AC ESTIMATION-BASED IMAGE WATERMARKING METHOD

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ABSTRACT

An effective and novel technique for blind image watermarking is presented. Each watermark bit is hidden by the modification of the AC components of the DCT of the image, where the AC components are estimated from the DC components in the adjacent blocks. Experimental results are presented which demonstrate the effectiveness of this algorithm for numerical image processing attacks, such as compression, filtering, and adding noise. Since the algorithm is simple, and both the information embedding and information extraction operations are in the block DCT domain, it is very suitable for data hiding in block DCT-based compressed video, such as MPEG-2.

1. INTRODUCTION

Digital watermarking is the communication of information by embedding additional information in host multimedia data, without introducing perceptual changes. An algorithm is used to extract the information later. The embedded information can be used for copyright information or as a message. There are two classes of watermarking techniques: spatial domain-based and transform domain-based techniques. The former is weaker against attacks, so most researchers use the latter. Since the discrete cosine transform (DCT) is the core of JPEG and MPEG compression standards, many watermarking techniques operate in the DCT domain, most of which are directly or indirectly derived from I. J. Cox's spread spectrum technique [1] or B. Chen's quantization index modulation (QIM) technique [2]. In this paper, the bit embedding is based on the relative modulation of the AC components of an 8x8 pixel block DCT with its predicted one. Therefore interference to the watermark detection by the host image is eliminated. Moreover, the AC values are predicted from the DC components of a group of adjacent blocks, which makes the technique simple and congenitally robust against common numerical processing.

2. AC PREDICTION WITH DC COMPONENTS

For the common 8x8 block DCT shown in Fig. 1(a), most of the signal energy of the block is compacted in the DC component and the remaining energy is distributed diminishingly in the AC components in zigzag scan order. For most images the primary characteristics of the DCT coefficients in one block have a high correlation with the adjacent blocks. The watermarking technique [3, 4] is complicated and is not always robust. The reason is that the estimation model of DCT coefficients is too imprecise and variable. C.A. Gonzales et al., [5] described a technique which predicts a few low frequency AC coefficients. The method only uses the DC values of a 3x3 neighbourhood of 8x8 blocks to estimate the AC coefficients of the central block, as shown in Fig. 1(c). The prediction formulae for the first five unquantized AC coefficients are shown in the equations below.

$$
\begin{aligned}
AC(0,1) &= 1.13884*(DC_4 - DC_6)/8 \\
AC(1,0) &= 1.13884*(DC_2 - DC_8)/8 \\
AC(0,2) &= 0.27881*(DC_4 + DC_6 - *DC_5)/8 \\
AC(2,0) &= 0.27881*(DC_2 + DC_8 - *DC_5)/8 \\
AC(1,1) &= 0.16213*(DC_1 + DC_9 - DC_3 - DC_7)/8
\end{aligned}
\quad (1)
$$

3. PROPOSED WATERMARKING SCHEME

To embed the watermark, the whole image is divided into nine 8x8 blocks, each of which can embed up to 5 watermark bits by replacing the 5 AC components with the following rule.

$$
\begin{aligned}
&\text{Set } AC_i \geq AC'_i + \Delta \quad \text{to embed bit '1'} \\
&\text{Set } AC_i \leq AC'_i - \Delta \quad \text{to embed bit '0'}
\end{aligned}
\quad (2)
$$

In equation (2), AC_i is one of the 5 AC components: AC(0,1), AC(1,0), AC(0,2), AC(2,0) and AC(1,1). AC'_i is the value of AC_i predicted with equation (1). Δ is a reference threshold.

The original image is not needed for the watermark bit detection. We can compare AC_i with its predicted value AC'_i in the watermarked image, so the absolute values are not needed. If $AC_i > AC'_i$, then the extracted bit is '1', otherwise if $AC_i < AC'_i$, then the extracted bit

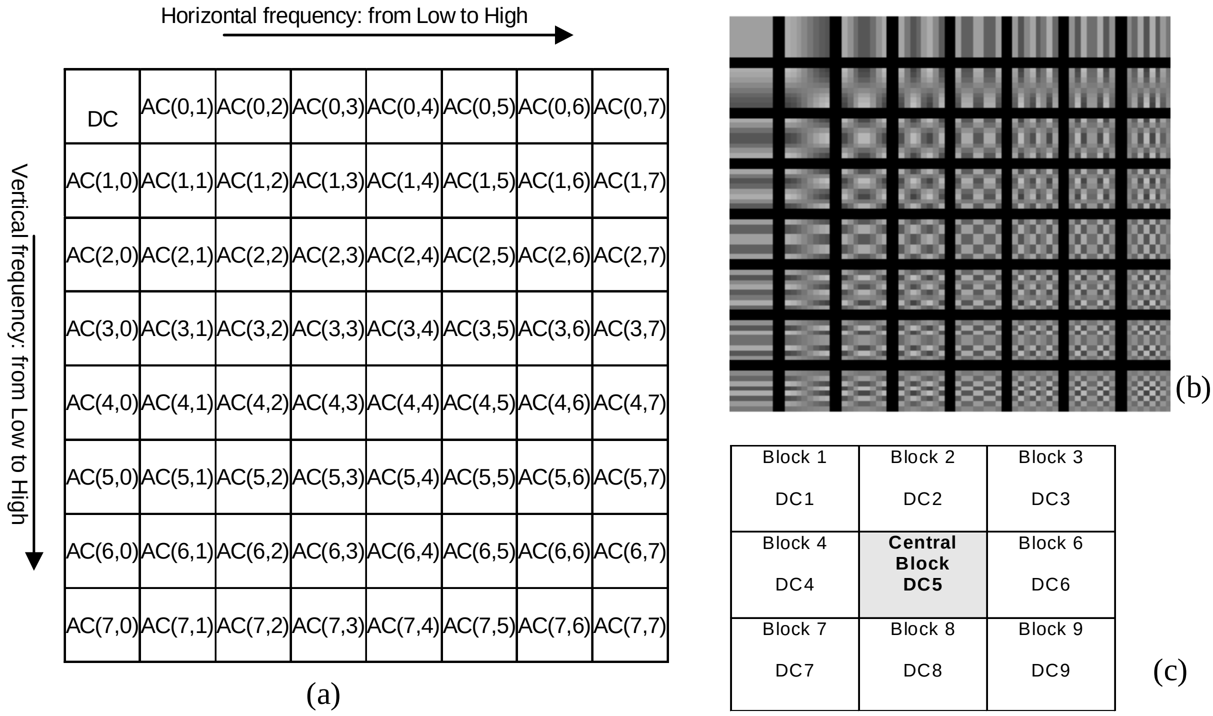

Fig. 1. DCT coefficients in one block and a group of adjacent blocks

(a) DCT coefficients in one 8x8 block
(b) DC values in a group of blocks used to estimate ACs of the central block
(c) DCT coefficients in one 8x8 block

is ‘0’. If $AC_i = AC'_i$, there is uncertainty about whether the watermark bit is ‘1’ or ‘0’. When some of the 3x3 blocks are inside the texture area and some are not, the estimated ACs are not accurate using (1). If the relative difference between AC_i and AC'_i is greater than a preset threshold ξ, no bit is embedded in that pair to avoid artifacts. In our experiment, ξ is set as 10%., and Δ is chosen as 5% of the original AC_i value. Not all the block can hide the same number of watermark bits, depending on the texture feature of the block. The smoother the targeted central block, the smaller will be the AC value and the fewer the number of bits that can be hidden in the block. If we attempt to hide more bits artefacts will appear or the extracted bits are wrong because in this situation the Δ value is very small, so the difference between the real value of AC_i and its replaced value, which acts as the decision threshold, is very near zero, The processing of the watermarked image and the limited operation precision, which introduces noise, will submerge the decision threshold and result in incorrect extracted bits. For most of the image, the lower frequency components AC(0,1) and AC(1,0) have higher energy than other AC components. For security reasons, we only choose these two ACs to hide information if the two ACs provide enough watermark capacity.

4. EXPERIMENTAL RESULTS

We embedded 2730 bits in the host image FRUIT (1024x768) imperceptibly using the above watermarking technique only on AC(0,1) and AC(1,0) in each central block. Figs 2(a) and 2(b) are the original image and the watermarked image respectively. In order to test the robustness of the watermark, we used the image processing tool Paint Shop Pro 7 to apply some typical image processing procedures (listed below) to the watermarked image, and the resultant images are shown in Figs. 2(c) --2(h).

1. Adding “salt and pepper” with the following parameters: speck size=7, sensitivity to specks=8. Aggressive action (checked), include all lower speck sizes (checked).
2. JPEG compression with Compress factor = 99, standard encoding (checked).
3. A pair of downsizing & upsizing: Percentage of original---Width: 25%, Height: 25%. Resize type: Bi-cubic resample.

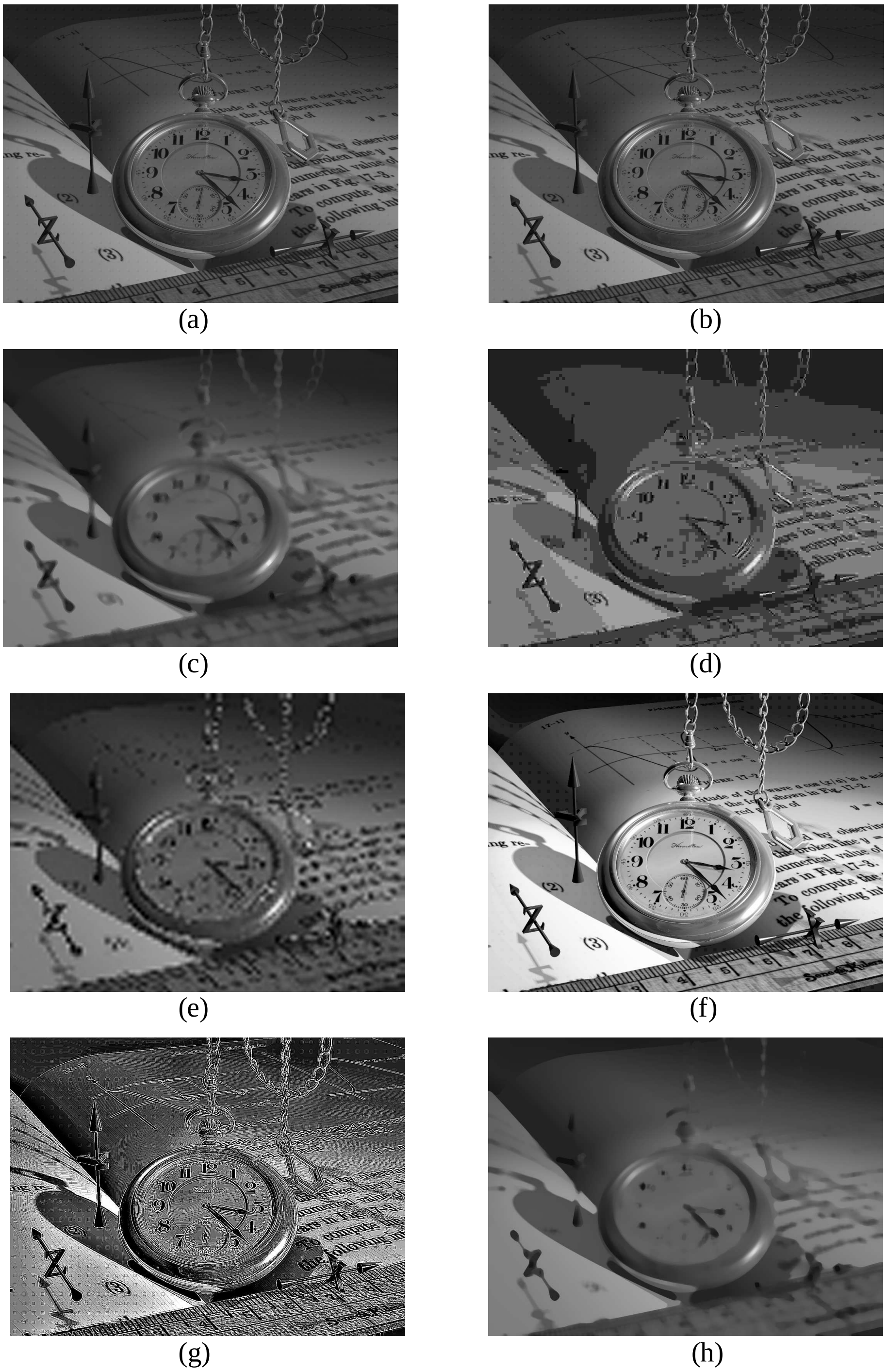

Fig. 2. Original, watermarked and processed images

(a) Original image (b) Watermarked image (c) Noise added (b)

(d) JPEG compressed (b) (Compression factor=99%) (e) Downsized & upsized (b) by factor 4

(f) Histogram equalized (b) (g) Sharpened (b) (h) Median filtered (b)

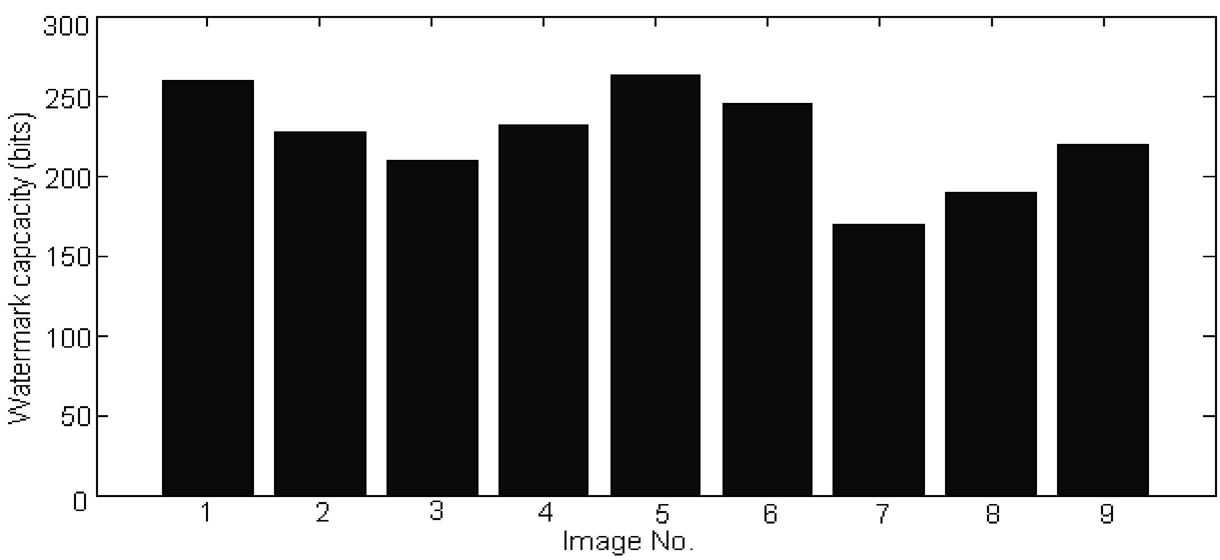

Fig. 3. Watermark capacity for different images in the same top-left 256x256 area

4. Histogram equalization.
5. Sharpen.
6. Median Filter with filter aperture = 19.

After each of these processing steps, we can still extract all the embedded watermarking bits correctly. Using the same processing listed above, the more texture the host image has, the more watermark bits can be hiden and survive the processing. We select 9 standard test images to hide watermark bits in the top-left 256x256 pixel area. Their robust watermark capacity is shown in Fig. 3. The 9 test images are WATER, WATCH, TERIFF, TEAPOT, MAN, PEPPERS, POOL, LENA and FRUITS respectively.

5. CONCLUSION

A novel blind watermarking technique is presented, which is based on the modification of the AC DCT components when these are values predicted from the DC components for the adjacent blocks. Since the watermark detection is determined by the difference in value between the AC value and the predicted one, the effect of global numerical attacks on the watermark is eliminated. Compared with other DCT-based techniques [1, 6], our technique has higher capacity and lower computational cost under the same robustness. The simplicity of the technique means that it can be extended to direct MPEG-2 bit stream video watermarking.

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