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

Azadeh Karimian¹ and Javad Vahidi²

The Student of Computer Engineering, Ayatollah Amoli Branch, Islamic Azad University, Amol, Iran
Department of Applied Mathematics, Iran University of Science and Technology, Behshahr, Iran

Phone Number: +98-912-6135064

*Corresponding Author's E-mail: azadeh_karimian_ak@yahoo.com

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 have been tested with different images in the size of $256 \times 256$, $512 \times 512$ and $1024 \times 1024$. 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-
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.](image)

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](image1.png)

**Figure 2:** A stage of decomposition.

![Figure 3](image2.png)

**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](image3.png)

**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

As in this heading, they should be Times New Roman 11-point boldface, initially capitalized, flush left, with one blank line before, and one after.

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.

\[
A'_R = A_R + C \ast W_R,
\]
\[
A'_G = A_G + C \ast W_G, \tag{1}
\]
\[
A'_B = A_B + C \ast W_B.
\]
Step 4: 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 \(A'\).

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:

Step 1: The watermarked image \(A'\) is decomposed of three components red, green and blue \((A_B', A_G', A_R')\).

Step 2: 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.

\[
\begin{align*}
(A'_R - A_R) / C &= W_R, \\
(A'_G - A_G) / C &= W_G, \\
(A'_B - A_B) / C &= W_B,
\end{align*}
\]  

\(2\)  

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

![Block diagram of the proposed watermarking extracting process.](image)

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 \(256 \times 256\), \(512 \times 512\) and \(1024 \times 1024\) and the size of the watermark is \(32 \times 32\).
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]:

$$PSNR = 10 \log_{10} \left( \frac{MAX^2_{P_1}}{MSE} \right)$$  \hspace{1cm} (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]:

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

$$NC = \frac{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} [W(i,j)W'(i,j)]}{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} [W(i,j)]^2}$$ \hspace{1cm} (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 Table 1, Table 2 and Table 3. 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 perceptual 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. Figure 13 is shown extracted watermarks after different attacks such as Salt & pepper, Gaussian, Compression JPEG, filter median and Wiener.

Table 4 and Table 5 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

<table>
<thead>
<tr>
<th>Type attacks</th>
<th>LL sub-band PSNR</th>
<th>NC</th>
<th>LH sub-band PSNR</th>
<th>NC</th>
<th>HL sub-band PSNR</th>
<th>NC</th>
<th>HH sub-band PSNR</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without attack</td>
<td>59.3864</td>
<td>0.6690</td>
<td>54.0732</td>
<td>0.9989</td>
<td>54.0737</td>
<td>0.8210</td>
<td>48.7605</td>
<td>0.8211</td>
</tr>
<tr>
<td>JPEG Compression90%</td>
<td>33.2258</td>
<td>0.5826</td>
<td>33.3357</td>
<td>0.9989</td>
<td>33.3337</td>
<td>0.8209</td>
<td>33.2902</td>
<td>0.8209</td>
</tr>
<tr>
<td>JPEG Compression80%</td>
<td>32.6666</td>
<td>0.5906</td>
<td>32.4642</td>
<td>0.9989</td>
<td>32.4627</td>
<td>0.8209</td>
<td>32.4462</td>
<td>0.8209</td>
</tr>
<tr>
<td>JPEG Compression50%</td>
<td>31.1450</td>
<td>0.5959</td>
<td>31.2144</td>
<td>0.9989</td>
<td>31.2130</td>
<td>0.8208</td>
<td>31.2144</td>
<td>0.8207</td>
</tr>
<tr>
<td>Cropping</td>
<td>11.0687</td>
<td>0.0669</td>
<td>11.0557</td>
<td>0.9988</td>
<td>11.0549</td>
<td>0.8208</td>
<td>11.0551</td>
<td>0.8009</td>
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<tr>
<td>Gaussian</td>
<td>20.1800</td>
<td>0.0859</td>
<td>20.1650</td>
<td>0.9989</td>
<td>20.1715</td>
<td>0.8204</td>
<td>20.1815</td>
<td>0.8208</td>
</tr>
<tr>
<td>Salt&amp;pepper</td>
<td>18.2443</td>
<td>0.0451</td>
<td>18.2002</td>
<td>0.9983</td>
<td>18.3552</td>
<td>0.8205</td>
<td>18.1995</td>
<td>0.8209</td>
</tr>
<tr>
<td>Salt&amp;pepper 0.002</td>
<td>31.9611</td>
<td>0.0662</td>
<td>32.2220</td>
<td>0.9987</td>
<td>32.0348</td>
<td>0.8215</td>
<td>35.1591</td>
<td>0.8208</td>
</tr>
<tr>
<td>Salt&amp;pepper 0.003</td>
<td>25.1272</td>
<td>0.0772</td>
<td>25.1723</td>
<td>0.9988</td>
<td>25.3199</td>
<td>0.8207</td>
<td>25.0567</td>
<td>0.8206</td>
</tr>
<tr>
<td>Wiener filter</td>
<td>33.7772</td>
<td>0.0124</td>
<td>33.7719</td>
<td>0.9988</td>
<td>33.7684</td>
<td>0.8204</td>
<td>33.7506</td>
<td>0.8102</td>
</tr>
<tr>
<td>Median filter</td>
<td>35.8705</td>
<td>0.0703</td>
<td>35.8745</td>
<td>0.9989</td>
<td>35.8734</td>
<td>0.8208</td>
<td>35.8623</td>
<td>0.8209</td>
</tr>
<tr>
<td>Rotation (90 deg)</td>
<td>11.5194</td>
<td>0.2286</td>
<td>11.5198</td>
<td>0.9990</td>
<td>11.5197</td>
<td>0.8209</td>
<td>11.5191</td>
<td>0.8009</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Type attacks</th>
<th>LL sub-band PSNR</th>
<th>NC</th>
<th>LH sub-band PSNR</th>
<th>NC</th>
<th>HL sub-band PSNR</th>
<th>NC</th>
<th>HH sub-band PSNR</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without attack</td>
<td>59.6496</td>
<td>0.0789</td>
<td>54.3401</td>
<td>0.9990</td>
<td>54.3402</td>
<td>0.8210</td>
<td>49.0306</td>
<td>0.8211</td>
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<td>JPEG Compression90%</td>
<td>36.5418</td>
<td>0.5997</td>
<td>36.7968</td>
<td>0.9989</td>
<td>36.7909</td>
<td>0.8209</td>
<td>36.7547</td>
<td>0.8208</td>
</tr>
<tr>
<td>JPEG Compression80%</td>
<td>35.8948</td>
<td>0.6082</td>
<td>36.1393</td>
<td>0.9989</td>
<td>36.3324</td>
<td>0.8209</td>
<td>36.1187</td>
<td>0.8208</td>
</tr>
<tr>
<td>JPEG Compression50%</td>
<td>34.7077</td>
<td>0.6026</td>
<td>34.8843</td>
<td>0.9989</td>
<td>34.8878</td>
<td>0.8208</td>
<td>34.8936</td>
<td>0.8207</td>
</tr>
<tr>
<td>Cropping</td>
<td>12.2073</td>
<td>0.0854</td>
<td>12.2022</td>
<td>0.9988</td>
<td>12.2022</td>
<td>0.8202</td>
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<tr>
<td>Gaussian</td>
<td>20.1690</td>
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<td>0.9991</td>
<td>20.1747</td>
<td>0.8208</td>
<td>20.1739</td>
<td>0.8208</td>
</tr>
<tr>
<td>Salt&amp;pepper</td>
<td>18.2045</td>
<td>0.0242</td>
<td>18.1938</td>
<td>0.9989</td>
<td>18.1954</td>
<td>0.8206</td>
<td>18.2011</td>
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</tr>
<tr>
<td>Salt&amp;pepper 0.002</td>
<td>32.1736</td>
<td>0.0579</td>
<td>32.0455</td>
<td>0.9990</td>
<td>32.0682</td>
<td>0.8207</td>
<td>32.0876</td>
<td>0.8208</td>
</tr>
<tr>
<td>Salt&amp;pepper 0.003</td>
<td>25.2187</td>
<td>0.0713</td>
<td>25.2594</td>
<td>0.9988</td>
<td>25.1573</td>
<td>0.8207</td>
<td>25.1629</td>
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<tr>
<td>Wiener filter</td>
<td>46.3257</td>
<td>0.0823</td>
<td>46.3399</td>
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<tr>
<td>Median filter</td>
<td>46.1155</td>
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<tr>
<td>Rotation (90 deg)</td>
<td>11.5934</td>
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<td>11.5940</td>
<td>0.9988</td>
<td>11.5939</td>
<td>0.8209</td>
<td>11.5933</td>
<td>0.8008</td>
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</table>
Table 3: The proposed algorithm by decomposing lena image (256×256) in different sub-bands

<table>
<thead>
<tr>
<th>Type attacks</th>
<th>LL sub-band</th>
<th>LH sub-band</th>
<th>HL sub-band</th>
<th>HH sub-band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSNR</td>
<td>NC</td>
<td>PSNR</td>
<td>NC</td>
</tr>
<tr>
<td>Without attack</td>
<td>58.8624</td>
<td>0.0647</td>
<td>53.5404</td>
<td>0.9986</td>
</tr>
<tr>
<td>JPEG Compression90%</td>
<td>54.3078</td>
<td>0.5917</td>
<td>34.5933</td>
<td>0.9988</td>
</tr>
<tr>
<td>JPEG Compression80%</td>
<td>33.1330</td>
<td>0.5875</td>
<td>33.2654</td>
<td>0.9988</td>
</tr>
<tr>
<td>JPEG Compression50%</td>
<td>31.3555</td>
<td>0.6040</td>
<td>31.4634</td>
<td>0.9988</td>
</tr>
<tr>
<td>Cropping</td>
<td>11.5565</td>
<td>0.8717</td>
<td>11.5595</td>
<td>0.9989</td>
</tr>
<tr>
<td>Gaussian</td>
<td>20.1673</td>
<td>0.4468</td>
<td>20.1529</td>
<td>0.9982</td>
</tr>
<tr>
<td>Salt&amp;pepper</td>
<td>18.3180</td>
<td>0.0239</td>
<td>18.2205</td>
<td>0.9988</td>
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<td>0.0502</td>
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<td>0.9988</td>
</tr>
<tr>
<td>Wiener filter</td>
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<td>0.9989</td>
</tr>
<tr>
<td>Median filter</td>
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<td>0.9988</td>
</tr>
<tr>
<td>Rotation (90 deg)</td>
<td>11.7088</td>
<td>0.2180</td>
<td>11.7095</td>
<td>0.9986</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Image</th>
<th>This paper 512 × 512</th>
<th>Golea et al [8] 256 × 256</th>
<th>This paper 512 × 512</th>
<th>Golea et al [8] 256 × 256</th>
<th>This paper 1024 × 1024</th>
<th>Golea et al [8] 1024 × 1024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena</td>
<td>54.0732</td>
<td>44.2581</td>
<td>53.5404</td>
<td>35.0987</td>
<td>54.3401</td>
<td>48.0918</td>
</tr>
<tr>
<td>Pepper</td>
<td>54.0732</td>
<td>42.4005</td>
<td>53.5404</td>
<td>33.8439</td>
<td>54.3401</td>
<td>46.7530</td>
</tr>
<tr>
<td>Baboon</td>
<td>54.0732</td>
<td>33.0856</td>
<td>53.5404</td>
<td>34.9357</td>
<td>54.3401</td>
<td>48.9978</td>
</tr>
<tr>
<td>Airplane</td>
<td>54.0732</td>
<td>43.2926</td>
<td>53.5404</td>
<td>34.3357</td>
<td>54.3401</td>
<td>48.6994</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Type attacks</th>
<th>This paper 256 × 256</th>
<th>Golea et al [8] 512 × 512</th>
<th>This paper 256 × 256</th>
<th>Golea et al [8] 512 × 512</th>
<th>This paper 1024 × 1024</th>
<th>Golea et al [8] 1024 × 1024</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>Without attack</td>
<td>0.9986</td>
<td>0.9989</td>
<td>0.9989</td>
<td>0.9990</td>
<td>0.9990</td>
<td>0.9990</td>
</tr>
<tr>
<td>Cropping 100-200</td>
<td>0.9989</td>
<td>0.4364</td>
<td>0.9988</td>
<td>0.8473</td>
<td>0.9988</td>
<td>0.9988</td>
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<tr>
<td>Cropping 10-100</td>
<td>0.9988</td>
<td>0.8094</td>
<td>0.9989</td>
<td>0.9590</td>
<td>0.9988</td>
<td>0.9774</td>
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<tr>
<td>Gaussian</td>
<td>0.9985</td>
<td>0.9497</td>
<td>0.9983</td>
<td>0.8365</td>
<td>0.9988</td>
<td>0.6540</td>
</tr>
<tr>
<td>Gaussian 0.1</td>
<td>0.9982</td>
<td>0.9301</td>
<td>0.9989</td>
<td>0.7945</td>
<td>0.9991</td>
<td>0.5460</td>
</tr>
<tr>
<td>Salt&amp;pepper 0.002</td>
<td>0.9989</td>
<td>0.9929</td>
<td>0.9987</td>
<td>0.9494</td>
<td>0.9990</td>
<td>0.5903</td>
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<td>Salt&amp;pepper 0.008</td>
<td>0.9988</td>
<td>0.9634</td>
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<td>JPEG Compression80%</td>
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<td>0.9202</td>
<td>0.9989</td>
<td>0.861</td>
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<td>Median filter</td>
<td>0.9988</td>
<td>0.4693</td>
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<td>Wiener filter</td>
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<td>0.7131</td>
<td>0.9988</td>
<td>0.7871</td>
<td>0.9988</td>
<td>0.9522</td>
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</tbody>
</table>

Figure 10: attacks of Salt & pepper, Gaussian
Conclusion

In this paper, a novel wavelet-based Watermarking algorithm for color images is presented. In this scheme, we used 3 levels discrete wavelet transform. The results that achieve 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.
References


