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A New Color Image Watermarking Algorithm using 3-level Discrete Wavelet Transform

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Abstract

In this paper, a new color image watermarking based on discrete wavelet transform algorithm is presented, so that this scheme can raise the perceptual quality of watermarked image. The scheme is used the discrete wavelet transform (DWT) and the biorthogonal filter banks to decompose the LH sub-bands of main image up to three levels. The proposed watermarking algorithm is invisible and Non-blind. These algorithms has been tested with different images in the size of 256×256, 512×512 and 1024×1024. To measure the robustness and perceptual quality, the proposed watermarking scheme have been checked with method decomposing different sub-bands and the previous method. Experimental results demonstrate that this method has a higher perceptual quality than previous methods. Also the proposed watermarking scheme is robustness than previous methods. The watermarked image is under different attacks such as the noisy, compress JPEG, rotate, crop and Median filter. The proposed algorithm is robust against different attacks.

Keywords: *watermarking, discrete wavelet transform, biorthogonal filter banks, robustness.*

1. Introduction

Today, with the rapid growth of multimedia data, hordes versions of this data published over the Internet and networks, the digital watermarking techniques are used to protect copyrights multimedia digital data. Digital watermarking is the process of content information in digital multimedia data, so that data (watermark) can be later used for different purposes such as the prevention and control of copy, extract or identify [9]. Up today, different algorithms has been proposed for digital watermarking. Usually these algorithms are divided into three categories: Spatial Domain Watermarking, Frequency Domain Watermarking, hybrid domain watermarking [10]. The most common Frequency Domain Watermarking can be referred to the discrete cosine transform (DCT) by Cox et al [3] and Koch et al [9] and Fast Fourier Transform (FFT) [8]. Hybrid domain watermarking can be referred to discrete wavelet transform (DWT) [8] that presented by Xie et al [12], xia et al [13] and wang et al [2]. In this paper, we have used discrete wavelet transform DWT in the proposed algorithm. Watermarking systems according to the type of their application can be divided into two categories visible watermarking system, invisible watermarking system, Blind Watermarking System and Non-

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blind Watermarking System [10]. Visible watermarking, watermark is embedded semitransparent in the original data [10]. Visible Watermarking is robustness against attacks of the image changes [10]. Invisible watermarking, watermark is embedded in the original data so that it is not visible with the naked eye[10].Blind Watermarking technique, for extract watermark from Watermarked data do not need the original image [10].Non-blind Watermarking technique, for extract watermark from Watermarked data do need the original image [10].Non-blind Watermarking System is robust than blind Watermarking System [10]. In this paper, we propose invisible and Non-blind watermarking algorithm.

In this paper , a novel wavelet-based Watermarking algorithm have represent with expansion of sub-band HL, on this algorithm the filter banks biorthogonal have been used.

In paper [7], the authors propose a color image watermarking based on singular value Decomposition scheme. In paper [7], Golea et al proposed invisible and blind watermarking algorithm. The proposed Watermarking algorithm is compared with watermarking algorithm in paper [7].

The rest of this paper is organized as follows: Section 2 review wavelet transform in image processing. Section 3 describes the proposed a new watermarking algorithm. Section 4 presents the results of tests to check the effectiveness of the proposed algorithm.

2. Wavelet transform in image processing

In this section, some basic wavelet transforms will be explained for image processing. The DWT is used to decomposition images by wavelet. The applications of wavelet in image processing, including image compression, edge detection, noise reduction and image optimization [1].

Wavelet analysis with application of high-pass and low-pass filtering are divided the original image into four sub-image which is contains into different frequency components. For an image which is N to N, the process produces wavelet coefficients N^2. Figure 1 is shown the first section of decomposition. High-pass and low-pass image filtered along the rows and the results of the down sampling filter is done by a factor of two. The two sub-signal is matched with the high and low frequency components along the rows and each of the N values are $\frac{N}{2}$. Each of these sub-signals will be filtered again to high-pass and low-pass, but this operation is performed along the columns. The Results will passed by down sampling with a factor of two once again [11].

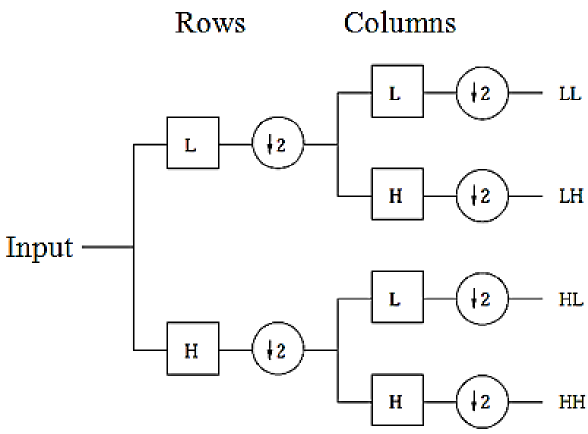

Figure 1: First stage of the input image is decomposed into four sub images.

The above method, the original image will be broken into four sub-image that each of their sizes is N/2 in N/2, that each of them is contains to information on the different frequency components. The four sub-bands are shown in specific order in Figure 2 [11]. LL sub-band is one of the results of low-pass filter in both rows and columns and it includes to a description of the image, so LL sub-band is called sub-band approximation. HH sub-band is high-pass filter in both directions and it includes to high frequency components along the diameter.HL and LH images are resulting from low-pass filter in one direction and high-pass filter and in the other direction. LH typically is includes to vertical information detailed that it will be matched with horizontal edges. HL horizontal information detailed is shown vertical edges. All three sub-bands HL, LH and HH are called sub-band details, because they are added the high frequency detail in to the image approximation [6]. The decomposition of an especial image into four sub-image is shown in Figure 3 [11].

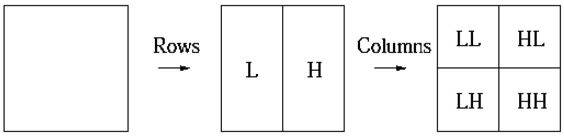

Figure 2: A stage of decomposition.

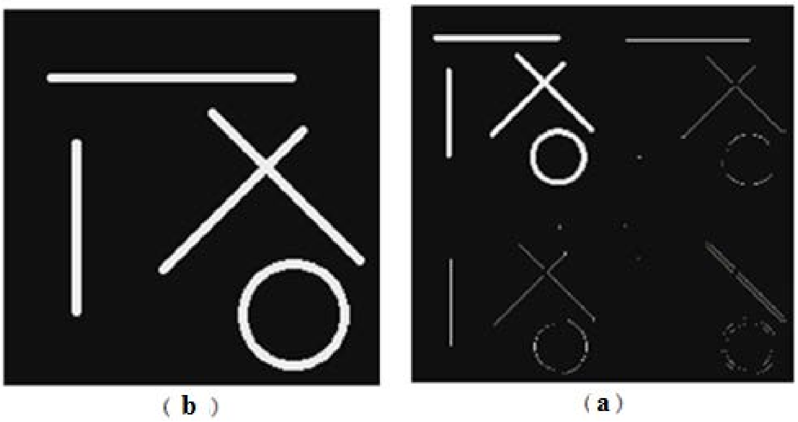

Figure 3: (A) main image, (b) the original image is decomposed of into four sub-bands.

The reverse process is shown in Figure 4. The informations are filtered to the four up-sampled image with the corresponding inverse filters along the columns. Two interdependent results are added together and then up-sampling is filtered by corresponding inverse filters. The results are added together in the end section and we will have original image again. When the image is decomposed, we do not have reduced of information and decomposed image will be carefully combined again [11].

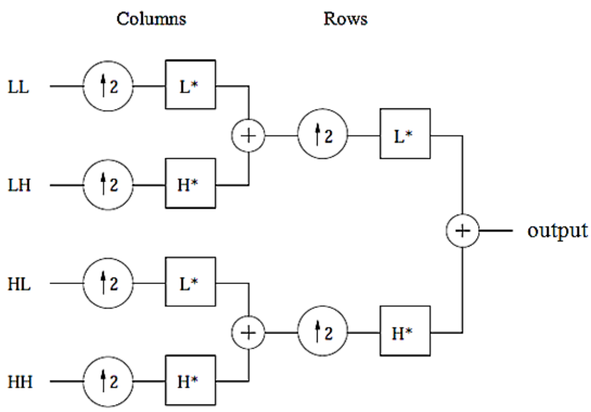

Figure 4: First stage of four sub images is combined into the output image.

3. The proposed scheme

A novel wavelet-based Watermarking algorithm for color images is presented in this section. This algorithm is used in the filter banks biorthogonal. The proposed algorithm has two procedures:

Watermark embedding and Watermark extraction, which will be discussed in sections 3.1 and 3.2 respectively.

3.1. Watermark embedding scheme

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In this section, a Watermarking algorithm for color images is presented. The block diagram of the proposed color image Watermark embedding algorithm is shown in Figure 5.

Input: a color host image, a color watermark image

Output: a watermarked image

Watermark embedding process parameters are as follows:

- A, color host image
- A_R, Red component image
- A_G, Green component image
- A_B, Blue component image
- W, color watermark image
- W_R, Red component image
- W_G, Green component image
- W_B, Blue component image
- C, watermark Weight
- A', watermarked image
- A'_R, Red component watermarked image
- A'_G, Green component watermarked image
- A'_B, Blue component watermarked image

The steps of the embedding phase are as follows:

Step1: A Color host image has three component: red, green, and blue. Image A is decomposed of three component red, green and blue (A_R, A_G, A_B).

Step2: Each of the red, green and blue components is decomposed into three levels using discrete wavelet transform and filter Bank bior2.4. The structure image decomposition has three levels which it is shown in figure 6. In this algorithm, HL sub-band (The coefficients of image Horizontal detail) is decomposed in each of the component image.

Step3: The Components of red, green and blue color watermark image (W_B, W_G, W_R) has separated and it will be multiplied in watermark Weight C and it will be added to the decomposition second stage. Data watermark using equation 1 is embedded.

$$A'_R = A_R + C * W_R,$$

$$A'_G = A_G + C * W_G, \qquad (1)$$

$$A'_B = A_B + C * W_B.$$

Step4: The results of the previous stage (A'_B, A'_G, A'_R) with inverse wavelet by three levels and filter Bank bior2.4 will be rebuild, the result is the watermarked color image A'.

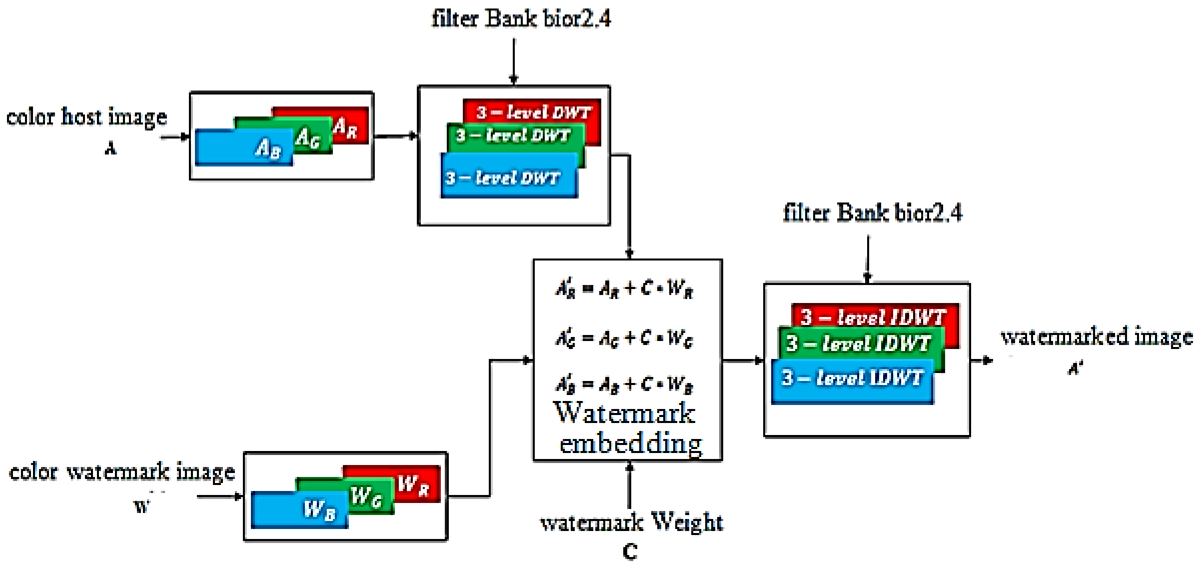

Figure 5: The block diagram of the proposed watermarking embedding process.

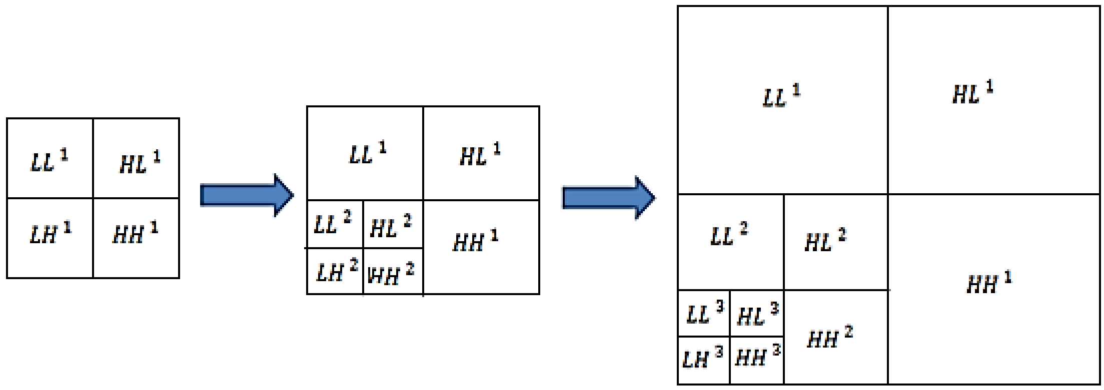

Figure 6: three level decomposition of image.

3.2. Watermark extraction scheme

The block diagram of the proposed color image watermarking extracting algorithm is shown in Figure 7.

Input: a watermarked image, a color host image

Output: a color watermark image

The steps of the extracting phase are as follows:

Step1: The watermarked image A' is decomposed of three components red, green and blue (A'_B, A'_G, A'_R).

Step2: Each of the red, green and blue components of watermarked image is decomposed into three levels using discrete wavelet transform and filter Bank bior2.4 (Figure 6).

Step3: The main image A is separated to the red blue and green components (A_R, A_G, A_B) and each of them is decomposed into three levels using discrete wavelet transform and filter Bank bior2.4 (Figure 6).

Step4: However, the Coefficients that achieved from the third stage of the original image and watermarking image are subtracted from each other and the results of them will be divided by watermark Weight C. Components of data watermark using equation 2 is extracted.

$$(A'_R - A_R)/C = W_R,$$
$$(A'_G - A_G)/C = W_G, \quad (2)$$
$$(A'_B - A_B)/C = W_B,$$

Step5: Now by combining the results of the fourth Stage (W_R, W_G, W_B), watermarking extracted image will be achieve.

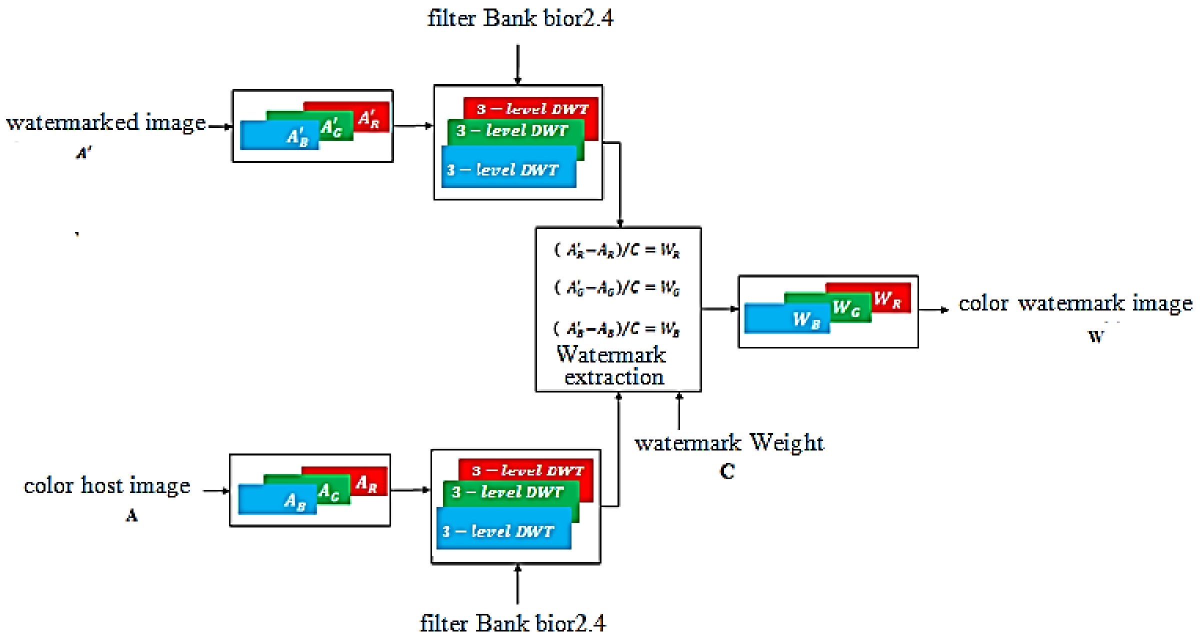

Figure 7: The block diagram of the proposed watermarking extracting process.

3. Experimental results

In this section, the proposed algorithm is evaluated with pictures Lena, Pepper, Babbon and Airplane (figure 8) as host image and the image of Peugeot logo (figure 9) as watermak. The Size of the host images used in the experiences are 256×256 , 512×512 and 1024×1024 and the size of the watermark is 32×32.

Figure 8: Standard images used in comparing the proposed algorithm

Figure 9: watermarked image

One of objective criteria Image quality measure is Peak signal to noise ratio (PSNR), PSNR is used to measure the similarity between the host image and the watermarked image. When the PSNR value is high, watermarked image will be more similar to the original image. The PSNR is defined as follows [4], [5]:

$$PSNR = 10\log_{10}\left(\frac{MAX_{P_1}^2}{MSE}\right) \tag{3}$$

MAX_{P_1} is the maximum amount of pixels of an image. The mean square error (MSE) that used in the equation PSNR is defined as follows [4], [5]:

$$MSE = \frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m}[A(i,j) - A'(i,j)]^2 \tag{4}$$

In the equation 4, the original image, the watermarked image, the number of rows and the columns of image are considered to be A, A', n and m [4], [5]:

Another objective criteria Image quality measure is Normalised correlation (NC), NC is used to measure the similarity between the main watermark and extracted watermarks after the attack. If the NC value is under attack closer to 1, the proposed method is more robust against attacks. The NC is defined as follows [4], [5]:

$$NC = \frac{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,j)W'(i,j)]}{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,j)]^2} \tag{5}$$

In the equation 5 , the original watermark and the extracted watermark are considered to be W and W'. The size of them are M_1 and M_2 [4], [5].

The proposed algorithm by decomposing the image is research in different sub-bands (LL, LH, HL, HH). PSNR and NC test results of the proposed algorithm by decomposing the images (the size of the images are 256×256, 512×512 and 1024×1024)in different sub-bands are stated and compared in Table1, Table2 and Table3. NC values in Table 1, Table 2 and Table 3 can be concluded by decomposing the image in LH sub-band with 3-level discrete wavelet transform is robustness against different attacks. By comparing PSNR values in Table 1, Table 2 and Table 3 can be concluded that the proposed algorithm by decomposing the image in LH sub-band has the best perceptive quality. The watermarked image is under attacks of Salt & pepper, Gaussian (figure 10), Compression JPEG, cut (figure 11), filter median and Wiener (figure 12) and the results is shown in the respective figure. Fingure13 is shown extracted watermarks after different attacks such as Salt & pepper, Gaussian, Compression JPEG, filter median and Wiener.

Table 4 and Table5 compares the proposed algorithm with the algorithm of Golea et al [7].Table 4 compares the proposed algorithm of PSNR values images Lena, Pepper, Babbon and Airplane that sizes of them are 256×256 , 512×512 and 1024×1024 with the algorithm of Golea et al [7].PSNR values in Table 4 show that our proposed algorithm is much better in perceptual quality than algorithm of Golea et al [7].Table 5 compares the proposed algorithm of NC values images Lena, Pepper, Babbon and Airplane that sizes of them are 256×256 , 512×512 and 1024×1024 with the algorithm of Golea et al [7]. NC values in Table 5 show that our proposed algorithm is robustness against different attacks than algorithm of Golea et al [7].

Table 1: The proposed algorithm by decomposing lena image (512×512) in different sub-bands

	LL sub-band		**LH sub-band**		**HL sub-band**		**HH sub-band**	
Type attacks	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**
Without attack	**59.3864**	0.6690	54.0732	**0.9989**	54.0737	0.8210	48.7605	0.8211
JPEG Compression90%	33.2258	0.5826	**33.3357**	**0.9989**	33.3337	0.8209	33.2902	0.8209
JPEG Compression80%	32.3666	0.5906	**32.4642**	**0.9989**	32.4627	0.8209	32.4462	0.8209
JPEG Compression50%	31.1450	0.5959	**31.2144**	**0.9989**	31.2130	0.8208	31.2144	0.8207
Cropping	**11.0687**	0.0669	11.0557	**0.9988**	11.0549	0.8208	11.0551	0.8009
Gaussian	20.1800	0.0859	20.1650	**0.9989**	20.1715	0.8204	**20.1815**	0.8208
Salt&pepper	**18.2443**	0.0451	18.2002	**0.9983**	18.1552	0.8205	18.1995	0.8209
Salt&pepper 0.002	31.9611	0.0662	**32.2220**	**0.9987**	32.0348	0.8215	35.1591	0.8208
Salt&pepper 0.003	25.1272	0.0772	25.1723	**0.9988**	**25.3199**	0.8207	25.0567	0.8206
Wiener filter	**33.7772**	0.0124	33.7719	**0.9988**	33.7684	0.8209	33.7506	0.8102
Median filter	35.8705	0.0703	**35.8745**	**0.9989**	35.8734	0.8208	35.8623	0.8209
Rotation (90 deg)	11.5194	0.2286	**11.5198**	**0.9990**	11.5197	0.8209	11.5191	0.8009

Table 2: The proposed algorithm by decomposing lena image (1024×1024) in different sub-bands

	LL sub-band		**LH sub-band**		**HL sub-band**		**HH sub-band**	
Type attacks	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**
Without attack	**59.6496**	0.0789	54.3401	**0.9990**	54.3402	0.8210	49.0306	0.8211
JPEG Compression90%	36.5418	0.5997	**36.7968**	**0.9989**	36.7909	0.8209	36.7547	0.8208
JPEG Compression80%	35.8948	0.6082	**36.1393**	**0.9989**	36.1324	0.8209	36.1187	0.8208
JPEG Compression50%	34.7077	0.6026	34.8843	**0.9989**	**34.8878**	0.8208	34.8936	0.8207
Cropping	**12.2073**	0.0854	12.2022	**0.9988**	12.2022	0.8202	12.2021	0.7007
Gaussian	20.1690	0.4240	**20.1754**	**0.9991**	20.1747	0.8208	20.1739	0.8208
Salt&pepper	**18.2045**	0.0242	18.1938	**0.9989**	18.1954	0.8206	18.2011	0.8209
Salt&pepper 0.002	**32.1736**	0.0579	32.0455	**0.9990**	32.0682	0.8207	32.0876	0.8208
Salt&pepper 0.003	25.2187	0.0713	**25.2594**	**0.9988**	25.1573	0.8207	25.1629	0.8206
Wiener filter	46.3257	0.0823	**46.3399**	**0.9988**	46.3455	0.8209	46.2477	0.8102
Median filter	46.1155	0.0641	**45.9860**	**0.9988**	45.9727	0.8208	45.6993	0.8209
Rotation (90 deg)	11.5934	0.2180	**11.5940**	**0.9988**	11.5939	0.8209	11.5933	0.8008

Table 3: The proposed algorithm by decomposing lena image (256×256) in different sub-bands

	LL sub-band		LH sub-band		HL sub-band		HH sub-band	
Type attacks	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**	**PSNR**	**NC**
Without attack	**58.8624**	0.0647	53.5404	**0.9986**	53.5393	0.8210	48.2168	0.8209
JPEG Compression90%	34.4078	0.5917	**34.5933**	**0.9988**	34.5863	0.8209	34.5078	0.8207
JPEG Compression80%	33.1330	0.5875	33.2654	**0.9988**	**33.2720**	0.8208	33.2354	0.8207
JPEG Compression50%	31.3555	0.6040	**31.4634**	**0.9988**	31.4532	0.8209	31.4527	0.8207
Cropping	11.5565	0.8717	**11.5595**	**0.9989**	11.5594	0.8201	11.5593	0.6007
Gaussian	20.1673	0.4468	20.1529	**0.9982**	**20.1710**	0.8208	20.1569	0.8206
Salt&pepper	18.3180	0.0239	18.2205	**0.9988**	18.2113	0.8206	**18.2866**	0.8208
Salt&pepper 0.002	32.0414	0.0498	32.0912	**0.9989**	32.0367	0.8208	**32.3552**	0.8207
Salt&pepper 0.003	25.1172	0.0502	25.1745	**0.9988**	**25.3472**	0.8206	25.1671	0.8208
Wiener filter	37.3383	0.0617	37.3339	**0.9989**	**37.3483**	0.8210	37.3270	0.8207
Median filter	35.3332	0.0046	**35.3360**	**0.9988**	35.3135	0.8207	32.2634	0.8207
Rotation (90 deg)	11.7088	0.2180	**11.7095**	**0.9986**	11.7091	0.8208	11.7084	0.8208

Table 4: Comparison of the PSNR of proposed watermarking scheme with previous scheme.

	This paper	Golea et al [8]	This paper	Golea et al [8]	This paper	Golea et al [8]
	512×512		256×256		1024×1024	
Image	**PSNR(dB)**	**PSNR(dB)**	**PSNR(dB)**	**PSNR(dB)**	**PSNR(dB)**	**PSNR(dB)**
Lena	54.0732	44.2581	53.5404	35.0987	54.3401	48.0918
Pepper	54.0732	42.4005	53.5404	33.8439	54.3401	46.7530
Baboon	54.0732	33.0856	53.5404	35.9606	54.3401	48.9978
Airplane	54.0732	43.2926	53.5404	34.9357	54.3401	48.6994

Table 5: Comparison of the robustness of proposed watermarking scheme with previous scheme.

Type attacks	**This paper**	**Golea et al [8]**	**This paper**	**Golea et al [8]**	**This paper**	**Golea et al [8]**
	$\mathbf{256 \times 256}$		$\mathbf{512 \times 512}$		$\mathbf{1024 \times 1024}$	
	NC	**NC**	**NC**	**NC**	**NC**	**NC**
Without attack	**0.9986**	0.9983	**0.9989**	0.9990	**0.9990**	0.9936
Cropping 100-200	**0.9989**	0.4364	**0.9988**	0.8473	**0.9988**	0.9750
Cropping 10-100	**0.9988**	0.8094	**0.9989**	0.9590	**0.9988**	0.9774
Gaussian	**0.9985**	0.9497	**0.9983**	0.8365	**0.9988**	0.6540
Gaussian 0.1	**0.9982**	0.9301	**0.9989**	0.7945	**0.9991**	0.5460
Salt&pepper 0.002	**0.9989**	0.9929	**0.9987**	0.9494	**0.9990**	0.5903
Salt&pepper 0.008	**0.9988**	0.9634	**0.9989**	0.7354	**0.9988**	0.1852
JPEG Compression80%	**0.9988**	0.9202	**0.9989**	0.861	**0.9989**	0.7359
Median filter	**0.9988**	0.4693	**0.9989**	0.6842	**0.9988**	0.8632
Wiener filter	**0.9989**	0.7131	**0.9988**	0.7871	**0.9988**	0.9522

Figure 10: attacks of Salt & pepper, Gaussian

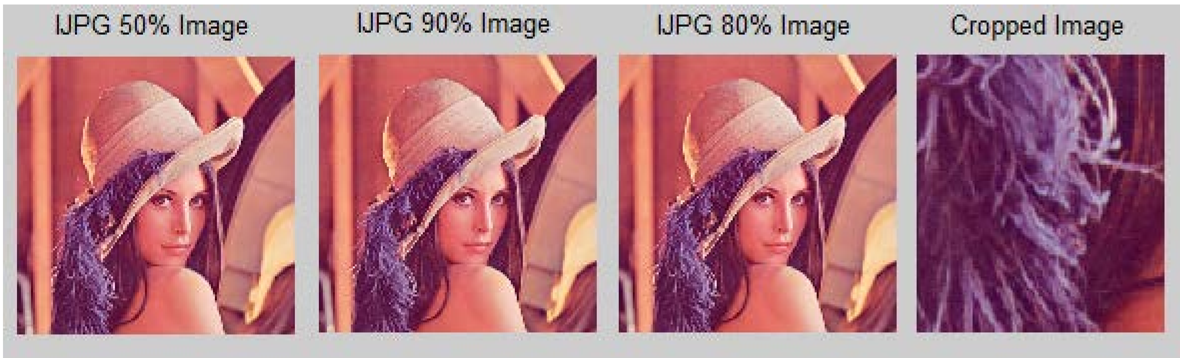

Figure 11: attacks of Compression JPEG, cut

Figure 12: attacks of filter median and Wiener

Figure 13: Extracted watermarks after different attacks.

Conclusion

In this paper, a novel wavelet-based Watermarking algorithm for color images is presented. In this scheme, we were used 3 levels discrete wavelet transform. The results that achieves from The proposed algorithm with decomposing image were compared in different sub-bands and As you can see, The proposed algorithm with sub-band LH have better perceptual quality and it is more robust against various attacks. By comparing the proposed algorithm with the algorithm of Golea et al[7],we achieved this result that our algorithm have better perceptual quality and it is more robust against various attacks such as Salt & pepper, Gaussian , Compression JPEG, cut, filter median and Wiener. Also the result show that The proposed algorithm is robust against forgery attacks. This algorithm is designed for natural images.

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