Wavelet-Based Image Watermarking Using the Genetic Algorithm

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Abstract. Image watermarking provides copyright protection of digital image by hiding appropriate information in the original image in such a way that it does not cause degradation of the perceptual image quality and cannot be removed. The watermarking methods for transform domains are usually achieved by using the discrete cosine transform or the discrete wavelet transform. In this paper, we develop a technique for optimizing the image watermarking using the genetic algorithm applied to the wavelet transform domain to improve the quality of the watermarked image and the robustness of the watermark. We then compare our experimental results with the results of previous works.

1 Introduction

Due to the advent of digital computer and subsequence development of digital multimedia technology, the demand for network distribution of images and video pictures has increased dramatically in the past decade. Although digital data has been shown to have many advantages over analog data, one of the potential problems on handling the digital data is that it can be easily duplicated. Thus, the importance of copyright protection becomes very crucial. As a solution to this problem, various digital watermarking techniques have been investigated to address the issue of ownership verification.

In general, digital watermarking can be performed in spatial domain or transform domain, where the properties of the underlying transform domain can be exploited. Previous works on digital image watermarking in spatial domain utilized the modified least significant bit of some pixels in an image. This scheme is fast and straightforward. Cox *et al.* [1] proposed a watermarking technique by embedding the watermark in the large discrete cosine transform coefficients using the concept of spread spectrum communication. Xia *et al.* [2] introduced

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a new multiresolution watermarking method based on the discrete wavelet transform. The watermark is embedded to the large wavelet coefficients at high and middle frequency bands of the discrete wavelet transform of an image. In [3], Huang et al. proposed a watermarking method based on the discrete cosine transform (DCT) and the genetic algorithm. The genetic algorithm is applied to search for the locations to embed the watermark in the DCT coefficient block such that the watermarked image quality is optimized.

In this paper, we present the watermarking method using the genetic algorithm in the wavelet transform domain. The watermark is embedded to the wavelet coefficients larger than some threshold values based on [4] which does not require the original image in the detection process. We applied the genetic algorithm to search for optimal threshold values and the strength of the watermark to improve the quality of the watermarked image and the robustness of the watermark. We then compare our experimental results with the results of the previous works [4].

2. Proposed Method

In order to achieve an optimum performance of digital image watermarking, we always encounter three conflicting objectives. These are imperceptibility, robustness and data capacity. This work employs the genetic algorithm (GA) to optimally increase performance of the traditional watermarking methods. The diagram in Fig. 1 illustrates the optimization process in which GA is applied for the watermark embedding and the watermark detection processes, respectively.

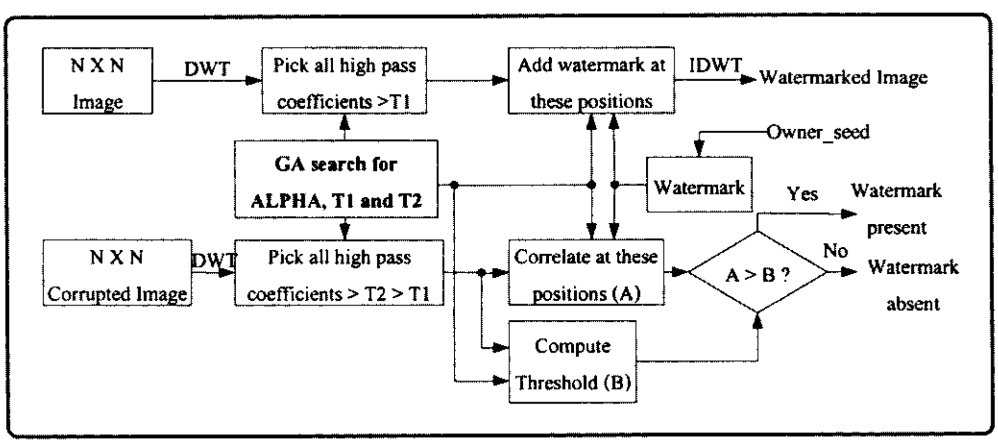

Fig. 1. Optimization diagram for digital image watermarking using genetic algorithm

2.1 Watermarking Method

We use the watermarking method based on the method proposed by Dugad [4]. The watermark insertion is performed in the discrete wavelet transform (DWT) domain by applying the 3-level wavelet decomposition with the Daubechies-8 wavelet. Fig. 2 shows the image subbands with their labels. Since the approximation subband (LL3) contains high-energy components of the image, we do not embed watermark in this subband to avoid visible degradation of image quality. Furthermore, the watermark is not embedded in the subbands of the finest scale (LH1, HL1 and HH1) due to the low-energy components to increase the robustness of the watermark. In other subbands, we choose all coefficients which are greater than the embedding threshold T_1. These coefficients are named V_i and applied to the following equation

$$V_i^{'} = V_i + \alpha|V_i|x_i \tag{1}$$

where i runs over the wavelet coefficients V_i. $V_i^{'}$ denotes the coefficients of the watermarked image. denotes the watermark which is the Guassian sequence of pseudo-random real number.

For watermark detection, we apply the same procedure but we pick the coefficients greater than the detection threshold $T_2 > T_1$ from all subbands except the approximation subband and the subbands of the finest scale. These coefficients are referred to as $\widetilde{V}_i$. Then we compute the correlation Z

$$z = \frac{1}{M}\sum_i \widetilde{V}_i y_i \tag{2}$$

where i runs over the wavelet coefficients $\widetilde{V}_i$. Y_i is the different watermark generated similar to X_i. M is the $\widetilde{V}_i$ number of the . We compare the correlation Z with the threshold S described by

$$S = \frac{\alpha}{2M}\sum_i |\widetilde{V}_i| \tag{3}$$

If the correlation Z is greater than S, the watermark has been detected.

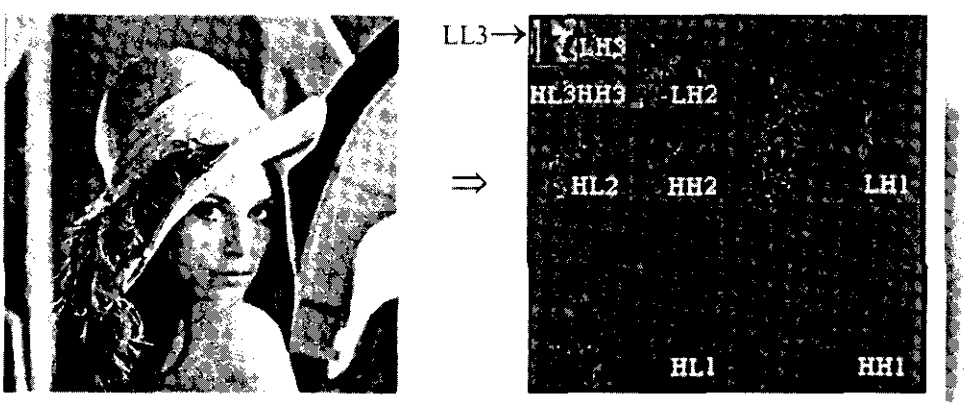

Fig. 2. Three level wavelet decomposition of Lena image

2.2 Genetic Algorithm for Improving the Watermarking Performance

Genetic algorithm is applied to search for optimal parameters in order to improve performance of watermarking. There are 3 parameters to search for: watermark strength (ALPHA or α), embedding threshold (T_1) and detection threshold (T_2). These parameters are searched for each subband with embedded watermark. Our optimization process employs a weighted objective function, W. W composes of the terms reflecting the quality of the output images, and the robustness of the watermarks, respectively. This objective function is created based on the parameters obtained from the embedding and the detection of watermarks. Details of GA are described as follows:

Chromosomes in GA represent desired solutions to be searched. Number of chromosomes used in this work is 30. The encoding scheme is binary string with 32 bit resolutions for each solution. Since digital image processing can result in DWT coefficients of values $>T_1$. Care must be taken to ensure whether the watermark is embedded. Also for watermark detection, these DWT coefficients are not desirable in correlation Z computation. Thus, should be greater than T_1. The parameter can be computed from equation (4).

$$T_2 = T_1 + T_d \tag{4}$$

where T_d is the optimal value for $T_2 > T_1$. The chromosomes then have the length of 96 bits representing , and.

The objective functions use the mean-square-error (*MSE*) as the output image quality performance index, and the difference between correlation Z and the threshold S (*DIFF*) as a watermark detection performance index respectively. An objective value W can be computed from equation (5).

$$W = \delta_{MSE} \times MSE + \delta_{DIFF} \times DIFF \tag{5}$$

where δ_{MSE} and δ_{DIFF} are weighting factor of *MSE* and *DIFF*, respectively. These weighting factors represent the importance of both indexes used in GA searching processes. If both indexes are both important, the values of these factors can both be 0.5 where the relationship $\delta_{MSE} + \delta_{\mathrm{DIFF}} = 1.0$ must hold. The parameter α, T_1 and T_2 are then searched for in order to achieve the best output image quality and watermark robustness.

Besides using the MSE in the objective function as the output image quality performance index, a mean-structural-similarity (MSSIM) [5] is also applied as in equation (5) with slight modification to compare the performance from both objective functions. In this work, the selection process employs ranking approach. The crossover and mutation probabilities are fixed at 0.7 and 0.05, respectively. The best chromosomes are then partially replaced (steady-state GA).

3. Experimental Results and Discussions

The output image quality and watermark robustness are two indexes for testing the performance. The images used in this test are grayscale of pixels. The watermark is Gaussian sequence of uniformly-distributed pseudo-random real number with zero mean , and variance of one. The results obtained from the GA based on MSE and MSSIM, which are called GA1 and GA2, respectively, are compared to the method proposed by Dugad [4], which is called METHOD1. In METHOD1, the parameter α, T_1 and T_2 are fixed at 0.2, 40 and 50, respectively, while these parameters are varied during the GA searching process.

Fig. 3 shows the convergence of GA optimization of LH2 subband using MSE as an output image quality index at 50 generations of the tested image "Lena". The resulting parameter α, T_1 and T_2 are shown in Table 1. These parameters are optimally varied to archive the most suitable for the tested image.

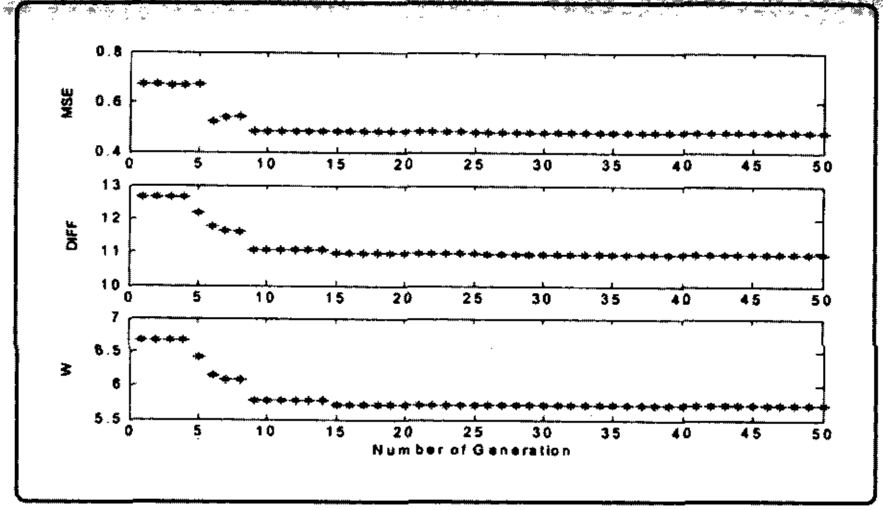

Fig. 3. *MAE* , *DIFF* and *W* from optimization of LH2 subband

Table 1. Comparisons between α, T_1 and T_2 and from GA and results from METHOD1

Watermarking Parameters	6-Subbands in GA1(MSE)						METHOD 1
	LH2	HL2	HH2	LH3	HL3	HH3	
ALPHA(a)	**0.105**	**0.103**	**0.116**	**0.109**	**0.113**	**0.106**	**0.2**
T1	**31.61**	**31.21**	**30.35**	**38.49**	**30.13**	**30.62**	**40**
T2	**46.58**	**42.37**	**40.01**	**53.01**	**41.55**	**41.08**	**50**

3.1 Invisibility Test

The output image quality is tested by watermarking the original image with the resulting parameters from GA. Next, standard values between the original image and the output image are computed and used to evaluate the quality of the output image. These standard values are peak signal to noise ratio (PSNR) and mean structural similarity (MSSIM). The tested results of output image quality from the optimization GA1 (MSE) and GA2 (MSSIM) are shown in Table 2, and our proposed method can improve the PSNR of the watermarked image about 6 dB.

Table 2 Comparisons of PSNR and MSSIM between GA1, GA2 and METHOD1

IMAGES	GA1(MSE)		GA2(MSSIM)		METHOD1	
	PSNR	MSSIM	PSNR	MSSIM	PSNR	MSSIM
1. Lena	46.55	0.9963	47.36	0.9969	41.33	0.9885
2. Baboon	42.09	0.9967	41.58	0.9973	34.68	0.9868
3. Gold Hill	46.49	0.9968	46.59	0.9970	40.41	0.9890
4. Boat	44.10	0.9956	44.54	0.9960	38.34	0.9851
5. Camera Man	43.14	0.9932	43.23	0.9933	37.10	0.9771

3.2 Robustness Test

To verify the robustness of the watermark, we apply different attacks to the watermarked image and compare the results with METHOD 1. In the detection process, we also calculate the correlation output which is the ratio of the number of subbands that have the coefficients $>T_2$ and the number of all subbands which are searched for the watermark (in this case, 6). For example, if we detect the watermark in 5 different subbands from the total of 6 subbands, then the correlation output is 5/6. Fig. 4 (a) shows the results when the watermarked image is attacked by the JPEG compression. The results show that our method yields almost the same results as METHOD1. Then, we apply different attacks using common image processing such as lowpass filtering, and median filtering. In addition, we attack the watermarked image by adding Gaussian noise. From Fig. 4(b)-4(d), the results shows that our method yields better results than the METHOD1.

4 Conclusions

In this paper, the optimization for digital image watermarking using genetic algorithm has been presented. There are 3 parameters from watermarking process to be searched. These parameters are optimally varied to achieve the most suitable for the characteristic of each image. Our method is applicable to any images. The GA search guarantees the global optimum solution. The testing results of the output image quality and watermark robustness with various watermark attacks show that our proposed method can improve the performance of the watermarking such that the better output image quality and watermark robustness are achieved.

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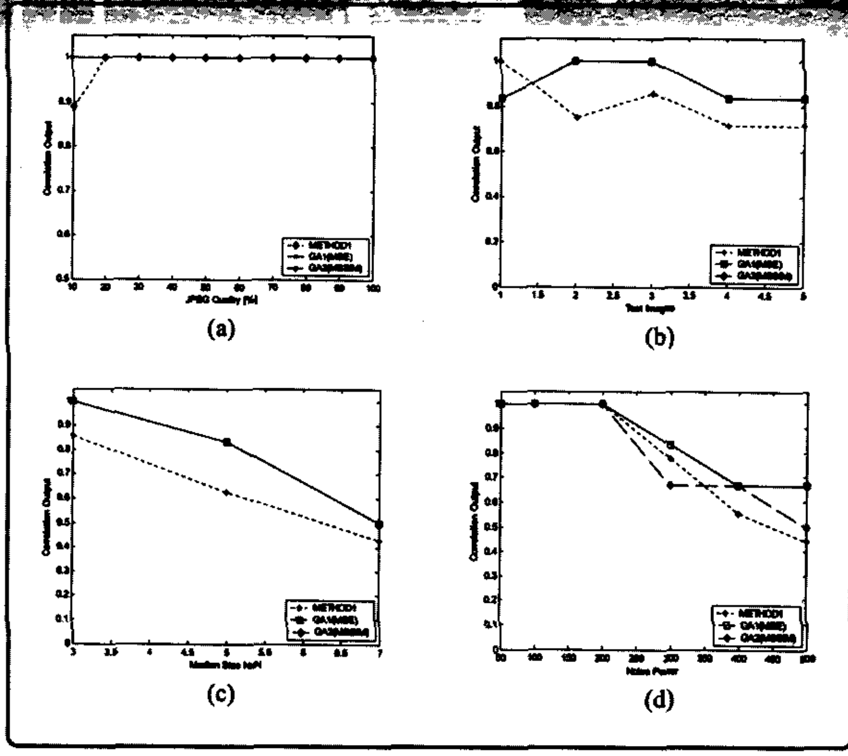

Fig. 4. Correlation output using different attacks.(a) JPEG compression with various JPEG quality. (b) Lowpass filtering of 5 images (Lena, Baboon, Gold Hill, Boat and Camera Man), (c) Median filtering of Lena image, and (d) adding Gaussian noise to the Lena image

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