Intra-Block Algorithm for Digital Watermarking*

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Abstract

We present a variant to the DCT-based block algorithm proposed in [2] for signal embedding in digital images. Instead of inter-block relations, our algorithm uses intra-block relations to generate the watermarked image. We describe the algorithm and its performance against translation and cropping. The features of our method are : (1) the watermark is perceptually invisible; (2) few loss of relevant information of original image; (3) the watermark can be retrieved by using a secret key; and (4) the watermark is robust against translation and area cropping.

1. Introduction

Digital watermarking is becoming increasingly popular and important as users seek ways to protect their proprietary information being transmitted over Internet. Digital watermarking is useful in the authentication of multimedia information such as text, sound, image, and video, to ensure the undisputed proof of ownership on copyrighted materials.

The digital watermarking is not unlike image coding when an *original signal* is embedded with the *watermarking signal* with additional requirements depending on the applications. These requirements must guard against tempering of the watermarked signal. For example, the watermarking should resist geometric transformations, compression, and sampling to ensure that the watermarking signal can still be retrieved with a high degree of accuracy.

2. Previous Works

One early watermarking method obtained a checksum of the image data, then embedded the checksum into the least significant bits of randomly chosen pixels for watermarking [4]. Others have added a maximal length linear shift register sequence to the pixel data and identified the watermark by computing the spatial cross-correlation function of the sequence and the watermarked image. Watermarks also can modify the image's spectral or transform coefficients directly. These algorithms often modulate DCT coefficients according to a sequence known only to the owner[1]. A straightforward technique is proposed to gray scale images by adding a watermark image to the original image[3].

In [2], Hsu presented a DCT-based algorithm using inter-block relation to implement the middle-band embedding. Our method is different from [2]. Instead using inter-block relations, our algorithm use intra-block relations to generate the watermarked image. From our experiments we found this method to be more robust against localized distortions since the size of the blocks is smaller and the blocks are closer together.

3 Proposed Algorithm

3.1 Embedding Approach

Let OI and OW be the original grayscale image and the original binary digital watermark respectively. They are defined as,

$$OI = \{oi(i,j), 1 \le i,j \le N\}, oi(i,j) \in \{0, \cdots, 2^L - 1\}$$

where L is the number of grayscale levels for the image.

$$OW = \{ow(i,j), 1 \le i,j \le N'\}, ow(i,j) \in \{0,1\}$$

with $N' = N/2$ in our case.

Permutation of the Watermark Data

A secret key $K(l)$ is a random permutation of the integers from 1 to N'^2. It is used to permute the watermark.Order,

$$K[(i-1) \times N' + j] - 1 \equiv i' \ (mod\ N') + j' \quad (1)$$

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then,

$$W'(i,j) = OW(i'+1, j'+1) \tag{2}$$

After this permutation step of the watermark data is performed, we have a scrambled binary watermark data which can be used in the next step.

Block Transformation of the Image

The image OI is divided into 8-by-8 blocks $BOI_{m,n}$, and the two-dimensional Discrete Cosine Transform (DCT) is computed for each block using $D_{m,n} = DCT(BOI_{m,n}) = \{d_{m,n}(k,l), 1 \leq k,l \leq 8\}$ with $M = N/8$ in our case.

Modification of DCT Coefficients

The permuted watermark W' is also divided into $M \times M$ block $BW'_{m,n}$ with the block size 4-by-4.

When $BW'_{m,n}(k) = 1$, we perform an exchange of $d_{m,n}(2k)$ with $d_{m,n}(2k-1)$; when $BW'_{m,n}(k) = 0$, we do nothing.

After the modification of DCT on D, we obtain the modified D' which requires the inverse to obtain the watermarked image.

Inverse DCT

Computing the inverse 2-D DCT of each block,

$$BWI_{m,n} = IDCT(D'_{m,n}) \tag{3}$$

and then put the blocks back together in a single watermarked image.

3.2 Extracting Method

The extraction of watermark W requires the original image OI, the test image TI and the key sequence K. The extraction steps are as follow:

Block Transformation

Both the original image OI and the test image TI are divided into $M \times M$ block $BOI_{m,n}$, $BTI_{m,n}$ with the block size 8-by-8. Each block is DCT transformed.

$$D0_{m,n} = DCT(BOI_{m,n});\ D1_{m,n} = DCT(BTI_{m,n}).$$

Extracting the Permuted Watermark

$$\begin{aligned} BW1_{m,n}(k) \;=\; & \text{sign}(D0_{m,n}(2k) - D0_{m,n}(2k-1)) \oplus \\ & \text{sign}(D1_{m,n}(2k) - D1_{m,n}(2k-1)) \end{aligned} \tag{4}$$

where $\oplus$ is the exclusive OR function and $1 \leq k \leq 16$. Then puts the blocks $BW1_{m,n}$ back together in a single extracted permuted watermark EPW. Finally, the extracted watermark EW is obtained by using of the follow equation.

$$EW(i'+1, j'+1) = EPW(i,j) \tag{5}$$

where the relations among i, j, i', j' meet Eq. (1).

4 Experimental Results

We perform two basic transformations: (1) translation and (2) cropping. The original image is a 256 level 256×256 grayscale image.

We defined the Average Intensity Error (AIE) when comparing the watermarked image with the original as,

$$\text{AIE} \equiv \frac{\sum |OI - WI|}{N \times N}. \tag{6}$$

We found that the AIE is around 4.4 for the watermarked image shown in Fig. 2(b). This result is quite acceptable since we cannot distinguish the original image and the watermarked image perceptually.

4.1 Translation

Using cropped watermarked image of the same cropping size over different location of the watermarked image to extract watermark, the results are shown in Fig. 1.

The Average Pixel Error (APE) is defined as:

$$\text{APE} \equiv \frac{\sum |OW - EW|}{N' \times N'}. \tag{7}$$

The Relative Error Rate (RER) is defined as,

$$\text{RER} \equiv \frac{\sum |OW - EW|}{\sum |OW - EW'|} \times 100\%. \tag{8}$$

where EW' means the extracted watermark from black image.

Our method is translational invariant since there is no significant effect under translation with a constant size when we used a cropping image of 50×230 selected horizontally and vertically as shown in Fig. 1. The error obtained is fairly similar which shows that this method is invariant to translation.

4.2 Cropping

Our experiment shows that the proposed method is sensitive to the size of the cropped area. The error is linear and inversely proportional to the size of the cropped areas as shown in Fig. 3. Here we varied the size of the cropped image from 100% (256×256) to 0.055% (11×11) with the RER ranges from 1.21% to 100% respectively (shown

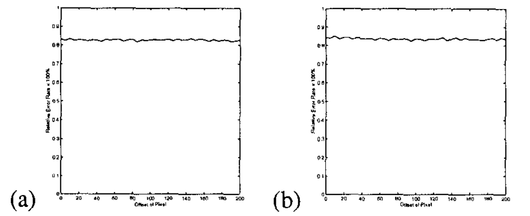

Figure 1. Translating a cropped image of 50×230 **horizontally in (a) and vertically in (b).**

in Fig. 3(b)). It is interesting to observe that the APE under cropping is asymptotically approaching 0.5 since the watermark image retrieved becomes a random image (shown in Fig. 3(a)). Furthermore, we observed that when the RER is greater than 63.6% (the cropped image size is less than 37.13%) the retrieved watermark cannot be distinguished with the original watermark image perceptually (shown in Fig. 3(b)).

5 Discussion & Conclusion

The average retrieved watermark error per pixel is linear and inversely proportional to the percentage of cropping image. When the cropped watermarked image is around 37% of the original image, the retrieved watermark is illegible perceptually. Even when we used the whole watermarked image without cropping, there is still error arising from the DCT computation. This background error is about 1-2%.

In our experiments we added the watermark to the image by modifying the more perceptually significant components of the image spectrum. The result is quite acceptable since we cannot distinguish the original image and the watermarked image perceptually. We demonstrated the algorithm and its performance against translation and area cropping and found this method is fairly robust.

References

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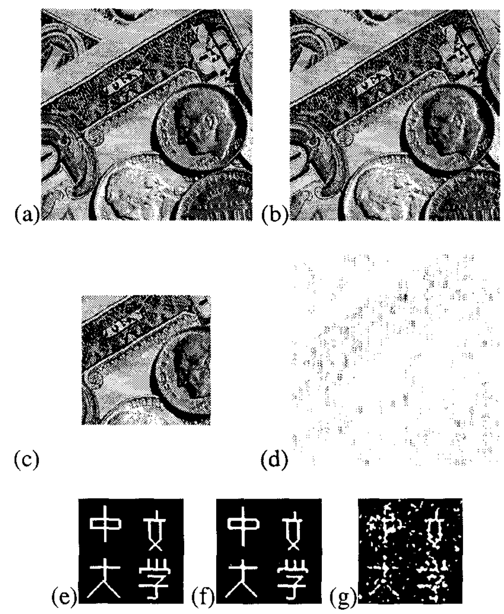

Figure 2. (a) original image, (b) watermarked image, (c) minimum size cropping watermarked image, (d) error image between (a) and (b), (e) original watermark, (f) extracted watermark from (b), (g) a poor extracted watermark from (c) with RER of 63.6% using 37.13% of the image area from the watermarked image.

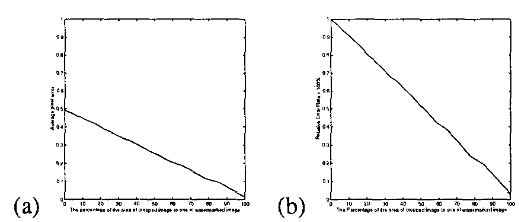

Figure 3. Varying the size of the cropped image at the center of the image and found that the error is inversely proportional to the size of the cropped image. (a) Average Pixel Error (APE) and (b) Relative Error Rate (RER).