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To cite this version:
Wassila Belferdi, Ali Behloul, Lemnaouar Naoui. A blind dual color images watermarking based on IWT and sub-sampling. 3rd international Conference on Complex Systems CISC’2014, Dec 2014, Jijel, Algeria. hal-03283306

HAL Id: hal-03283306
https://hal.science/hal-03283306
Submitted on 9 Jul 2021

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A blind dual color images watermarking based on IWT and sub-sampling

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Abstract

With more color images being widely used in the Internet, embedding color watermark image into color host image is one of the most challenging issues in robust image watermarking, it is usually termed as dual color image watermarking. Based on integer wavelet transform (IWT) and sub-sampling, this paper proposes a blind dual color image watermarking scheme, which is different from some existing works using the binary or gray-level image as watermark. Firstly, the color host image is subsampled into four sub-images and each sub-image is transformed via IWT to obtain four LL sub-bands, we can find that there is a strong correlation between the LL sub-bands coefficients, this property can be explored for embedding and extracting watermark in a blind way. Experimental results, show that the proposed color image scheme has stronger robustness against most common attacks such as image compression, cropping, noising and scaling etc.

Keywords- blind detection; IWT; subsampling; Edge mask

1. Introduction

In recent years, the copyright protection of digital contents from illegal use has been receiving more and more attention, digital watermarking is considered as a powerful solution arisen through this need [1]–[3]. The feature of digital watermarking is to allow for imperceptibly embedding watermark information in the original host image, once created the watermark can be detected or extracted for the purpose of owner identification or/and integrity verification of tested data [4], [5].

According to the processing domain of the host image, existing techniques of image watermarking may be divided into two categories: spatial and frequency domain watermarking [6]. The frequency domain technique is more widely used in digital watermarking, due to its stronger robustness, and its main feature is to convert the host image into frequency coefficients by using transformation methods such as DCT, DFT, DWT or IWT [6], [7].

According to whether the original data is required or not when extracting watermark, digital watermarking can be classified into blind detection and non-blind detection watermarking [8]. The blind detection means to extract watermark without the use of the original host image and the original watermark [6], [8]. On the contrary, the non-blind detection requires the original host image or the original watermark [6]. Generally, the latter one has stronger robustness than the former one, but it is not realistic that need the original data to extract watermark in many applications. Hence, the blind detection watermarking technology has been recently receiving more attention.

Generally, the existing image watermarking schemes use binary or gray-level image as watermark, and many of them belong to non-blind watermarking methods. It is a challenging problem to design a blind color image watermarking scheme [9]. Among these existing dual color image watermarking techniques, Chou in [10] propose to embed color image watermark in color image, which was performed in the spatial domain and had the feature of simplicity in the computation. In [11] a robust digital watermarking scheme using sub-sampling is proposed, a binary watermark image is embedded into the DCT coefficients.
Motivated by the above discussion, a blind watermarking method based on IWT and sub-sampling is proposed for embedding color image watermark into color host image in frequency domain.

Thus, we are interested in three challenges: The first one is to use the integer wavelet transform (IWT), which can map integer to integer without the rounding error, and can further concentrate the energy of each sub-image to obtain a good imperceptibility. The second one is to embed color image watermarking into color host image. This is motivated by the fact that compared with gray level watermarking; digital color image has more amounts of data. The last but not the least is that the proposed watermarking is blind detection [8], [12].

In this paper, the proposed IWT and sub-sampling algorithm is very different to the method in [13], where a blind sub-sampling based watermarking scheme has been investigated for digital images. Hence, in this paper, the watermark will be embedded into LL sub-band coefficients according to an edge mask. Firstly, an energy compaction region is obtained by IWT after sub-sampling the color host image. And then, the watermark is embedded into the LL neighboring sub-bands coefficients.

The rest of the paper proceeds as follows: Sect.2 introduces the technique of IWT and sub-sampling technology. The detailed watermark embedding and extracting procedures are presented in Sects.3 and 4, respectively. Subsequently, Sect.5 provides the experimental results. Finally, we draw our conclusion of this paper.

2. Preliminary

2.1. Integer Wavelet Transform (IWT)

The existing watermarking algorithms based on the traditional wavelet transform are not suitable for color image due to the disadvantages of computational complexity and rounding error [12]. It uses non-integer filter, which produces non-integer transform coefficients [14].

Since the color image has great amount of information and its pixel values are integers, the integer wavelet transform can map the pixel value to integer without any rounding error see [14], [15] and the bibliography therein.

2.2. Image sub-sampling

Since the pixel values of any image have a good correlation with their pixel values neighboring, the sub-sampling allows as mapping the pixel values of any image into four highly correlated sub-images.

Given the image \( V \) of size \( N \times M, N = 0... n-1, M = 0... m-1 \), the sub-sampling process is as follows:

\[
\begin{align*}
V_1 \{k_1; k_2\} &= V \{2n; 2m\}; \\
V_2 \{k_1; k_2\} &= V \{2n+1; 2m\}; \\
V_3 \{k_1; k_2\} &= V \{2n; 2m+1\}; \\
V_4 \{k_1; k_2\} &= V \{2n+1; 2m+1\};
\end{align*}
\]

For \( k = 0,...,N/2-1, k_2 = 0,...,M/2-1 \), \( V[k_1,k_2] \) is an \( i \) sub-image obtained by sub-sampling Fig.(1). Since the sub-images \( V_i \)'s are highly correlated, it is expected that the IWT coefficients of different sub-images are approximately equal, i.e. \( Y_i \) for \( i \neq j \) except edge, where \( Y_i \) and \( Y_j \) denote that the IWT of the sub-image \( V_i \) and \( V_j \) [11], [13].

![Image](image1.png)

Figure 1. Sub-sampling image into four sub-images.

2.2. Edge masking

As it discussed, the IWT sub-images have approximately same coefficients at the same spatial location except edge areas [4], [11], [13]. To deal with this problem, the proposed method uses an edge mask as in Fig.(2). It is used to consider the edge of local image characteristics [4]. The edge mask is constructed according to the pixel-wise relationship between the selected sub-band and neighboring two sub-bands.

Once we select a sub-image to embed the watermark, we have to select neighboring sub-images to compare for later watermark extraction. Using the edge mask we select just a horizontal or vertical neighboring sub-image for comparison purpose.

![Image](image2.png)

Figure 2. Selecting neighboring sub-images (two white blocks enclosed in dashed line are neighboring sub-images of gray block sub-image).
3. Watermark embedding

Firstly, the 24-bit P×Q color watermark image W is divided into R, G and B components; every component is encoded to 1D sequence, then in order to further remove the space correlations between the watermark coefficients and enhance the robustness of watermarking the 1D sequence is randomly permuted by a secret key K.

Next, the 24-bit M×N color host image H is divided into R, G and B components. Each component is decomposed into four sub-images according to Eq.(1), each of the four sub-images is transformed via IWT to obtain four LL's sub-bands, one of which is selected for embedding a watermark. Then, one pair of coefficients from two different sub-images situated in the same LL sub-band location is used to insert one watermark value.

According to the mask the LL_3 sub-band values are modified according to the following equation:

\[ LL_{Mask(i)} = LL_i + \alpha W_i \]  

Where LL_i is the chosen sub-band to compare with, Mask(i)={H,V}, H and V are horizontal or vertical neighboring respectively, the positive constant \( \alpha \) is known as watermark strength control variable, the choice of \( \alpha \) is a tradeoff between image distortion (watermark invisibility) and detection accuracy (robustness).

Once the watermark is embedded, every sub-image is firstly transformed by the inverse IWT, and then the inverse sub-sampling is applied to obtain the watermarked image H'.

Embedding steps are described in Fig. (4)

4. Watermark extraction

The procedure of watermark extraction is the inverse operation of the embedding process Fig. (5). The watermarked image H' (probably attacked) is firstly sub-sampled into four sub-images and each of them is transformed via IWT. And the same watermark insertion order sequence is required to select the chosen sub-band LL_3 and two neighboring LL_2 and LL_4 sub-bands. To recover the watermark Eq.(3) is performed:

\[ W_i = (LL_{Mask(i)} - LL_i')/\alpha \]  

Where \( W_i \) is the extracted watermark value, Mask(i)={H,V} is the edge mask value, LL_{Mask(i)} is the neighboring value of the watermarked image, chosen according to the edge mask value. LL_i' is the chosen sub-band to compare with. Then the next process is to inverse the permutation for extracting a visually recognizable watermark. Fig. (5) describes the watermark extraction process.

5. Experimental results

Five 24-bit color images in the CVG-URG data base with size of 512x512 are selected as original host image, and two 24-bit color images with size of 64x64 are used as original watermarks Fig(6).
The strength of watermark $\alpha=0.05$ chosen according to a tradeoff between image distortion and robustness as it shown in Fig.(7), in other words when the strength of watermark $\alpha$ increase the invisibility of watermark decrease and conversely.

For the imperceptible capability, we make use the peak signal to noise ratio (PSNR) defined in Eq.(4) in units of dB, where $H$ is the original image, $H'$ is the watermarked image, and $N, M$ denote the height and width of the image respectively.

$$\text{PSNR} = 10 \log{\frac{M \times N \times \max([H(x,y)])^2}{\sum_{x=1}^{M} \sum_{y=1}^{N} [H(x,y) - H'(x,y)]^2}}$$

In general, if the PSNR value is greater than 35 dB the perceptual quality is acceptable, that’s mean that the watermark is invisible to human eyes [4], [12].

Besides, in order to measure the robustness of watermark, we use the normalized correlation (NC) between the original watermark $W$ and the extracted watermark $W'$, which is shown as follows.

$$\text{NC} = \frac{\sum_{x=1}^{P} \sum_{y=1}^{Q} W(x,y) \times W'(x,y)}{\sqrt{\sum_{x=1}^{P} \sum_{y=1}^{Q} W(x,y)^2 \times \sum_{x=1}^{P} \sum_{y=1}^{Q} W'(x,y)^2}}$$

Where $P$ and $Q$ denote the row and column size of the watermark image. Generally, the NC can take a value between 0 and 1. If the NC value is closer to 1, the extracted watermark is getting more similar to the embedded one, which means that the watermarking has strong robustness. In general, the watermark may be efficient if the NC is more than or equal to 0.750, conversely may be inefficient [7].

In this section, the invisibility and robustness of the proposed method are proved; by comparing it with the performance of the algorithms in [10] and [7].

5.1. Invisibility test

As can be seen from Table.(1), the embedded watermarks are visually transparent and the watermarked images have high values of PSNR. Beside, most of the extracted watermarks remain high quality without any attacks performed on the watermarked images.

Moreover, the proposed algorithm is compared with the dual color image watermarking algorithm in [7] and [10]. It can be seen from Table.(1) that the two algorithms have higher PSNR values, but the proposed method is the less complicated one. Compared with the exiting method [7], the extracted watermarks by the proposed method have better quality, which also prove that the proposed method has well invisibility.

5.2. Robustness test

In order to show the robustness of the proposed method, various attacks such as compression, cropping, adding noise, scaling and rotation are performed on the watermarked image. The obtained results can be seen in Table.(2) and (3).

Notice the high quality of the extracted watermark especially under the cropping, salt and peppers noise and compression attacking; this proposed method has well robustness obtained by the use of image sub-sampling, and the failure of extraction after rotation with large angles. The failure in this case is due the large changes of the watermarked image caused by the rotation.
Table 1. The performance comparison between proposed algorithm and the proposed one in [7].

<table>
<thead>
<tr>
<th>Attacks</th>
<th>Watermarked image PSNR (dB)</th>
<th>extracted watermark</th>
<th>Watermarked image PSNR (dB)</th>
<th>Extracted watermark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without attacks</td>
<td>48.6235</td>
<td>0.9997</td>
<td>38.9599</td>
<td>0.9995</td>
</tr>
<tr>
<td>Cropping</td>
<td>43.8840</td>
<td>0.9960</td>
<td>38.4909</td>
<td>0.9999</td>
</tr>
<tr>
<td>Scaling 4</td>
<td>42.4400</td>
<td>0.9984</td>
<td>39.1033</td>
<td>1.000</td>
</tr>
<tr>
<td>Rotation 0.002°</td>
<td>43.6407</td>
<td>0.9983</td>
<td>38.0118</td>
<td>0.9999</td>
</tr>
<tr>
<td>Compression ratio 10</td>
<td>45.5024</td>
<td>1.000</td>
<td>39.2608</td>
<td>1.000</td>
</tr>
<tr>
<td>Gaussian noises (0.002)</td>
<td>46.4709</td>
<td>0.9969</td>
<td>39.1197</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 2. The performance comparison between proposed algorithm and the proposed one in [10].

<table>
<thead>
<tr>
<th>Host image</th>
<th>Attacks</th>
<th>Chou [10] Extracted watermark</th>
<th>NC</th>
<th>Proposed method Extracted watermark</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropping 50%</td>
<td></td>
<td></td>
<td>0.539</td>
<td>0.709</td>
<td></td>
</tr>
<tr>
<td>Scaling 4</td>
<td></td>
<td>2001 007</td>
<td>0.851</td>
<td>0.996</td>
<td></td>
</tr>
<tr>
<td>Compression Ratio 10</td>
<td></td>
<td>2001 007</td>
<td>0.439</td>
<td>0.602</td>
<td></td>
</tr>
<tr>
<td>Rotation 30°</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Gaussian noises (0.002)</td>
<td></td>
<td>2001 007</td>
<td>0.982</td>
<td>0.864</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. The results of extracted watermark (NC) under different attacks

<table>
<thead>
<tr>
<th>Attacks</th>
<th>Attached Image (PSNR = 39.2169)</th>
<th>Extracted watermark</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without attacks</td>
<td></td>
<td></td>
<td>0.9997</td>
</tr>
<tr>
<td>Cropping</td>
<td></td>
<td></td>
<td>0.9440</td>
</tr>
<tr>
<td>Scaling 4</td>
<td></td>
<td></td>
<td>0.8415</td>
</tr>
<tr>
<td>Rotation 0.002°</td>
<td></td>
<td></td>
<td>0.7654</td>
</tr>
<tr>
<td>Compression ratio 10</td>
<td></td>
<td></td>
<td>0.4651</td>
</tr>
<tr>
<td>Gaussian noise variance 0.01</td>
<td></td>
<td></td>
<td>0.8413</td>
</tr>
<tr>
<td>Salt &amp; peppers</td>
<td></td>
<td></td>
<td>0.7425</td>
</tr>
<tr>
<td>Salt &amp; peppers</td>
<td></td>
<td></td>
<td>0.9848</td>
</tr>
<tr>
<td>Salt &amp; peppers</td>
<td></td>
<td></td>
<td>0.5716</td>
</tr>
<tr>
<td>Salt &amp; peppers</td>
<td></td>
<td></td>
<td>0.9880</td>
</tr>
</tbody>
</table>

6. Conclusion

In this paper, a blind watermarking algorithm for embedding color image watermark into color host image is proposed. Its main features is to transform the host image via IWT after sub-sampling it, obtained sub-bands are used to embed the watermark, exploiting the advantage of high correlation between LL sub-band coefficients. Experimental results have shown that the proposed algorithm not only guarantees the invisibility of watermarking but also has strong robustness against the operations of common image processing, and its performance outperforms other methods considered in this work.
7. References


