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A Robust Blind Image Watermarking Based on Generalized Gaussian Distribution

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Abstract: The modeling of signal by a general parametric family of statistical distributions plays an important role in many image processing applications. Some image watermarking methods based on Gaussian distribution to model the image coefficients in the transform domain. In this study, the Generalized Gaussian Distribution (GGD) is used for modeling the wavelet detail sub-band coefficients and for image watermarking scheme. In the procedure of watermark embedding, the image significant information entropy is considered. Its improved robustness and imperceptibility are due to embedding in the significant wavelet coefficients. In case of watermark detection, the hypothesis test is used to detect the watermark. Experimental results demonstrate that the effectiveness of the presented watermarking and its robustness against common signal processing and some kinds of geometric attacks.

Key words: Digital watermarking, generalized gaussian distribution, wavelets, hypothesis test

INTRODUCTION

It has improved the ease of access to digital multimedia with the rapid development of information technologies and it also leads to the problem of illegal copying and redistribution of multimedia in the internet (Zheng *et al*., 2007). Digital watermarking is one of the technologies which for the purpose of copyright protection, broadcast monitoring, data authentication and so forth. It is demonstrated that the transform-based watermarking has superior performance than the spatial-based watermarking. (Cox *et al*., 1997). Some common transform consists of the DFT (Discrete Fourier Transform) (Xiang *et al*., 2009), DCT (Discrete Consine Transform) (Li and Cox, 2007) and DWT (Discrete Wavelet Transform) (Emir and Ahmet, 2005), etc.

In the transform domain, correlation detector is suboptical for watermark detection. As well, some alternative optimum and locally optimum watermark decoders have proposed by Cox *et al.* (1997) and Kirovski and Malvar (2001). Cox *et al.* (1997) proposed a robust optimum detector using the DCT and DWT. According to the non-Gaussian property of high frequency coefficients, the generalized Gaussian distribution is used to model the high frequency coefficients of Consine transform and wavelet transform. As well, the alpha-stable distribution is also adopt model the mid-frequency Consine coefficients. A watermark decoder for Cauchy distributed Consine coefficients based on the framework of Hernandez *et al.* (2000). But the both methods are based on the strong assumption that the watermark embedding strength is known to the process of watermarking detection.

Based on the above analysis, in this work, the host image is transformed by the DWT and the watermark data is embedded in the significant wavelet coefficients in the mid-frequency region. The wavelet detail coefficients are modeled by the distribution of generalized Gaussian density (Do and Vetterli, 2002). Finally, the watermark data is embedded into the mid-frequency wavelet coefficients.

PROPOSED WATERMARKING

Proposed watermarking: The embedding algorithm performs the watermark embedding as follows:

Step 1: Segment the image into non-overlapping blocks. The size of host image I is M×N

Step 2: Calculate the image information entropy of each block then these blocks were sorted in descending by its entropy

Step 3: Apply the 3-level DWT to the each block

Step 4: Use the Pseudo-random Noise generator to generate a watermark data sequence

Step 5: Select the mid-frequency regions in the image wavelet coefficients for embedding in each block Then the watermark embedding formula is as the following:

$$y[t] = x[t] + \alpha w[t] \tag{1}$$

where, α is the strength factor, x represents the host image, y is the watermarked image, The watermark data were denoted by $w[t], t = 1, \ldots, N_w, w[t] \in \{-1, 1\}$

Step 6: Apply the inverse DWT for each block

Step 7: Combine the watermarked image blocks with the non-watermarked image blocks to get the watermarked image

Watermark detection: The watermark detection is summarized as the following:

Step 1: Segment the watermarked image into non-overlapping blocks

Step 2: Select high entropy blocks as the same as the watermark embedding process

Step 3: Apply the 3-level DWT to the selected image blocks

Step 4: To drive a watermark detector, a Likelihood-Ratio Test (LRT) is constructed as the embedding. A two-sided parameter test can be defined as:

$$\begin{cases} H_0 : \alpha = 0, \theta \text{ (no watermark)} \\ H_1 : \alpha \neq 0, \theta \text{ (watermarked)} \end{cases} \tag{2}$$

where, θ denotes the vector of unknown parameters. H_1 and H_0 denotes null hypothesis and alternative hypothesis, respectively. θ contains the shape and scale parameter of the generalized Gaussian distribution. Given α and θ, if:

$$\rho(y) = \frac{p(y, H_1)}{p(y, H_0)} > T \tag{3}$$

where, y denotes received image, T denotes detection threshold. ρ (y) is called the LRT

Step 5: According to GGD, The LRT statistics is defined as:

$$\rho(y) = \frac{1}{c^{\beta}} \sum_{t=1}^{N} \left(|y(t)|^{\beta} - |y(t) - \alpha w(t)|^{\beta} \right) \tag{4}$$

where, c, β denote the scale parameter and the shape parameter of the GGD, respectively. Compare the LRT with the detection threshold T to judge if the image was watermarked

EXPERIMENTAL RESULTS

In this regard, several experiments are performed to test the proposed watermarking algorithm.

Invisibility test: In Fig. 1, the difference of histogram between original image and corresponding watermarked image was computed. It can be seen that the difference is a little and the watermarking scheme has good invisibility without any attacks.

Robustness test: Apart from invisibility, the robustness is tested by Bit Error Rate (BER) and Normalized Coefficients (NC). The relation of BER and NC is that NC = 1-2 BER. Table 1 shows the results for Barbara. From Table 1, it can be seen that the relation of BER and NC agrees closely with the experimental results. Thus the proposed watermarking has good robustness. However, when confront geometric attacks, the watermarking is not good. This may due to the method discards the spatial information and the geometric structure.

Table 2 illustrates the comparison of proposed method with the method by Al-Khassaweneh and Aviyente (2006) by the NC for Barbara. From Table 2, the proposed method has superior performance than Al-Khassaweneh and Aviyente (2006) when against common image processing. But when resist the rotation attack, Al-Khassaweneh and Aviyente (2006) has better than the proposed algorithm. The main reason may be the multi-bit was embedding into the watermarkable coefficients by Al-Khassaweneh and Aviyente (2006).

Detection performance analysis: Figure 2 shows the plots for the Likelihood ratio test detector by Roland *et al.*

Table 1: Normalized coefficients and bit error rate results of extracted watermark under common image processing and geometric distortion attacks

Attack	Parameters	Normalized coefficients	Bit error rate (%)
Median filtering	3×3 window	0.9207	3.97
Median filtering	5×5 window	0.8133	9.34
Gaussian filtering	3×3 window	0.8786	6.13
Gaussian filtering	5×5 window	0.9118	3.87
JPEG compression	QF = 50%	0.9071	5.01
JPEG compression	QF = 40%	0.8503	6.95
Noise	Density 0.02	0.8546	7.48
Pepper salt	Density 0.02	0.8624	7.65
Scaling	0.8	0.8386	8.37
Scaling	1.5	0.8503	7.39
Rotation	3 (Degree)	0.7893	10.47
Rotation	5 (Degree)	0.6935	14.58
Cropping	0.25	0.8461	7.95
Cropping	0.50	0.5379	23.20

Table 2: Watermark detection results under common image processing and geometric distortions

Attack	Parameters	(Al-Khassaweneh and Aviyente, 2006)	Proposed
Median filtering	3×3 window	0.9101	0.9314
Median filtering	5×5 window	0.5900	0.8152
JPEG compression	QF = 70%	0.7900	0.9106
JPEG compression	QF = 90%	0.9600	1.0000
Noise	Density 0.01	0.9700	0.9837
Noise	Density 0.02	0.8800	0.8548
Scaling	0.8	-	0.8385
Scaling	1.2	-	0.8573
Rotation	3 (Degree)	0.9800	0.7875
Rotation	5 (Degree)	0.9700	0.6921

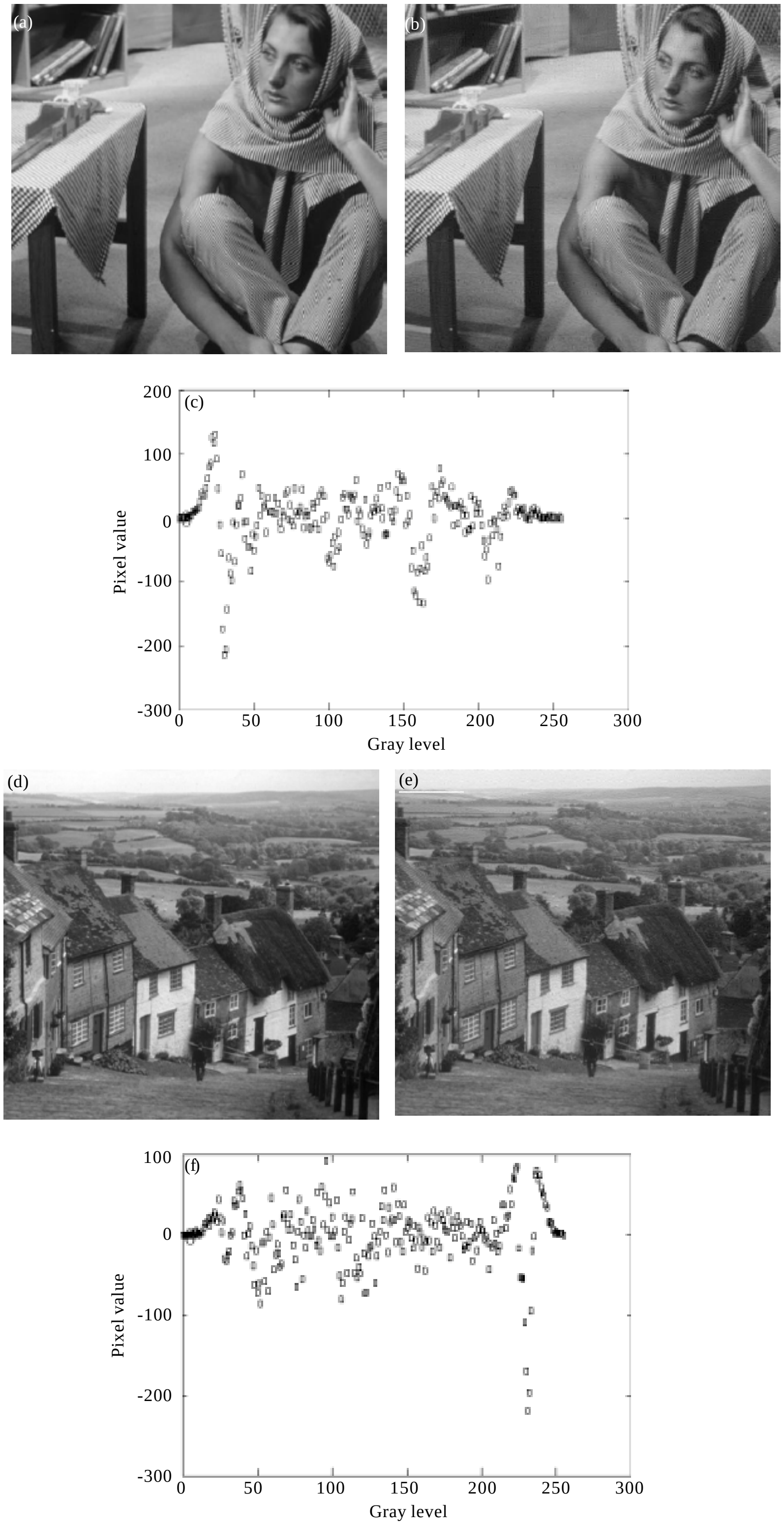

Fig. 1(a-f): Host image and watermarked image: Barbara and Goldhill. (a-c) Host image, watermarked image and histogram difference for Barbara and the (d-f) is for Goldhill

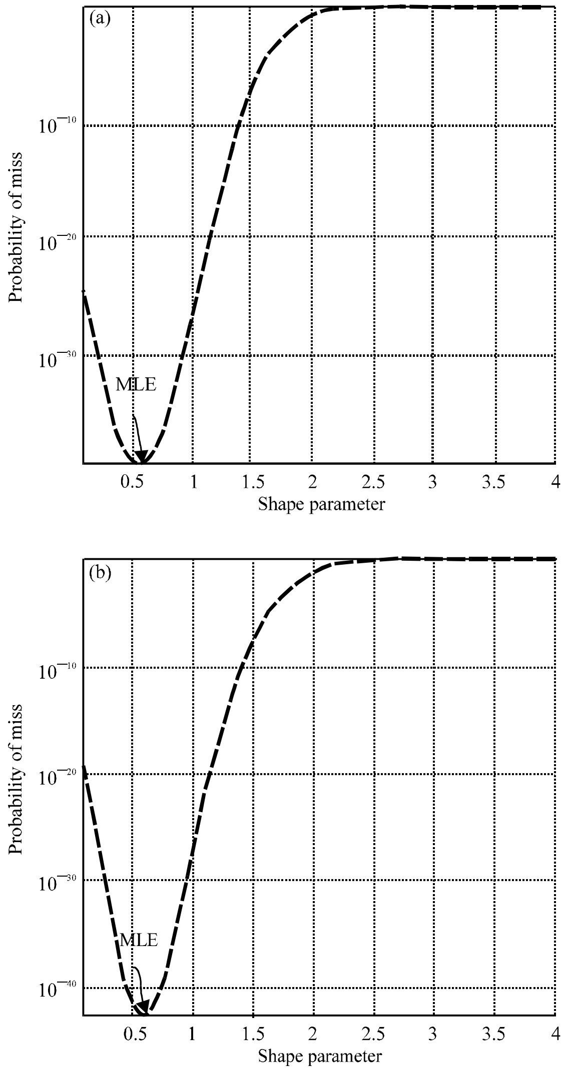

Fig. 2(a-b): Detection performance of the LRT-GGD as a function of the scale parameter (a) Barbara and (b) Goldhill

(2009). The β of GGD varies from 0.02-4 and the Y-axis denotes the probability of missing, given that the probability of false positive is 1.0×e-6. The text arrow is the ML (Maximum Likelihood) estimate; it can be see that the peak performance is missed by only a small margin from the results. According to this test, it has the conclusion that the GGD model can well capture the marginal distribution of wavelet coefficients.

CONCLUSION

In this study, a blind watermarking based on the significant wavelet coefficients has been presented. This algorithm embeds the watermark by modifying the DWT coefficients in the middle frequency regions and use the hypothesis test to develop the blind detector based on the general Gaussian distribution model. The experimental results show superior performance to common image processing attacks and some geometric attacks. Further work concentrates on developing robust watermarking scheme against geometric distortions.

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