A Blind DCT Domain Digital Watermarking

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Abstract: A new blind gray-level watermarking scheme is described. In the proposed method, the host image is first divided into 4x4 non-overlapping blocks. For each block, five first AC coefficients of its DCT are then estimated using DC coefficients of its neighbor blocks. A gray-level watermark is then added into estimated values. Since embedding watermark does not change the DC coefficients, watermark extracting could be done by estimating AC coefficients and comparing them with their actual values. Several experiments are made and results suggest the robustness of the proposed algorithm.

Key words: Blind Watermarking, Information Hiding, Image Watermarking.

1. Introduction

Under the rapid growth of the internet, digital data can now be distributed fast and easy. Because of the easy access to digital contents, copy control of digital data became an important issue. In the recent years, there was a great interest in digital watermarking. A digital watermark technique permits imperceptibly embedding a watermark, including a signature or a copyright message. It must be resilience against attempts to remove the hidden data.

Depending on the application, the original host image is or is not available to the watermark recovery system. While most watermarking techniques require the original picture, there is a great interest in techniques that do not require the original data for recovering, i.e., blind watermarking techniques. That is because of the larger applications of such techniques (Katzenbeisser et al., 2000). Watermark embedding could be done in spatial or transform domain. Frequency domain techniques are more robust and resistant to various attacks, and most watermarking techniques use frequency domain to embed data.

In (Cox et al., 1997), authors describe a method for embedding a binary watermark sequence in the highest magnitude DCT coefficients. Hsu and Wu (Hsu et al. 1998 and 1999) use the middle frequency coefficients of DCT/Wavelet transform to embed a binary watermark. These mentioned methods are robust against image processing. Their main drawback is requiring the original image to extract the watermark.

Wang et al. (Wang et al., 2004) describe a kind of blind watermarking based on relative modulation of the DCT coefficient value by referring to its estimated one. In their method, the DC values of a 303 neighborhood of 8x8 blocks are used to estimate the AC coefficients of central block. For each group of nine 8x8 blocks, 5 watermark bits can be embedded by modulating the first five DCT AC coefficients in central block with the following rule:

Set $AC_i \leftarrow AC_i + \Delta$ to embed bit $i$ 11
Set $AC_i \leftarrow AC_i - \Delta$ to embed bit $i$ 01

Where, $AC_i$ and $AC'_i$ are the real and estimated value of the AC coefficients, respectively. The watermark recovery is done by comparing $AC_i$ and its estimated value. If $AC_i > AC'_i$, then the extracted bit is $i$ 11, otherwise it is $i$ 01. The watermark capacity depends on the texture feature of the block, and, for a MxN image, its maximal value is:

$$\frac{M \times N}{24 \times 24} \times 5$$

(1)

Where, N is the number of pixels in host image. In this paper we propose a blind scheme for gray-level data embedding, which has a larger watermark capacity than Wang method.
2. The proposed Scheme

In the proposed algorithm, the host image is first divided into 404 non-overlapping blocks. Our embedding procedure contains two parts. The first part is estimating the first five DCT AC coefficient of each block in a zigzag order, using its neighbor blocks. Gonzales et al. (Gonzales et al., 1990) proposed a technique for estimating low frequency AC DCT coefficients of a block using the DC values of its 3×3 neighbor blocks using the following equations:

\[ AC'(0,1) = 1.13884 \times (DC_4 - DC_6) / 8; \]
\[ AC'(1,0) = 1.13884 \times (DC_2 - DC_8) / 8; \]
\[ AC'(0,2) = 0.27881 \times (DC_4 + DC_6 - 2DC_3) / 8; \]
\[ AC'(2,0) = 0.27881 \times (DC_2 + DC_8 - 2DC_5) / 8; \]
\[ AC'(1,1) = 0.16213 \times (DC_1 + DC_9 - DC_3 - DC_7) / 8. \]

Where, \( DC_i \) presents the DC coefficient of \( i \)-th block in Fig.1.

The second part is embedding a gray-level value of watermark by replacing each low frequency AC value in the central block with its estimated modified value according to the following formulae:

\[ AC_1 \leftarrow AC_1 + \alpha \times lw(k, l) \]  

Here \( lw(k, l) \) is the current pixel value in watermark image and \( \alpha \) is a constant. If \( \alpha \) is chosen small, the watermark will be very weak to attack. In the other hand, a large value of \( \alpha \) will degrade the quality of watermarked image. From our experiment, \( \alpha \) can be chosen 0.1.

<table>
<thead>
<tr>
<th>Block1</th>
<th>Block2</th>
<th>Block3</th>
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</thead>
<tbody>
<tr>
<td>DC1</td>
<td>DC2</td>
<td>DC3</td>
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<tr>
<td>Block4</td>
<td>Block5</td>
<td>Block6</td>
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<tr>
<td>DC4</td>
<td>DC5</td>
<td>DC6</td>
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<tr>
<td>Block7</td>
<td>Block8</td>
<td>Block9</td>
</tr>
<tr>
<td>DC7</td>
<td>DC8</td>
<td>DC9</td>
</tr>
</tbody>
</table>

Figure 1: The central block and its neighbor blocks

To recovery the watermark, one can simply calculate the difference between \( AC_1 \) and its estimated value, so, the original image is not required.

Remark: embedding a watermark value will not change the DC component of the block, so, all blocks could be chosen for watermark embedding (excepted blocks in the margins of image).

If an AC coefficient has too small value, embedding watermark will degrade the watermarked image quality. So, to embed a watermark, we choose only AC coefficients larger than a threshold value.

The watermark capacity depends on the texture feature of the block, and, for a M×N image, its maximal value is:

\[ \frac{(M-8) \times (N-8)}{16} \times 5 \times 8 \text{ bits} \]  

3. Experimental results

In our experiment, we used two test images i Lena and i Vilagei with a size of 512×512, and, two gray-level 64×64 watermarks, as shown in Fig.2. The watermarked images are presented in Fig.3.

To detect the existence of a watermark, one can calculate the normalized cross-correlation score, S, (Wong 2002) between original watermark and extracted watermark.

Our algorithm survives all attacks. The results for i Vilagei image are shown in Fig.4. As these results show, there is a meaningful correlation between the extracted, and original watermark.

Figure 2: a1, b1) Host images, a2, b2) their respective watermark images

Figure 3: Watermarked images
To demonstrate robustness of our algorithm, we performed different attacks by applying some typical image processing techniques:
- Adding salt and pepper noise
- JPEG compression with a compress factor of 40%
- Histogram equalization
- Sharpen

3. Median filter

4. Conclusion

For most watermark application, it is desired to recover the embedded data without using host image. In this paper, such a watermarking scheme for embedding gray-level watermarks is presented. In the proposed method, the five first DCT AC coefficients are estimated by their neighbor blocks. Then, a number proportional to the gray-level watermark value is added to each estimated AC coefficient. The recovery procedure consists of comparing the estimated values with actual ones. Though our technique, can be considered as an extension of blind watermarking technique proposed by Wang et al., it has some advantages:
- it has a very larger watermark capacity (a maximum capacity of 635040 bits for a 5120512 image, against 2205 bits for Wang technique)
- it is able embedding gray-level watermarks

Several attacks are performed, and, results confirm robustness of the proposed algorithm.

5. References
