An Adaptive DCT Domain Visible Watermarking Technique for Protection of Publicly Available Images

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Abstract - **At present, with the growth of computer networks and information technology there is a trend to move from conventional libraries to digital libraries. In the digital libraries images and texts are made available through the internet for scholarly research. At the same time care is taken to prevent the unauthorized use of the images commercially. For this purpose the owner needs to use visible watermarking. In this paper, we describe a visible watermarking scheme that is applied into the host image in the DCT domain. A mathematical model has been developed for that purpose.**

I. INTRODUCTION

Digital watermarking is defined as a process of embedding data (watermark) into a multimedia object to help to protect the owner's right to that object. The embedded data (watermark) may be either visible or invisible. In visible watermarking of images, a secondary image (the watermark) is embedded in a primary (host) image such that watermark is intentionally perceptible to a human observer.

Some of the desired characteristics of visible watermarks are listed below [1][2].

- A visible watermark should be obvious in both color and monochrome images.
- The watermark should be spread in a large or important area of the image in order to prevent its deletion by clipping.
- The watermark should be visible yet must not significantly obscure the image details beneath it.
- The watermark must be difficult to remove; removing a watermark should be more costly and labor intensive than purchasing the image from the owner.
- The watermark should be applied automatically with little human intervention and labor.

There are very few visible watermarking techniques available in current literature. The IBM digital library organization has used a visible watermarking technique to mark the digitized pages of manuscript from the Vatican archive [3][9]. Kankanhalli et al. [4] have proposed a visible watermarking technique in DCT domain. They divide the image into different blocks, classify the blocks by perceptual methods proposed in [5] and modify the DCT coefficients of host image as follows.

$$c'_{ij}(n) = \alpha_n c_{ij}(n) + \beta_n w_{ij}(n) \quad n = 1,2\ldots \quad (1)$$

The α_n and β_n coefficients are for block n. The $c_{ij}(n)$ are the DCT coefficients of the host image block and $w_{ij}(n)$ the DCT coefficients of the watermark image block.

In this paper, we propose a visible watermarking technique that modifies the DCT coefficients of the host image using eqn.(1). But, the α_n and β_n values are found out using a mathematical model developed by exploiting the texture sensitivity of the human visual system (HVS). This ensures that the perceptual quality of the image is better preserved. We call α_n the scaling factor and β_n as the embedding factor. We have also proposed a modification to make the watermark more robust.

II. Finding the Scaling and Embedding Factors

While finding the scaling factors (α_n) and embedding factors (β_n), the following are taken into consideration [4][5][6][7] so that the quality of the watermarked image is not degraded.

- The edge blocks should be least altered to avoid significant distortion of the image. So one can add only small amount of watermark gray value in the edge block of host image. This means that scaling factor α_n should be close to α_{max}, (the maximum value of the scaling factor) and embedding factor β_n should be close to β_{min}, (the minimum value of the embedding factor).
- The distortion visibility is low when the background has strong texture. In a highly textured block, energy tends to be more evenly distributed among the different AC DCT coefficients. That means AC DCT coefficients of highly textured blocks have small variances and we can add more to those blocks. So for convenience, we assume α_n to be directly proportional to variance (σ_n) and β_n to be inversely proportional to variance (σ_n).
- Let us denote the mean gray value of each image block as μ_n and that of the image as μ. The blocks with mid-intensity values ($\mu_n \approx \mu$) are more sensitive to noise than that of low intensity blocks ($\mu_n < \mu$) as well as high intensity blocks ($\mu_n > \mu$). This means that α_n should increase with μ_n as long as ($\mu_n < \mu$) and should decrease with μ_n as long as ($\mu_n > \mu$). For convenience, the relationship between α_n and μ_n is taken to be truncated Gaussian. The variation of β_n with respect to μ_n is the reverse of that of α_n. The mean gray value of each block is given by its DC DCT coefficient.

To confirm to the above requirements we have chosen α_n and β_n as follows.

- The α_n and β_n for edge blocks are taken to be α_{max} and β_{min} respectively.
- For non-edge blocks α_n and β_n are computed as:

$$\alpha_n = \sigma'_n \ \exp.\left(- (\mu'_n - \mu')^2 \right) \quad (2)$$

$$\beta_n = (1/\sigma'_n)\left(1 - \exp.\left(- (\mu'_n - \mu')^2\right)\right) \quad (3)$$

  where, μ'_n, μ' are the normalized values of μ_n and μ respectively, and σ'_n is normalized logarithm of σ_n (the variance of the AC DCT coefficients).
- α_n and β_n are then scaled to the ranges (α_{min} , α_{max}) and (β_{min} , β_{max}) respectively, where α_{min} and α_{max} are the minimum and maximum values of the scaling factor, and β_{min} and β_{max} are the minimum and maximum values of the embedding factor. These are the parameters determining the extent of watermark insertion.

We divide the original image I into 8x8 blocks and find the DCT coefficients of each block. Let us denote the DCT coefficients of block n by, $c_{ij}(n)$ = 1,2, ... N, where n represents the position of block in image I (if we traverse the image in a raster-scan manner). N is the total number of 8x8 blocks in the image and given by (row x col)/64, "row" is the number of rows and "col" is the number of columns of the image.

The normalized mean gray value of block n is found out using eqn.(4):

$$\mu'_n = c_{00}(n) / c_{00max} \quad (4)$$

where, c_{00max} is the maximum value of $c_{00}(n)$.
The normalized mean gray value of the image I is calculated using eqn.(5):

$$\mu' = (1/N)\ \Sigma^{N}_{n=1} c_{00}(n) \quad (5)$$

The variance of the AC DCT coefficients (σ_n) of block n is found using eqn.(6):

$$\sigma_n = (1/64)\ \Sigma_i \Sigma_j \left(c_{ij} - \mu_n^{AC}\right)^2 \quad (6)$$

where, μ_n^{AC} is the mean of the AC DCT coefficients.
The normalized variance of the AC DCT coefficients of block n is of the value given by

eqn.(7). Let us denote the natural logarithm of σ_n as σ^*_n.

$$\sigma'_n = \sigma^*_n / \sigma^*_{max} \qquad (7)$$

where, σ^*_{max} is the maximum value of σ^*_n.

III. INSERTION OF WATERMARK

The steps for watermark insertion are discussed now.

- The original image I (to be watermarked) and the watermark image W are divided into blocks of size 8x8. (Both the images may not be of equal size).
- The DCT coefficients for each block of the original image are found out.
- For each block of the original image I, the normalized mean gray value μ'_n is computed using eqn.(4) and are scaled to the range 0.1-1.0. The normalized image mean gray value μ is found out using equation (5).
- For the AC DCT coefficients, the normalized variances σ'_n are computed using equation (7) and scaled to the range 0.1-1.0.
- The edge blocks are identified using the Sobel edge operator.
- The α_n and β_n are found by using equations (2) and (3).
- The DCT of watermark image blocks are found out. The n^{th} block DCT coefficient of the host image I is modified using eqn.(1). The IDCT of modified coefficients give the watermarked image.

Fig.1: Image used as Watermark

Fig.1 shows the image used as watermark. Fig.2 shows the original 'Lena' image. Fig.3 and Fig.4 show the watermarked 'Lena' image with different sizes of watermarks.

Fig.2: Original "Lena"

Fig.3: Watermarked "Lena"
(watermark over the whole image)

Fig 4: Watermarked "Lena"
(small watermark at the corner)

IV. MODIFICATIONS TO MAKE THE WATERMARK MORE ROBUST

The algorithm proposed here and also that of the classification schemes proposed in [4] are not robust for images having very few objects and large uniform areas like in Fig.5. In [4] most of the blocks will be classified to be in one class for this type of image. If the algorithm discussed in Section III is applied then most of the blocks will have the same α_n and β_n values. So in either of the cases, it is easy for a digital thief to remove the watermark from the watermarked image as it would be easy to predict the α_n and β_n values. We have proposed a modification to our above watermark insertion technique in [10].

Fig.5: 'hardware' image

V. CONCLUSIONS

A visible watermarking technique has been proposed in the DCT domain. A mathematical model has been developed for this purpose exploiting the texture sensitivity of the HVS. We have also proposed a modification to increase the robustness of the watermark when used for images with very few objects. For more robustness, the watermark should not be made available publicly; the watermark should be used in different sizes and should be put in different portions for different images. The typical values of α_{min}, α_{max}, β_{min} and β_{max} are 0.95, 0.98, 0.07 and 0.17 respectively. The visible watermark can be used in digital TV [8], digital library, e-commerce [1][2] etc.

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