

**International Journal of Enterprise Computing and Business
Systems**

ISSN (Online) : 2230-8849

<http://www.ijecbs.com>

Vol. 1 Issue 2 July 2011

**A NOVEL SECURE, IMPERCEPTIBLE AND ROBUST CDMA
DIGITAL IMAGE WATERMARKING IN JPEG-YCBCR CHANNEL
USING DWT2**

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ABSTRACT

Digital watermarking has been widely used in digital rights management and copyright protection. In this paper, a new cryptographic CDMA watermark scheme is proposed. Compare to the existing watermarking techniques, this proposed watermarking scheme combine imperceptibility, security and robustness that none of the existing schemes can do. In this paper a wavelet-based watermarking approach for hiding watermark image in color host images is proposed. The experimental results show that the proposed approach provides extra imperceptibility, security and robustness against JPEG compression and different noise attacks such as Gaussian and salt & pepper compared to the similar proposed methods such as [5]. Moreover, the proposed approach has no need of the original image to extract watermarks.

Keywords : Adopted watermark, digital watermarking, CDMA, DWT2, JPEG-YCbCr, pseudo- random number generator.

1. Introduction

Nowadays, watermarking of images is becoming increasingly of interest in tasks such as copyright control, image identification, verification, and data hiding [4]. Advances in computer networking and high speed computer processors have made duplication and distribution of multimedia data easy and virtually costless, and have also made copyright protection of digital media an ever urgent challenge. As an effective way for copyright protection, digital watermarking, a process which embeds (hides) a watermark signal in the host signal to be protected, has attracted more and more research attention [1-3]. A variety of watermarking techniques has been proposed in recent years. One of the earlier watermarking techniques, which used wavelet transform, was based on the adding pseudo random codes to the large coefficients at the high and middle frequency bands of the discrete wavelet transform [6]. This paper is allocated to CDMA digital images watermarking for ownership verification and image authentication applications, which for more security, watermark W is converted to a sequence and then a random binary sequence R of size n is adopted to encrypt the watermark, where n is the size of the watermark. This adopting process uses a pseudo-random number generator to determine the pixel to be used on a given key. This adopted watermark embeds into the selected subbands coefficients of Y channel of JPEG-YCbCr of host image using the correlation properties of additive pseudo-random noise patterns. Because, watermarking in YCbCr color space versus image processing attacks is more robust than watermarking in RGB color space, and has higher transparency [7]. Obtained results of the experiments show the efficiency of proposed technique in acceptable transparency, high security and robustness against jpeg compression and different noise attacks such as Gaussian and salt & pepper in comparing earlier works such as [5].

2. CDMA

CDMA (Code Division Multiple Access) is a form of spread spectrum where the signal i.e., watermark information, is transmitted on a bandwidth much greater than the frequency content of the original information, in this case, an image. In other words the transmitted signal bandwidth is much greater than the information bandwidth. Spread spectrum uses wide-band, noise-like signals, hence making it hard to detect. The band spread is accomplished by a pseudo-random code, which is independent of the data [14].

3. JPEG-YCbCr

YCbCr color model is a chroma model of CCIR601 coding mode, which is widely used in color display of TV and so on. In this color space, The Y denotes the luminance component. It means that Y shows the brightness (luma). Also both of Cb and Cr represent the chrominance actors. It means that Cb is blue color minus luma (B_Y) and Cr is red color minus luma (R_Y) [10].

The cause of use YCbCr color space was for six reasons [10]. (1) The luminance component (Y) can be adopted to solve the illumination variation problem and it is easy to program because of its independency of the color. (2) According to [9], in YCbCr color space, the skin color cluster is more compact than in other color spaces. (3) YCbCr color space has the smallest overlap between skin and non-skin data in under various illumination conditions. (4) YCbCr color space is very useful in video compression standards (e.g., MPEG and JPEG) [15]. (5) YCbCr color space is a family of color spaces used in video systems. YCbCr color space was defined for standard-definition television use in the ITU-R BT.601 standard for use with digital component video. (6) YCbCr color space accompanied by RGB color space are two primary color spaces used to represent digital component video. JPEG-YcbCr is a rescaling of YCbCr which used in the JPEG image format, with Y, Cb and Cr in [0,1]. The transform from RGB to JPEG- YCbCr and the backward transform from JPEG- YCbCr to RGB are as follow:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix} + \begin{bmatrix} 0.29890 & 0.58660 & 0.11450 \\ -0.16874 & -0.33126 & 0.50000 \\ 0.50000 & -0.41869 & -0.8131 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \& \quad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.40200 \\ 1 & -0.34414 & -0.71414 \\ 1 & 1.7720 & 0 \end{bmatrix} \times \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} - \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

4. Proposed Watermarking Scheme

The current study task of digital watermarking is to make watermarks invisible to human eyes as well as robust to various attacks. The proposed watermarking scheme can hide visually recognizable patterns in images. This scheme is based on the discrete wavelet transform (DWT). Moreover, it has no need of the original host image to extract the

embedded watermarks. RGB color space is highly correlated and is not suitable for watermarking applications [8]. So, in the proposed scheme, the host image is converted into JPEG-YCbCr channels; the Y channel is then decomposed into wavelet coefficients. For more security of watermark, the watermark W is converted to a sequence and then a random binary sequence R of size n is adopted to encrypt the watermark, where n is the size of the watermark. This adopting process uses a pseudo-random number generator to determine the pixel to be used on a given key. The selected details subbands coefficients for embedding i.e. HL and LH coefficients are quantized and then their most significant coefficients are embedded by the adopted watermark using the correlation properties of additive pseudo-random noise patterns according to equation shown in below:

$$I_{W_{x,y}}(u,v) = \begin{cases} I_{x,y} + k * W_i & \text{if } W = 0 \\ I_{x,y} * W_i & \text{Otherwise} \end{cases} \quad (2)$$

In this equation k denotes a gain factor for completely controlling the imperceptibility of watermarked images and the robustness of watermarks and also I_w is the resulting watermarked image. This adaptive casting technique is utilized to embed the watermark coefficients for completely controlling the imperceptibility of watermarked images and the robustness of watermarks. To retrieve the watermark, after converting watermarked image from RGB color space to GPEG-YCbCr channels, the Y channel will be decomposed into the wavelet coefficients. Then the same pseudo-random noise generator algorithm is seeded with the same key, and the correlation between the noise pattern and possible watermarked image in details subbands embedded coefficients will be computed. By computation of the each coefficient correlation whit a certain threshold T , the watermark is detected, and a single bit is set. The block diagram of the proposed watermarking scheme is shown in Fig (1).

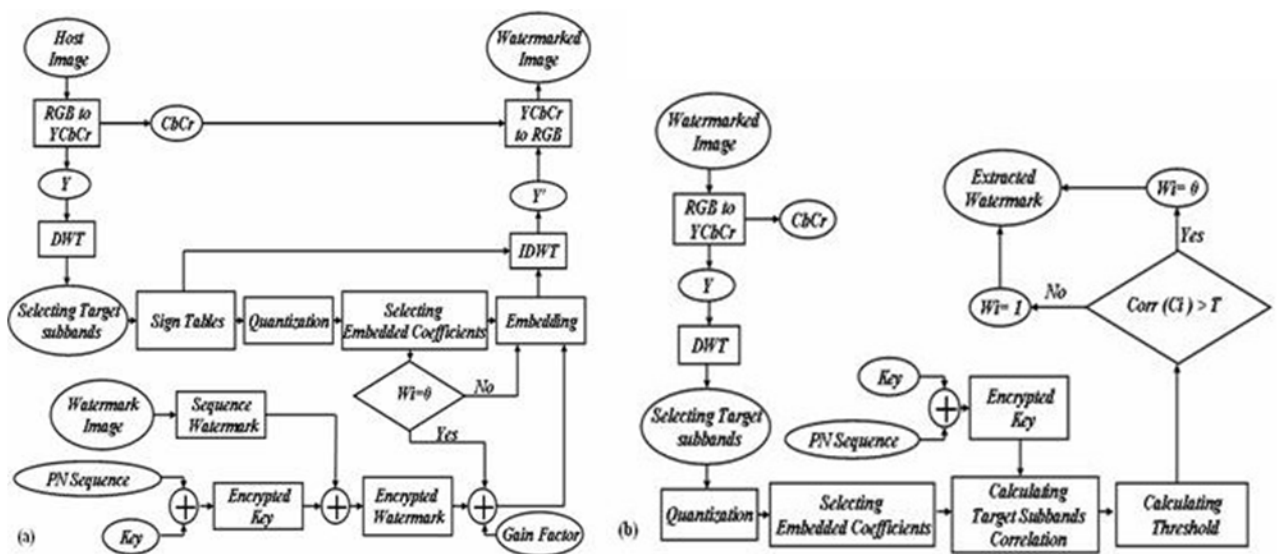


Fig 1. Block diagrams of the proposed watermarking scheme.
(a)Embedding procedure. (b)Extracting procedure.

4.1. Watermark embedding Framework

The algorithm for embedding watermark in details subbands coefficients of the Y channel of host image is described as follows:

Step 1: Convert RGB channels of the host image I into JPEG-YCbCr channels using equation (1).

Step 2: For more security of watermark, the watermark W is converted to a sequence and then a random binary sequence R of size n is adopted to encrypt the watermark, where n is the size of the watermark image. Then, the encrypted watermark sequence $W1$ is generated by a pseudo- random number generator to determine the pixel to be used on a given key.

Step 3: Decompose the Y channel into a one-level wavelet structure with four DWT subbands, $F(H)$. The coarsest coefficient of subbands HL and LH are taken as the target for embedding the watermark.

Step4: Take absolute values on coefficients of all LH and HL, and record their signs in sign matrices.

Step 5: Quantize absolute values of selection coefficients.

Step 6: Embed encrypted watermark $W1$ into the coarsest coefficient of subbands HL and LH by the watermark embedding strategy shown in equation (2).

Step 7: Effect sign matrices into the embedded coefficients.

Step 8: Reconvert JPEG-YCbCr channels of the changed host image into RGB channels.

Step 9: A watermarked image I' is then generated by inverse DWT with all changed and unchanged DWT coefficients.

Step 10: Record the pseudo-random noise generator algorithm and the key.

4.2. Watermark extracting Framework

The embedded watermark in details subbands coefficients of the Y channel of host image is extracted using the same pseudo-random noise generator algorithm is seeded with the same key, and computation of the correlation between the noise pattern and possible watermarked image as follows:

Step 1: The RGB channels of the watermarked image are converted into JPEG-YCbCr channels.

Step 2: Decompose the Y channel into four DWT subbands.

Step 3: Seeding the recorded key using the recorded pseudo-random noise generator algorithm.

Step 4: Quantize absolute values of HL and LH subbands.

Step 5: Computation of threshold T as follows:

$$T = \frac{\text{Correlation}(HL) + \text{Correlation}(LH)}{2} \quad (3)$$

Step 6: Computation of the threshold T and each embedded coefficient correlation, separately.

Step 7: The sequence watermark is extracted as follows:

$$\begin{cases} W_i = 0 & \text{if } C_i > T \\ W_i = 1 & \text{Otherwise} \end{cases} \quad (4)$$

Step 8: The image watermark is produced by reconvertng the extracted sequence watermark.

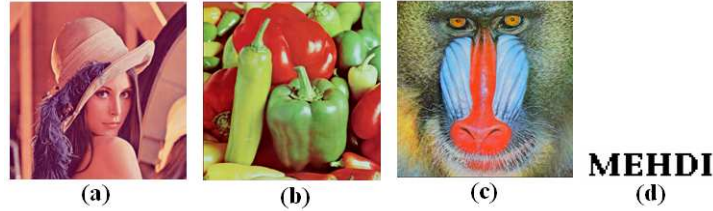
5. Experimental Results

Robustness is the most highly desired feature of a watermarking algorithm especially if the application demands copyright protection, and persistent owner identification.

The proposed perceptual watermarking scheme was implemented for evaluating both properties of imperceptibility and robustness against different attacks such as jpeg compression and noise.

Three 512x512 famous images: Lena, Peppers and Baboon, shown in Fig. 2(a-c) were taken as the host images to embed a 15x64 binary watermark image, shown in Fig 2(d). For gain factor k, different values 0.5, 1.0 and 1.5 were taken entire implementation of the proposed CDMA scheme. For the entire test results in this paper, MATLAB R2007a software

is used, too. 9 digit "key" used as initial state of MATLAB random number generator. Also for computation of the wavelet transforms, 9-7 biorthogonal spline (B-spline) wavelet filters are used. Cause of use of B-spline function wavelet is that, B-spline functions, do not have compact support, but are orthogonal and have better smoothness properties than other wavelet functions [6, 10].



**Fig 2. (a-c) The host images (Lena, Peppers, and Baboon).
(d) The watermark image.**

After watermark embedding process, the similarity of original host image x and watermarked images x' was measured by the standard correlation coefficient (Corr) as follows [4, 7, 11]:

$$Correlation = \frac{\sum (x - x')(y - y')}{\sqrt{(x - x')^2} \sqrt{(y - y')^2}} \quad (5)$$

where y and y' are the discrete wavelet transforms of x and x' , respectively. Moreover, the peak signal-to-noise ratio (PSNR) was used to evaluate the quality of the watermarked image. The PSNR is defined as [4, 7, 11]:

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \quad (dB) \quad (6)$$

where mean-square error (MSE) is defined as [5, 7, 11, 12]:

$$MSE = \frac{1}{mn} \sum_{i=1}^m \sum_{j=1}^n (h_{i,j} - h'_{i,j})^2 \quad (7)$$

Where $\{h_{i,j}\}$ and $\{h'_{i,j}\}$ are the gray levels of pixels in the host and watermarked images, respectively. The larger PSNR is, the better the image quality is. In general, a watermarked image is acceptable by human perception if its PSNR is greater than 30 dBs. In other words, the correlation is used for evaluating the robustness of watermarking technique and the PSNR is used for evaluating the transparency of watermarking technique [4, 7 and 11].

Also the normalized correlation (NC) coefficient was used to measure the similarity between original watermarks W and the extracted watermarks W' that is defined as [4, 7, 11]:

$$NC = \frac{\sum_i \sum_j w_{i,j} * w'_{i,j}}{\sum_i \sum_j w_{i,j}^2} \quad (8)$$

The proposed CDMA watermarking scheme yields satisfactory results in watermark imperceptibility and robustness. The embedding of large watermarks using CDMA requires the embedding gain k to be lowered to preserve the visual quality of the image. The obtained results show that larger gains are reason that CDMA will be remained as more PN sequences are added to the host image but it will be caused to decrease the transparency of the image, because of decreasing correlation between original image and watermarked image. Also, this results show that, the best compression can be made with CDMA, although CDMA is more resistant to different noise attacks such as Gaussian and salt & pepper. The PSNRs of the watermarked images produced by the proposed scheme for different gain factors k are all greater than 87 dBs, NCs between original watermark images and extracted watermark images are all equal 1,. The results for effecting k on PSNRs, correlation between original images and watermarked images and NSs between original watermark images and extracted watermark images are illustrated in Figure (3) and table (1). The PSNR and correlation plots shown in figure (3) indicates that the proposed scheme satisfy imperceptibility as well. After able to achieve the desired fidelity, various attacks were performed to test the robustness of the proposed scheme and it was found, that the proposed scheme performs excellently against JPEG compression and different noise attacks.

Table 1. Obtained results of watermark extracting with different values and gain factors k

Image	k	PSNR (dB)	Corr	NC	Error Bit %
Lena	0.5	106.31	0.9992	1.00	0
	1.0	96.36	0.9959	1.00	0
	1.5	87.45	0.9654	1.00	0
Baboon	0.5	106.30	0.9993	1.00	0
	1.0	94.37	0.9968	1.00	0
	1.5	87.42	0.9874	1.00	0
Peppers	0.5	106.29	0.9991	1.00	0
	1.0	94.32	0.9951	1.00	0
	1.5	87.34	0.9810	1.00	0

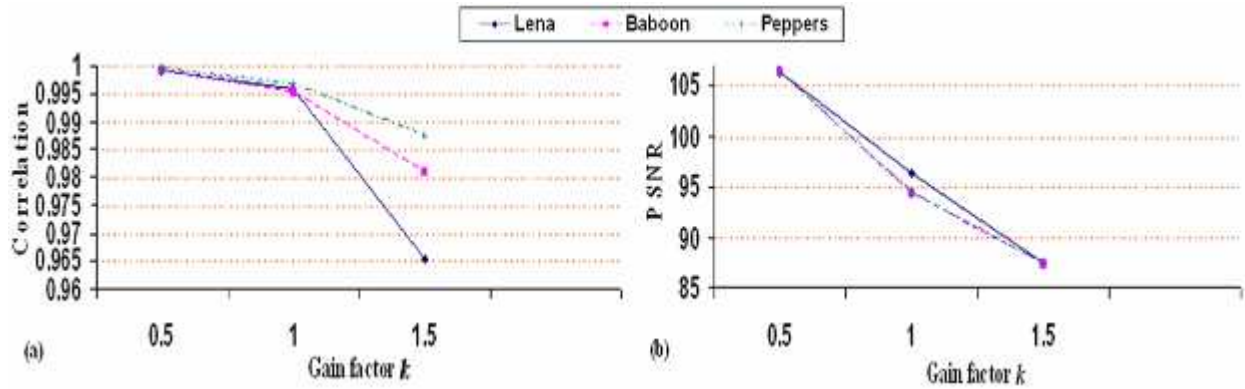


Fig 3. (a) Influence of the gain factor k on correlation.
(b) Influence of the gain factor k on PSNR.

5.1. Robustness to Compression Attacks

To evaluate the response of the watermarking scheme to JPEG compression, watermarked images were compressed with different JPEG qualities Q_s . Figure (4) shows the JPEG compression of the watermarked images under quality 10 and gain factor 1. Figure (5) shows the extracted watermarks from watermarked images after JPEG compression under different qualities and different gain factors. Comparing with the similar reference [12], whether the effect of the extracted watermark or the robustness to the JPEG compression have been improved greatly. To the similar references [5, 12], we compared the experimental results respectively under different JPEG qualities and gain factors.

The percentage of the error bit for extracted watermarks under JPEG compression is shown in figure (6). As it is seen, the percentage of error bit plot shown above indicates that the margin of error is very less for the detection statistic, and CDMA proposed scheme has increased in comparing with the earlier works such as [5]. Table (2), shows the response of the detector to extract the watermark in JPEG compression. From the above results it can be said that for JPEG compression with a quality factor of 75 and gain factor 0.5, a quality factor of 50 and gain factor 1 and also a quality factor of 15 and gain factor 1.5 the watermark detection and extraction is near perfect. The recovered watermark for a quality factor of 25 and gain factor 1 shows a number of detection errors and this only becomes highly noticeable for a quality factor of 15 and gain factor 1. The watermark is still recognizable for a quality factor of 10 and gain factor 1. The overall robustness of proposed scheme for JPEG compression is considered high level, according to the robustness requirements table provided by Petitcolas [13] and is higher than earlier works such as [5]. It can be seen that

the proposed scheme is more robust than earlier works such as [5] against JPEG compression, even for low JPEG quality.

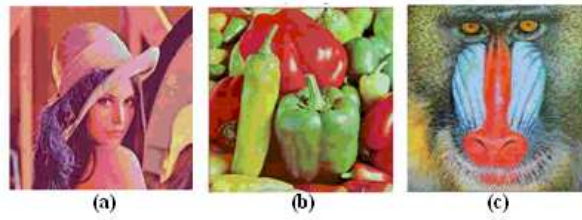


Fig 4. Watermarked images under JPEG compression (Q=10, k=1).
(a) Lena, (b) peppers and (c) Baboon

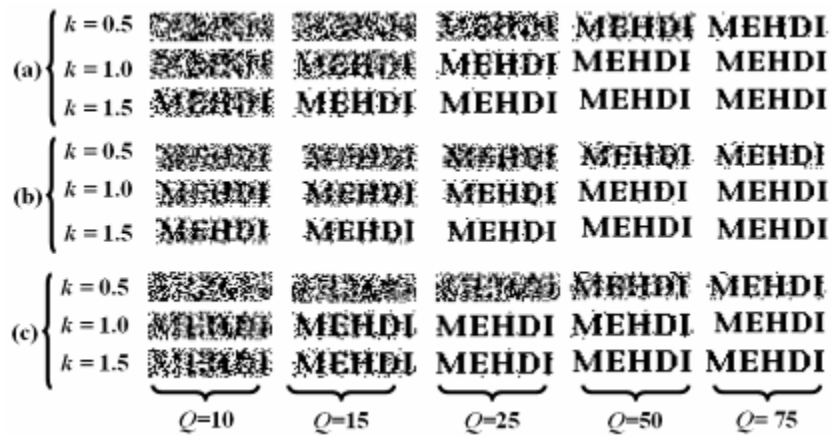


Fig 5. Extracted watermarks from watermarked images after JPEG compression with different values for Q and k. (a) Lena, (b) Baboon, and (c) Peppers.

Table 2. Obtained results of extracted watermarks in JPEG compression under different qualities and gain factors

k=0.5

Image	Q	10	15	25	50	75
Lena	NC	0.089	0.1680	0.4243	0.8027	0.9681
	PSNR(db)	90.66	93.34	96.15	99.38	102.75
Baboon	NC	0.0943	0.1576	0.3109	0.7283	0.9549
	PSNR(db)	86.03	88.06	90.02	92.23	94.29

Peppers	NC	0.3270	0.3978	0.5569	0.7572	0.8997
	PSNR(db))	72.90	81.50	83.34	85.92	88.64

k=1.0

Image	Q	10	15	25	50	75
Lena	NC	0.2593	0.5353	0.8852	0.9953	1.00
	PSNR(db))	87.25	89.05	91.00	93.78	98.23
Baboon	NC	0.2240	0.4923	0.8304	0.9907	1.00
	PSNR(db))	83.90	85.45	87.07	89.27	92.23
Peppers	NC	0.5575	0.6749	0.8440	0.9815	1.00
	PSNR(db))	78.85	80.32	82.10	84.77	88.02

k=1.5

Image	Q	10	15	25	50	75
Lena	NC	0.5279	0.8787	0.9884	1.00	1.00
	PSNR(db))	83.60	84.93	86.66	90.01	95.98
Baboon	NC	0.4599	0.8133	0.9815	1.00	1.00
	PSNR(db))	81.21	82/47	84.02	86.73	91.01
Peppers	NC	0.7210	0.8806	0.9658	1.00	1.00
	PSNR(db))	77.38	78.77	80.51	83.60	87.56

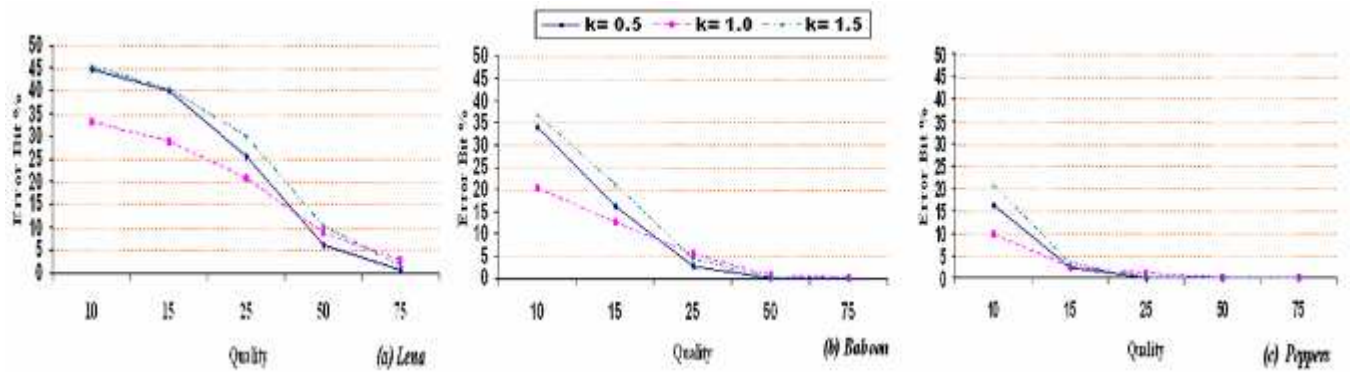


Fig 6. The percentage of error bit in extracted watermarks in JPEG compression under deferent qualities and gain factors.

5.2. Robustness to Noise Attacks

The CDMA proposed scheme was tested for its robustness against different types of noise. This is done by first introducing noise into the watermarked images. Gaussian noise with zero mean is introduced to verify as to what extent the proposed scheme can withstand noise. From the results shown below, it is observed that for a Gaussian noise of 1 % with the gain factor 0.5; the watermark recovery is almost recognizable, for a Gaussian noise of 1 % with the gain factor 1, the watermark recovery is moderate and for a Gaussian noise of 1 % with the gain factor 1.5, the watermark recovery is near to perfect with very few detection errors. We must keep in mind that most schemes offer moderate robustness to noise [14]. Figure (7) shows added Gaussian noise of 0.5 % with gain factor 1 to watermarked images. Figure (8) shows the extracted watermarks in Gaussian noise of 1 % with different gain factors. Figure (9) shows the percentage of error bit in extracted watermarks under different variances of Gaussian noise and gain factors. As it is obvious, the maximum error bit rate is still lower than 34% (Gaussian noise of 1 % with gain factor 0.5). Figure (10) shows the results of PSNR in Gaussian noise experiment. Figure (11) shows the results of NC in Gaussian noise experiment. It is visible, the NC is acceptable for Gaussian noise of 1 % with the gain factor 1.5 and it is moderate in Gaussian noise of 1 % with gain factor 1. The obtained results from Gaussian noise experiment show that, the proposed CDMA scheme is more robust than the earlier works such as [5]. When the salt & pepper noise with zero mean and different variance of 0.01 to 0.5 with different gain factor introduced in the watermarked images, the extracted watermarks are recognizable in gain factor 0.5 and noise density 0.5, they are recovered in gain factor 1 and noise density 0.5 moderately and they are recovered in gain factor 1.5 and noise density 0.5 with a few detection errors. Figure (12) shows the

watermarked images under salt & pepper noise attacks with noise density of 0.5 and gain factor 1. Figure (13) shows the extracted watermarks from noisy watermarked images under noise density 0.5 with different gain factors and figure (14) shows the percentage of error bit in extracted watermarks under different noise densities of salt & pepper noise with different gain factors. As it is obvious, the maximum error bit rate is still lower than 34% (Salt & Pepper noise of 1 % with gain factor 0.5).

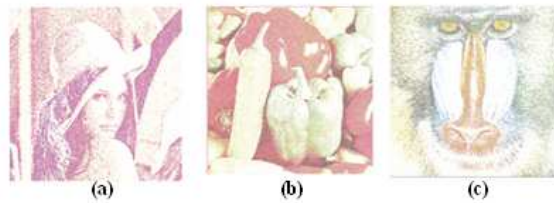


Fig 7. Watermarked images in Gaussian noise under variance 0.5 with gain factor 1. (a) Lena, (b) peppers and (c) Baboon.

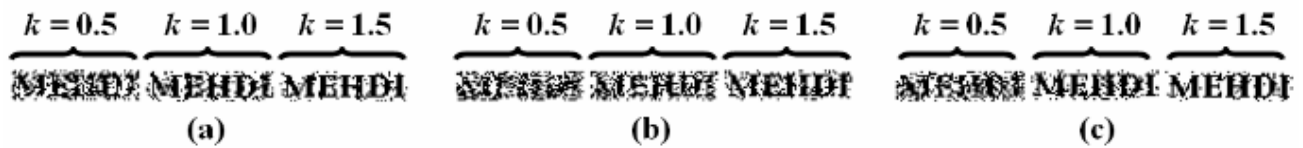


Fig 8. Extracted watermarks from Gaussian noise under variance 1 with different gain factors. (a) Lena, (b) Baboon and (c) Peppers.

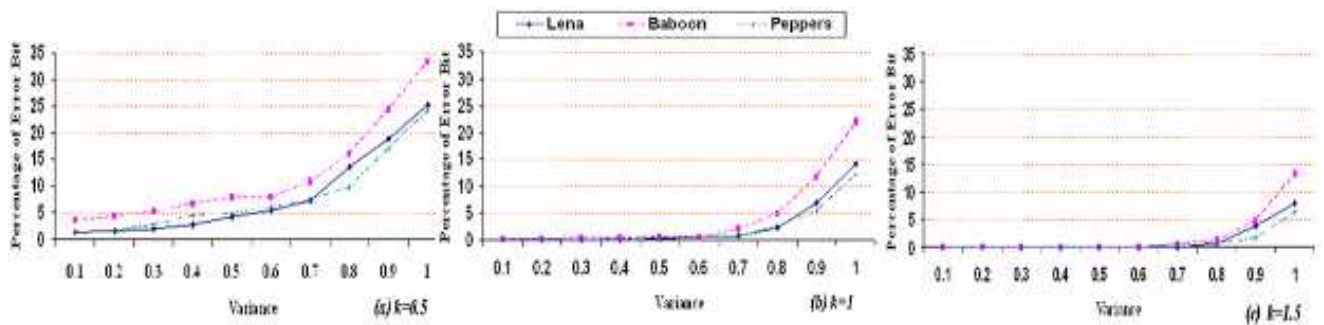


Fig 9. Percentage of error bit in extracted watermarks under different variances and gain factors.

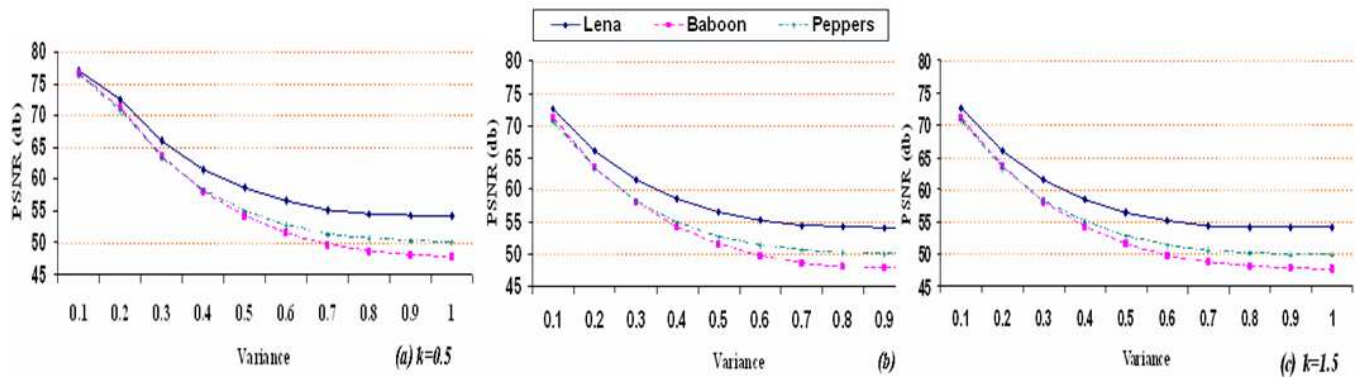


Fig 10. PSNR under Gaussian noise experiment.

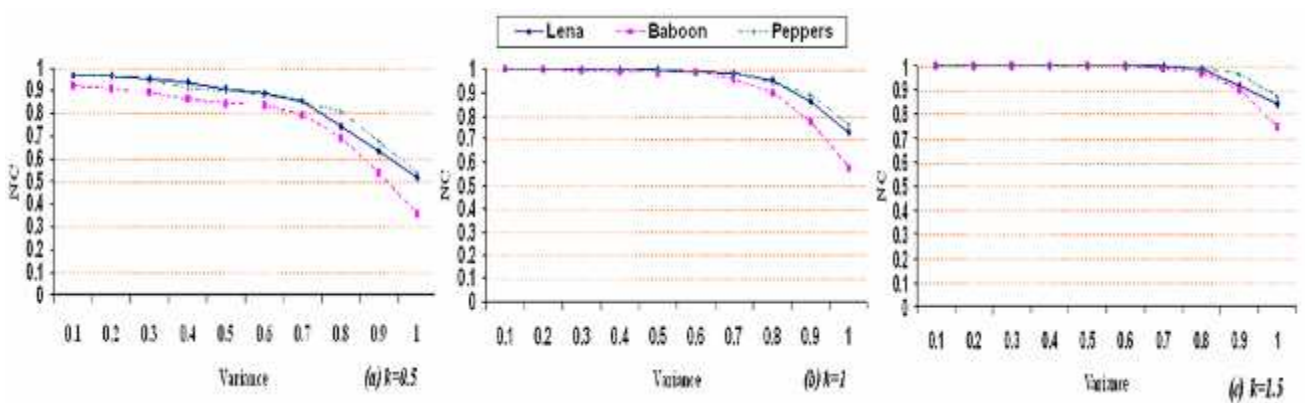


Fig 11. NC in Gaussian noise experiment.

The PSNR results in salt & pepper noise experiment is shown in figures (15). Figure (16) shows the NC results in salt & pepper noise experiment. The obtained results show that, NC in salt & pepper noise experiment is acceptable for noise density of 0.5 with the gain factor 0.5, it is moderate for the same noise density with the gain factor 1 and it is near to perfect for the same noise density and gain factor 1.5 with a few detection errors. From the obtained results it can be said that the proposed CDMA scheme is very efficient in robustness against salt & peppers attacks and it improves the results in the earlier works such as [5].

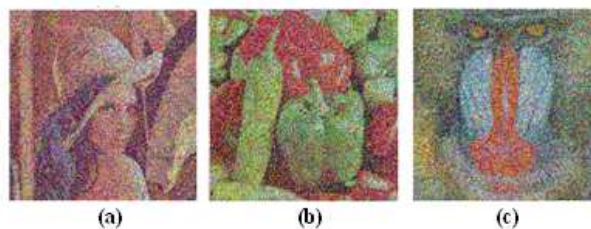


Fig 12. Salt & pepper noise on watermarked images with noise density 0.5.

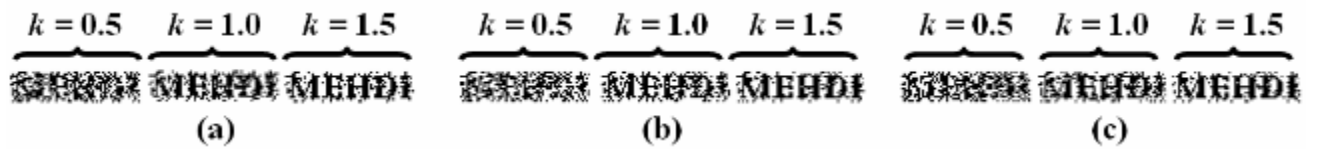


Fig 13. Extracted watermarks from salt & pepper noise under noise density 0.5 with different gain factors.

(a) Lena, (b) Baboon and (c) Peppers.

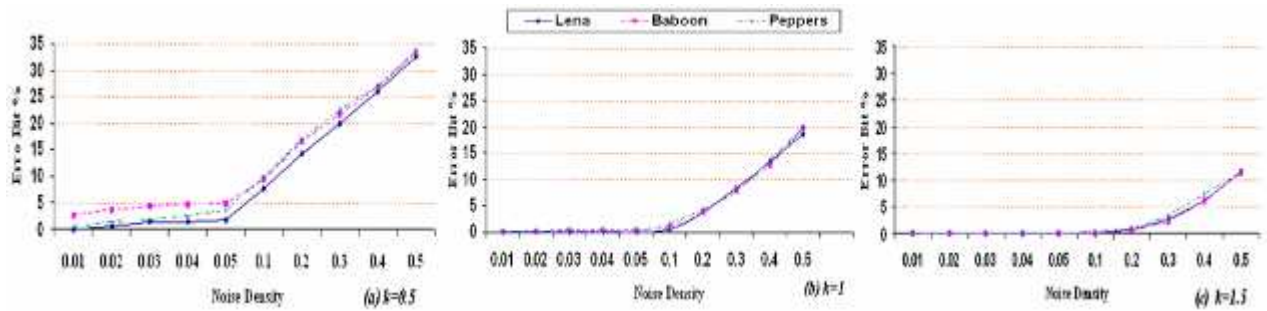


Fig 14. Percentage of error bit under of salt & pepper noise experiment with different noise densities of and gain factors.

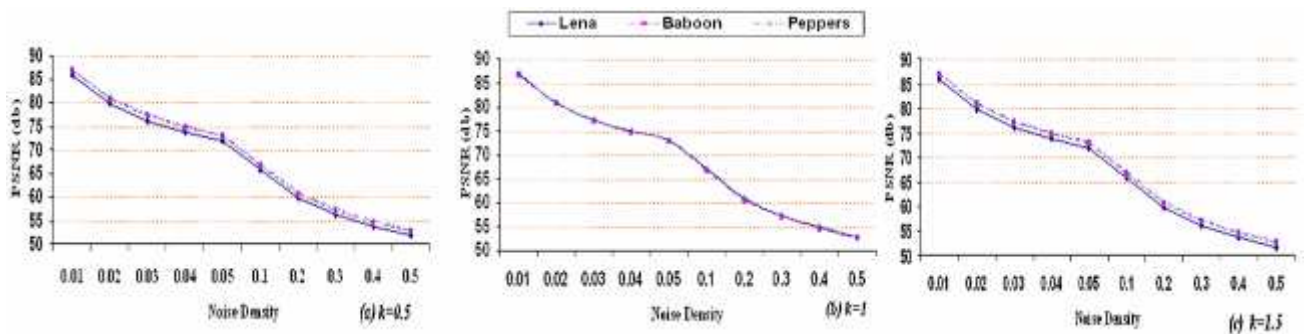


Fig 15. PSNR under salt & pepper noise experiment.

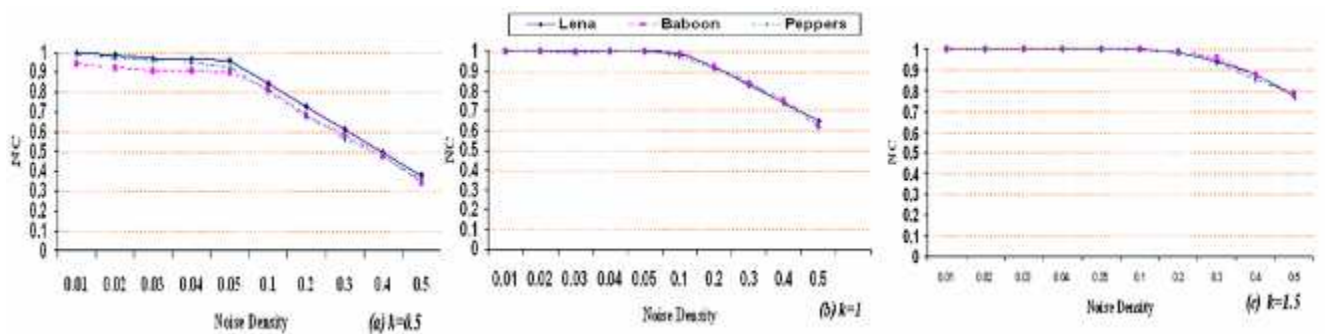


Fig 16. NC under salt & pepper noise experiment.

6. Conclusions

This paper provides a novel CDMA watermarking scheme using DWT2 with satisfactory results in watermark imperceptibility, robustness and security that improves upon the earlier work such as [5]. In the scheme, the host image is converted into JPEG-YCbCr channels; then, the Y channel is decomposed into wavelet coefficients. For more security of watermark, the watermark W is converted to a sequence and then a random binary sequence R of size n is adopted to encrypt the watermark, where n is the size of the watermark using a pseudo-random number generator to determine the pixel to be used on a given key. The selected details subbands coefficients for embedding are quantized and then their most significant coefficients are replaced by the adopted watermark using the correlation properties of additive pseudo-random noise patterns. To embed the watermark coefficients for completely controlling the imperceptibility and the robustness of watermarks, an adaptive casting technique is utilized using a gain factor k . Also, the CDMA watermark scheme has no need to original Image in extracting process. The observations regarding the proposed watermarking scheme are summarized as follows: (1) Increasing gain factor k increases the PSNR and NC. In a result, it decreases the percentage of error bit and increases the robustness of the watermark against JPEG compression and different noise attacks such as Gaussian and salt & pepper. In opposite, increasing gain factor k , decreases the transparency property. (2) The robustness of the proposed scheme to JPEG compression is found to be very good at a quality factor of 75 and gain factor 0.5, a quality factor of 50 and gain factor 1 and also a quality factor of 15 and gain factor 1.5. Reasonably, the robustness of the proposed scheme to JPEG compression is found to be good at a quality factor of 25 and gain factor 1 with a number of detection errors and for a quality factor of 15 and gain factor 1, this becomes highly noticeable. (3) The results show that, the watermark is still recognizable for a quality factor of 10 and gain factor 1. This result shows that, the proposed scheme improves the results in earlier works such as [5]. (4) The robustness of the proposed scheme to Gaussian noise with zero mean is found to be very good for a Gaussian noise of 1 % with the gain factor 1.5, and it is good for a Gaussian noise of 1 % with the gain factor 1, and it is recognizable for a Gaussian noise of 1 % with the gain factor 0.5. This results show the improving in comparing with the earlier works such as [5]. (5) The robustness of the proposed scheme to salt & pepper noise with zero mean with noise density 0.5 is found to be very good for a gain factor 1.5, it is good for a gain factor 1 and it is recognizable for a gain factor 0.5.

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