A Procedure for Optimal Image Watermark Detection

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Abstract-**An approach to watermarking by using the discrete cosine transforms (DCT) coefficients of nonoverlapping 8x8 blocks of image is presented. Optimal watermark detection procedure is based on analysis of the power density function (pdf) of the watermarked coefficients. In order to achieve an efficient detection in different cases of the pdf distribution new forms of watermark detectors are introduced.**

Keywords – **optimal detection, DCT domain, watermark, kurtosis**

I. INTRODUCTION

Very intensive applications of digital audio, image and video signals in multimedia communications result in significant requests for an efficient digital watermarking .It is the reason that in the last few years numerous research group deal with this problem [1], [3], [6], [7], [8]. The aim of digital watermarking is to provide an algorithm for watermark embedding and watermark recovery. Thus the first requirement is in finding an appropriate scheme which will provide inserting an invisible signal i.e. watermark containing the information about copyright holder. The watermark has to be perceptual invisible, robust to the various signal processing algorithm etc. [8]. The second requirement is in providing reliable procedure for watermark detection [1], [2], [4].

The topic of this paper will be focused on the second requirement. For this purpose we will consider embedding of digital watermark in the DCT domain of image. Here we will consider the DCT coefficients obtained from the nonoverlapping 8x8 blocks used in the JPEG compression. With respect to watermark invisibility requirement, the watermark is embedded in a Bet of coefficients excluding the most significant coefficients (with the highest absolute values). It is shown that the various forms of watermark detectors can be used in order to achieve more reliable watermark detection.

II. WATERMARK EMBEDDING

We will consider the DCT coefficients in the nonoverlapping 8x8 blocks. A sequence of the DCT coefficients *Ii* for i = 1,2, ..., *M* x *N*, where *S* = *M* x *N*, is the image size is formed. The coefficients in the sequence will be sorted in the ascending order with respect to their absolute values. Denote this sequence as: *I sorti* for i = 1,2, ..., *S*. Since we will use positive and negative coefficients, it is important to finci the Bet *ai* i = 1,2, ..., *S* which will give the position of the sorted coefficients *Isorti* in the sequences *Ii*.

As a watermark *w* the Bet of the real random numbers for which the probability density function (pdf) is normal Gaussian with zero mean value is used. The watermark will be embedded in *K* coefficients which compose the sequence *I seqi* i = 1, 2, ..., *K*. This sequence contains the coefficients whose absolute values belong to *I sorti* i = *S* -*L* -*K* -1, *S* -*L* -*K*, ..., *S* -*L*. Thus, the watermark will be embedded according the following equation [2]:

$$I_w = I_{seq} + \alpha \, | I_{seq} | \, \mathrm{w} \qquad (1)$$

where a is the parameter controlling the watermark influence. Note that the last *L* coefficients are not corrupted by watermark, because change of these coefficients could cause significant image degradation. The parameters *L* and *K* specify number and positions of the coefficients used for watermarking. These parameters are crucial for the shape of the pdf distribution of the watermarked coefficients. Namely, although it has been shown that the sequence *Ii* for i = **1,2,** ..., *S* has dominant Laplacian pdf [2], [4], [5], for the sequence *I seq* the pdf will be significantly changed. Note that, the shape of the pdf determines the optimal watermark detector.

III. WATERMARK DETECTORS

Problem of finding the optimal detector can be considered as detection of the sequence *w* in the watermarked image *Iw*. For this purpose we will consider the locally optimal detector in the form [9]:

$$D = \sum_{i=1}^{K} w i g_{\mathrm{LO}}(\mathrm{I}_{\mathrm{wi}}) \qquad (2)$$

where:

$$g_{LO} = -\frac{P'(I_w)}{P(I_w)}$$

P(Iw) is the pdf of the watermarked coefficients, *P'(Iw)* is its derivative. Commonly used watermark detector assumes the Gaussian pdf, i.e.:

$$D_a = \sum_{i=1}^{K} w i I_{wi} \qquad (3)$$

The sequence *W* is the secret key for the watermark detection procedure. Watermark will be detected if the value obtained by *Da* has significantly higher value by using watermark key, i.e. true test *(Dakey)* as compared to one obtained with wrong key (wrong test) composed by any other sequence *Ww (Dawrong)* with the Gaussian zero mean values.

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$$DL = \sum_{i=l}^{K} w_i sign(I_{wi}) \qquad (4)$$ **In** the case of Laplacian pdf , the optimal detector is:

The modified version of *DL* detector can be written in the form:

$$DLM = \sum_{i=l}^{K} w(i) I_w / | I_w |^{p} \qquad (5)$$

Note that the parameter *p* in Eq. (5) determines *DLM* as optimal for the pdf between Gaussian and Laplacian (for *p* = 1 *DLM=DL*, while for *p* = 0, *LM=Da).*

By using the Kurtosis test we could be able to estimate which distribution will be the best approximation for the pdf of watermarked coefficients. The Kurtosis is defined as:

$$\gamma = \frac{(I_w - \mu_{Iw})^4}{N\sigma_{IW}^4} - 3 \qquad (6)$$

where μ_{Iw} = *E[Iw]* is the mean value of the watermarked coefficients, σ^2_{Iw} = $E[Iw - \mu I_w]^2$ is the standard deviation of *Iw.* Note that, for the Gaussian distribution, γ =0, in the case of Laplacian distribution γ = 3, while for uniform distribution γ = -3. Define now a generalized exponential pdf form :

$$P(I_m) = ce^{-\frac{I_w^n}{\sigma_{Iw}^N}}$$

Fig. 1. The original images "Lena" and "Baboon", of size 240x256.

which will be close to a uniform distribution for a high value of *n.*

Taking *P(Iw)* with *n* = 4, we obtain the form of detector as:

$$D_U = \sum_{i=1}^{K} w(i) I_w^3 \qquad (7)$$

An efficient watermark detection procedure by using Eqs. (3), (4), (5) and (7), for different pdf forms can be achieved. The Kurtosis test will be used as an indicator of the detector which is the most suitable for a specific application.

As a measure of the detector quality (reliability), the following equation can be used:

$$R = \frac{\bar{D}_{key} - \bar{D}_{wrong}}{\sigma_{key} + \sigma_{wrong}} \qquad (8)$$

where *Dkey* and *Dwrong* are the mean values obtained by using the true test and the wrong test respectively, while σ_{key} and σ_{wrong} are the standard deviations for the both cases.

IV. EXAMPLES

In this section we will consider the images "Lena" and "Baboon", Figure 1. Note, that by choosing different values for *L* and *K* the sequences *I seq* will have different pdfs.

Example 1. In this example we will use *L* = 2000, and *K* = 5000. Thus, we will not embed watermark in the last 2000 the most significant coefficients. It provides that the watermark is invisible in all images. In this case we obtain that the detector *Du* is the optimal for the both images. Namely, the factors *RU1* = 6.36, *RC1* = 3.50, *RLM1* = 2.42 and *RU2* = 8.26, *RC2* = 3.45, *RLM2* = 2.33 are calculated by using Eqs. (3), (5) with *p* = 1/3, (7), and (8), for Lena and Baboon, respectively. This test is performed on 200 realizations. The Kurtosis values are $\gamma 1$ = -1.31 for Lena, and $\gamma 2$ = -1.76 for Baboon. In this case we have obtained: *SNR1* = 40.11 and *SNR2* = 39.83.

Example 2. Here we have used the values *L* = 1000, and *K* = 30000. In this example we have obtained: *RU1* = 3.20, *RC1* = 4.83, *RLM1* = 4.44, *RU2* = 4.62, *RC2* = 6.51, *RLM2* = 5.18, $\gamma 1$ = 17.15, $\gamma 2$ = 3.10, *SNR1* = 34.69 and *SNR2* = 35.65.

In the previous examples a = 0.1 is used. Our visual perception, as well as the values of *SNR*, indicate invisibility of the watermark in the considered images, Figure 2.

V. CONCLUSION

It has been shown that the optimal watermark procedure requires determination and appropriate approximation of the pdf function of the watermarked DCT coefficients of nonoverlapping 8x8 blocks of image. Based on the Kurtosis test analysis the negative Kurtosis indicate that the pdf function width flatter top could be very efficient.

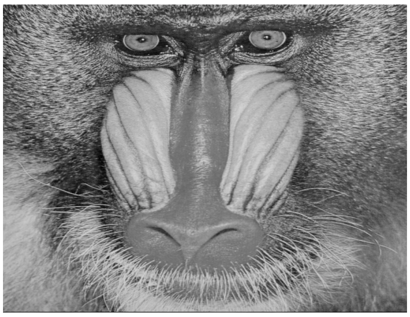

Fig. 2. The watermarked images “Lena” and “Baboon”, according to Example 1.

VI. ACKNOWLEDGMENT

This work is supported by the Volkswagen Stiftung, Federal Republic of Germany. Igor Djurovic is on leave at the Kyoto Institute of Technology, Kyoto, Japan, supported by the Japanese Society for Promotion of Science (JSPS).

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