,H} + K I_{V,H} I_W\right)^2 I_W\right] \quad \textbf{(5)}$$

$$sm_W = E\left[I_{V,H}{}^2\, I_W\right] + 2KE\left[I_{V,H}{}^2 I_W{}^2\right] + \left[K^2 E[I_{V,H}{}^2 I_W{}^3\right]$$

$$sm_V > sm_H \rightarrow c_v = c_v + 1$$

$$sm_H > sm_V \rightarrow c_h = c_h + 1$$

Step 4: For the detection decision, use :

$$sm_{WH} > th_{WH} \;\&\; sm_{WV} > th_{WV} \;\&\; c_h > c_v \rightarrow H\ watermarked$$

$$sm_{WV} > th_{WV} \;\&\; sm_{WH} > th_{WH} \;\&\; c_v > c_h \rightarrow V\ watermarked$$

….(6)

$$sm_{WH} > th_{WH} \;\&\; sm_{WV} < th_{WV} \;\&\; c_h \cong c_v \rightarrow false\ Detection$$

$$sm_{WH} < th_{WH} \;\&\; sm_{WV} < th_{WV} \;\&\; c_h \cong c_v \rightarrow No\ Watermark$$

The values of gain factor, PN sequences, seeds and thresholds which are listed in Table (1). They have been chosen after trying many values and we choose these values because they give the best results according to the high PSNR and BCR values as explained next .

5. DWT_DCT Evaluation

Peak Signal To Noise Ratio (PSNR) and Bit Correct Ratio (BCR) are used to evaluate the DWT_DCT technique after subjecting the watermarked image to different types of attacks. The effect of changing the algorithm's parameters like: subbands (A,H,V,D), gain factor (*K*), thresholds (*th*) and image sizes (256,512) on the watermarked image and watermark are described in the next sections .

5.1 The effect of gain factor

In the used technique, several values of gain factor (K) are used (from 1 to 2.4) and the PSNR values are calculated as shown in Table (2). The higher value of PSNR means the better quality of the watermarked images.

In the case of the gain factor (*K*=2), the PSNR value is higher and the watermarked image have a good quality, while other PSNR values are lower and the watermarked images are more distorted. Figure (5) shows the relation between the gain factor and PSNR.

5. 2 The effect of threshold

In the horizontal subband (*H*), the threshold (*th*) is set to (60) after trying many values because this value offering good quality to the extracted watermark image. While the watermark image is distorted for the other values as shown in the Table (3). In the case of *th* (60), the BCR value is the higher, while the BCR values are lower for the other threshold values. Figure (6) shows the relation between the threshold values and BCR.

In the vertical subband (*V*), many threshold values are tested (from 40 t0 60). As shown in the Table (4), the threshold value of 50 has higher BCR value. This value offers good quality to the extracted watermark image. Figure (7) shows the relation between the threshold and BCR.

5. 3 The effect of subband

When DWT separates the image into four subbands (*A, H, V, D*), the watermark image embedded in (*H,V*) subbands because these subbands contains the high frequency information of the image, so the Human Visual System (HVS) cannot notice adding the watermark information in such bands. In the DWT_DCT technique, the watermark is embedded in the *H* or *V* sub band, the results of PSNR and BCR values are higher which offers a good quality of the watermarked image. *A* and *D* bands are not preferred due to perceptibility and robustness concerns as the results showed. Embedding in the *A* and *D* subband makes the watermarked images suffer from high distortion, and the corresponding PSNR and BCR values are low as shown in Figure (8).

5.4 The effect of image size

The size of the image affects the watermarked image and it depend on both the watermark and the image type. The results shows that watermark image that extracted from the watermarked image of size (256x256) is suffering from a lot of distortion, while the watermark image is successfully extracted from the watermarked image of size (512x512) as shown in Figure (9) :

5.5 The effect of JEPG compression

The watermarked image is subjected to compression at different values of quality factor. The watermark image is successfully retrieved after compression with a quality factor: 30, 40, 50 and 60 and the corresponding BCR values are high, while the BCR values become low and the extracted watermark is distorted with a quality factor over 70 as shown in Table (5) and Figure (10).

Table (5) : BCR values for different compression

5. Conclusions

In this paper a robust technique of image watermarking based on DWT and DCT is used. The effect of gain factor, threshold value, sub band and image size parameters is experimented. From the results, it is found that the best value of gain factor is 2 which has the highest PSNR value. The H and V sub bands show the lowest effects on the watermarked image's quality where their PSNR and BCR values are higher than in A and D sub bands. The best threshold value is 60 for H sub band where it is 50 for V sub band. The watermark image is affected by the image size. When the image size is large, the watermark image will be successfully extracted from the watermarked image. The compression quality factor affects on the retrieved watermark image. When the quality factor is above 60, the BCR values become low which lead to distort the extracted watermark image.

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Table (1): The optimal parameter values.

Gain factor *(K)*	2
PN_0 and PN_1	{0,1}
Seed (PN_0)	1000
Seed (PN_1)	900
th (H)	60
th (V)	50

Table (2): PSNR values

K	PSNR (dB)
1	32.901
1.2	33.174
1.4	33.882
1.6	35.985
1.8	38.749
2	40.873
2.2	37.328
2.4	33.157

Table (3): BCR value

th (H)	BCR (bits)
50	**0.429**
54	**0.705**
58	**0.849**
60	**0.995**
62	**0.815**
66	**0.331**
70	**0.283**

Table (4): BCR value

th (V)	BCR (bits)
40	**0.415**
44	**0.691**
48	**0.864**
50	**0.991**
52	**0.822**
56	**0.652**
60	**0.229**

Table (5): BCR values for different compression

Compression	BCR (bits)
30	0.997
40	0.995
50	0.871
60	0.832
70	0.485

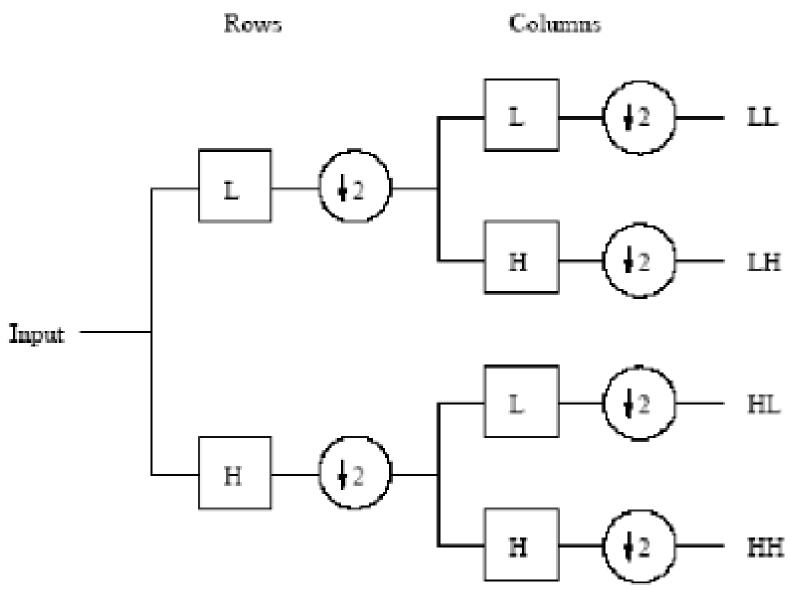


Figure (1): One decomposition step of the two dimensional image [9]

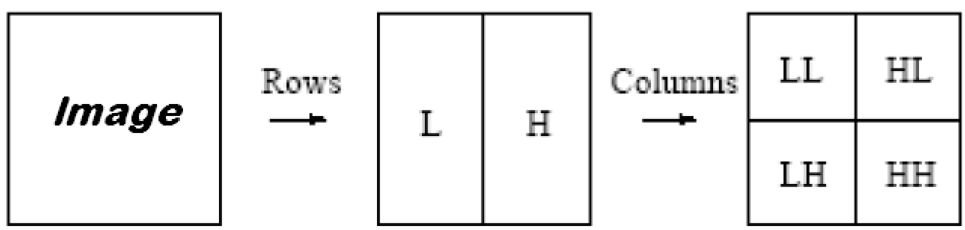


Figure (2): One DWT decomposition step [9]

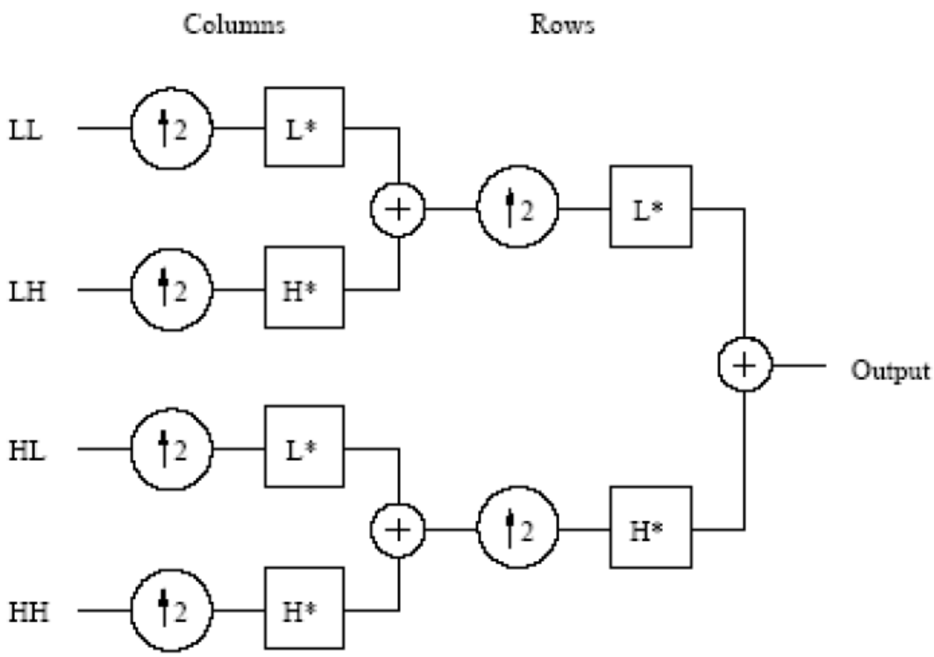


Figure (3): One composition step of the four sub images [9]

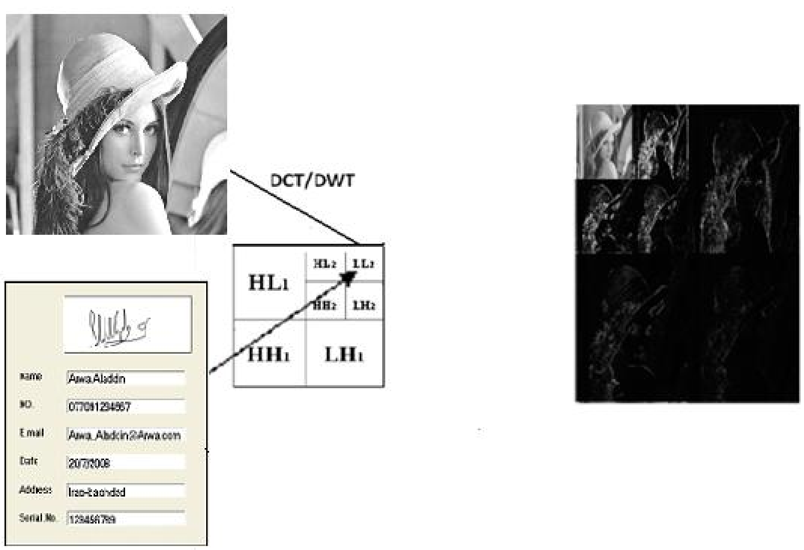


Figure (4): DWT applied to H subband

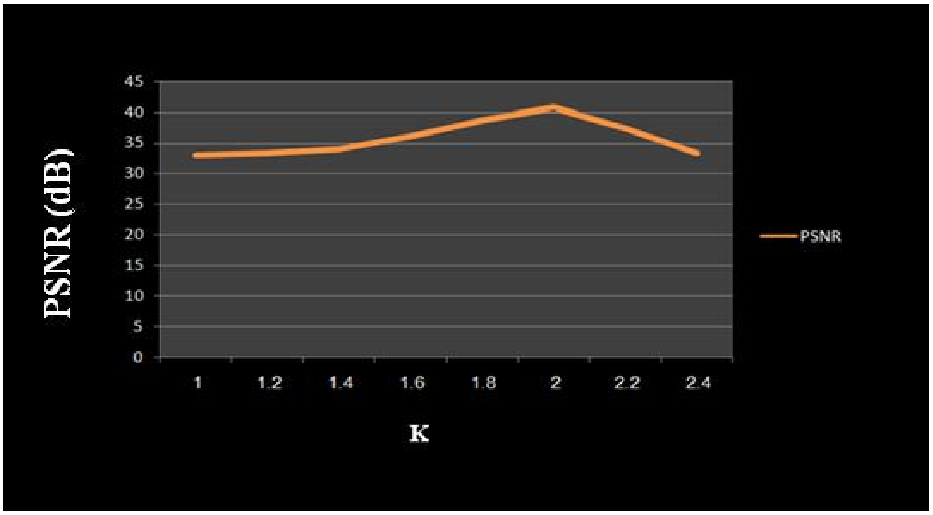


Figure (5) : The relation between the gain factor and PSNR

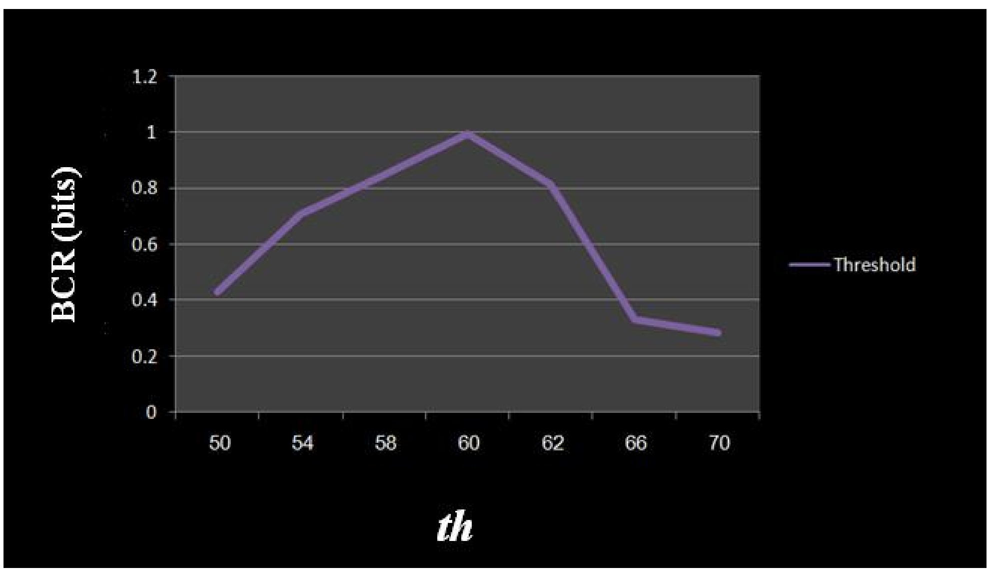


Figure (6): The relation between the threshold and BCR

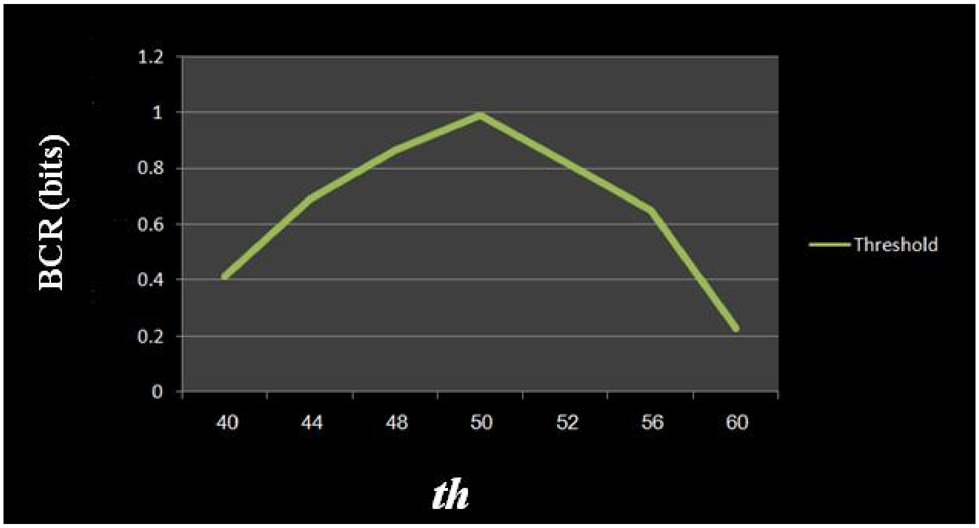
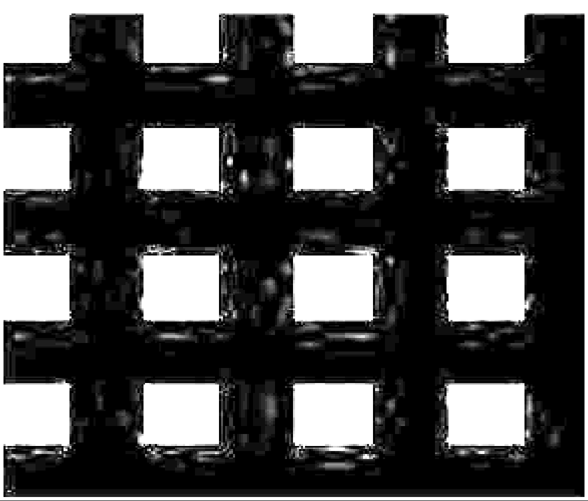
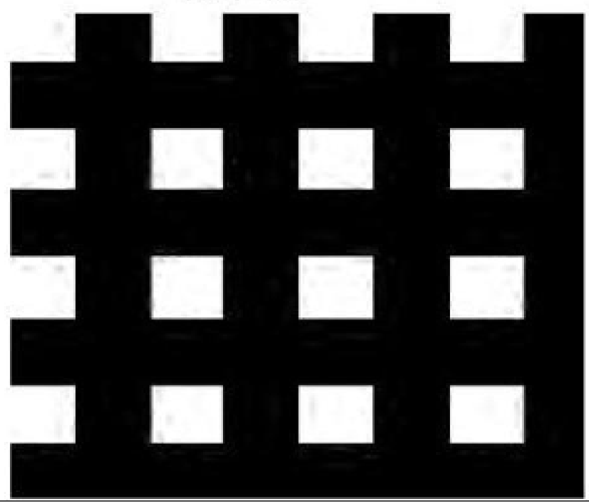
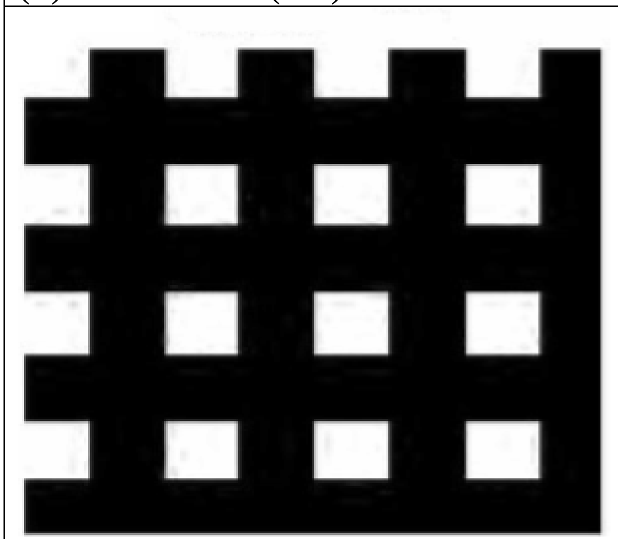
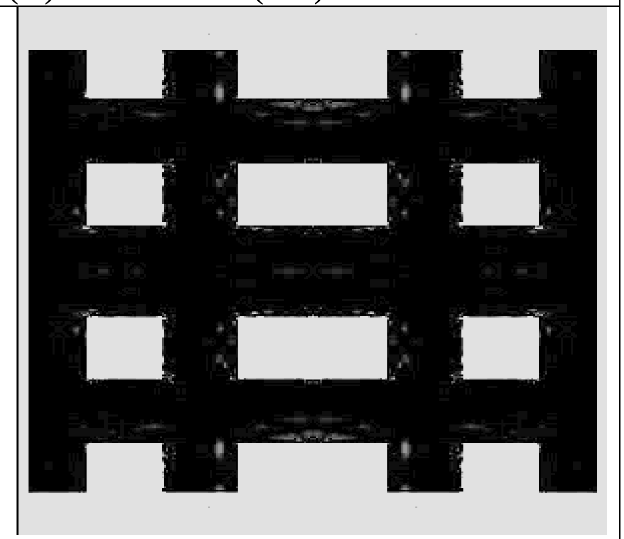


Figure (7): The relation between the threshold values and BCR

(*A*) BCR= 0.534(bits) PSNR=18.359dB	(*H*) BCR= 0.995(bits) PSNR=40.873dB
	

(a)

Figure (8) (a) The effect of A and H sub bands on BCR and PSNR values.

(*V*) BCR= 0.991(bits) PSNR=40.192dB	(*D*) BCR= 0.497(bits) PSNR= 19. 748dB
	

(b)

Figure (8) (b) the effect of V and D sub bands on BCR and PSNR values.

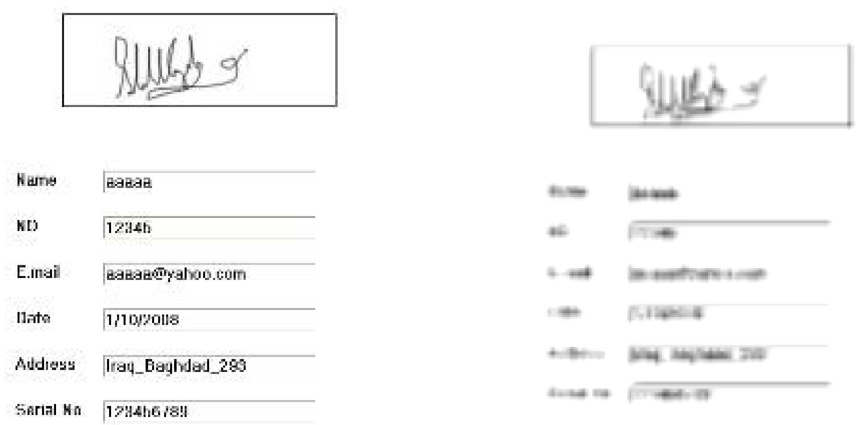


Figure (9): The effect of image size on the extracted watermark images

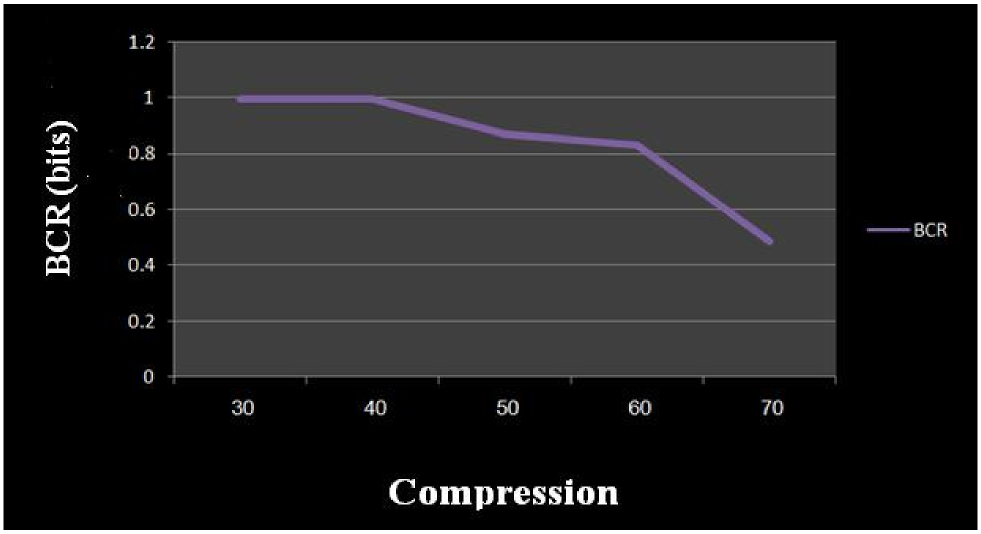


Figure (10): The relation between compression factor and BCR