A watermarking scheme for color still images based on wavelet transform using adaptive quantization

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Abstract

The digital image watermarking is studied for both copyright protection and content authentication, and needed to be better able to survive image processing operations and to be less degradation of image quality. The results for the gray scale images were presented with the methodology of watermarking by discrete wavelet transform using adaptive quantization in the previous works. The results of this methodology processed to the color images were reported in this paper.

Keywords : watermarking, color image, discrete wavelet transform, painting art,

1. Introduction

A drastic change emerged with the access of internet to everyone, which made it possible to copy and distribute the digital content illegally. Digital watermarking has been used for digital media protection. Many methodologies have been developed for effective watermarking [1]. A digital watermark encodes the owner's license information and embeds it into data. The many requirements for an acceptable technique of watermarking can be seen in ref [2]. Conventional watermarking schemes can be classified into two types, the space domain and the frequency domain. The robustness and the imperceptibility represent the most important characteristics. The several previous researches indicate that they can be more easily obtained in the frequency domain. Discrete wavelet transform (DWT) is popular in many image applications due to the unique feature of multi-resolution representation [3]. The results for the gray scale images by using the methodology of watermarking by DWT with adaptive quantization were reported in our previous works [4]. This methodology was adopted to color images in the present work. Original image is transformed by taking two levels DWT. Watermark is embedded in LL component which has robustness for the attacks but it much affect on the image quality taking account of human vision system (HVS). Therefore, the quantization step should be selected with depending on the property of embedded sub band. As the initial and fundamental report, the experimental conditions were set at the same as the previous work. In the following chapters, the methodology of the watermarking, the results of evaluation for the quality of embedded images and the robustness for the JPEG compression were reported.

2. The watermark scheme

2.1 The watermark in wavelet domain

The DWT of digital image data has been focused because it was adopted on the image compression technique; JPEG2000 and MPEG4. Since the watermarking is designed for invisible watermarks, invisibility of the watermark in a watermarked image should be take special consideration. HVS theory tells that human eyes are sensitive to the changes in low frequency part of image. Therefore, it is desirable to select the low-high(LH), high-low(HL), high-high(HH) wavelet coefficients for embedding sub-band for the HVS. However, the robustness is decreasing in high frequency components because the high frequency components can be removed thorough the typical image processing such as JPEG compression and noise reduction etc. Figure 1 shows the sub-band structure using two decomposition levels.

2.2 Methodology

The main steps performed in the present watermarking system are summarized in figure 2. At first, one of three color layers is selected from the original full color image. DWT is processed for the selected layer to get the sub-band coefficients. The selected layer is decomposed into 7 sub-bands by taking two-level DWT. The quantization step is selected by taking the small range block analysis of the original image data which is processed color-to-gray transform by using the approximation in conformity to CCIR Rec.601 data sheet. Those are just classified into two type block; flat/non-flat which is calculated from the standard deviation for each range block. The size of this range block is 4x4 pixels. The robustness depends on the magnitude of quantization step. The quantization step depends on the complexity of this range block evaluated by the standard deviation. The quantization step for the flat block and non flat block is set to M_1 and M_2, ($M_1 < M_2$) respectively. The robustness suppressed by the reduced embedding strength M_1 is compensated by using the error correct method as a majority-logic. The watermark signal is embedded cyclic every 8x8 block in low-low 2-level (LL2) component of decomposed image. The block size justly leads to decreasing the amount of embedding bits. The results of decision which block is flat or non-flat are recorded as the binary " flag image " for both processes of the embedding and the extraction as shown in figure2. The detecting process also starts from the DWT decomposition and the quantization step by using " flag image " obtained in the embedding process and the detection rate is calculated.

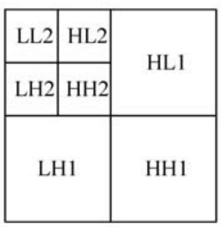

Figure.1. Sub-band decomposition structure.

3. Experiments, Results and Discussion

To demonstrate imperceptibility and robustness of this technique, three color images; Girl, Sail boat and Pepper, are used where the image size is 256×256 in each case shown in figure.3. For quantifying, the similarity between original and watermarked images two indicators are calculated in this experiment.

The Peak Signal to Noise Ratio (PSNR) is used frequently as an objective image quality metric, but it does not consider characteristics of HVS [6]. It is poor at comparing different watermarking methods, but provides a simple indicator for quantifying the similarity between original and watermark images. PSNR uses peak power of the original image and the mean squared value of the error signal. PSNR is expressed as follows;

$$MSE=\frac{\Sigma_{i=1}^{N}(x_i-y_i)^2}{N},\quad PSNR=10\log_{10}\frac{max^2}{MSE}$$

where, x_i and y_i are pixel values of watermarked image and original image, respectively. N is the amount of pixels in a image. The *max* is the maximum value of pixels (255 for 24bit bitmap images). The higher PSNR value suggests that the original and the watermarked image are quite similar.

The second measure used in this paper is Structural Similarity Measure (SSIM) index, which is a region-based numerical metric that places more emphasis on the HVS than PSNR [7]. This metric is adopted for x264 of H.264 encoder. SSIM metric is calculated on various blocks of an image. The measure between two blocks x and y is expressed as follows;

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_y^2+\sigma_y^2+C_2)}$$

where, μ and σ are the average and variance for each blocks respectively. σ_{xy} is the covariance of x and y. C_1 and C_1 are the variables to stabilize the division with weak denominator. This value lies within the range of 0 and 1. This value is 1 is only reachable in the case of two identical sets of data.

The results of PSNR between the original image and the watermarked image are shown in figure 4. The parameters are set as same as reference[4]; threshold T=7, M2=7, M1=2～7, Level=2. The performance of level 2 is higher than that of level 3 in the past report. The PSNR in these color images show higher results that in the gray scale images. The results of SSIM are shown in table 1. The SSIM value lying near 1 suggests that watermark is highly invisible since that difference between watermarked and original image is small. These are due to the same amount of embedded bits between color and gray images.

In the robustness test, the author attack watermarked images by Jpeg Compression. The result is seen in table 2. As the basic properties of this study, there is a trade-off between the embedding strength and the quality of the watermarked images and the robustness of the watermarking is increased for the embedding strength to be increased. However in this results, the optimal value of the extraction rate exist for the embedding strength; the extraction rate is increased from the embedding strength M=2 to 4 but the results on gray scale image in the previous report is greater than for color images. The reason of this lower performance is that the binary data (this is flag image in figure 2) is used for the detection of watermarked data which means the threshold value by deciding the flat/non-flat blocks. In the color image, one layer of full color layers (R,G,B) is selected and embedded according to the binary threshold data decided before embedding. Therefore the mismatching between the binary threshold data and the attacked image could be increased for the JPEG compression.

M1	SSIM		
	(Girl)	(Sailboat)	(Pepper)
2	0.9970	0.9979	0.9978
3	0.9963	0.9974	0.9973
4	0.9953	0.9969	0.9966
5	0.9940	0.9960	0.9956
6	0.9926	0.9949	0.9943
7	0.9906	0.9938	0.9931

Table1 SSIM of sample images.

		M		
		2	3	4
Jpeg	80	61.7	71.1	90.6
quarity	50	48.4	53.1	66.0
factor	20	46.1	45.7	50.4

Table2 detection rate for jpeg compression [%] (Girl).

4. Conclusions & Future Work

The methodology of watermarking by DWT using adaptive quantization for the gray scale image is adapted to experiment with the color images and the initial results are reported.

- The ratio of embedded signal to the carrier signal (which is original image) is decreased in the case of color image. This leads the quality of color image to become higher than the case of gray scale.
- This method needs the flag image to extract the embedded signals. The flag image which is generated as the gray scale image transformed from the original color image has the results of range blocks (flat/non-flat) for each range blocks. This leads to some differences about flat/non-flat information between the gray scaled image and the selected one color layer. RGB color region is used as a carrier for watermarking in this work, because the color information is very important in the painting arts and this methodology shows the good performance for the painting arts which is introduced by the previous work [8]. More implementation of the flag image is needed. It is should be verified that the analysis of flat/non-flat for the range block is better in the HSV region than the RGB region in the future work.

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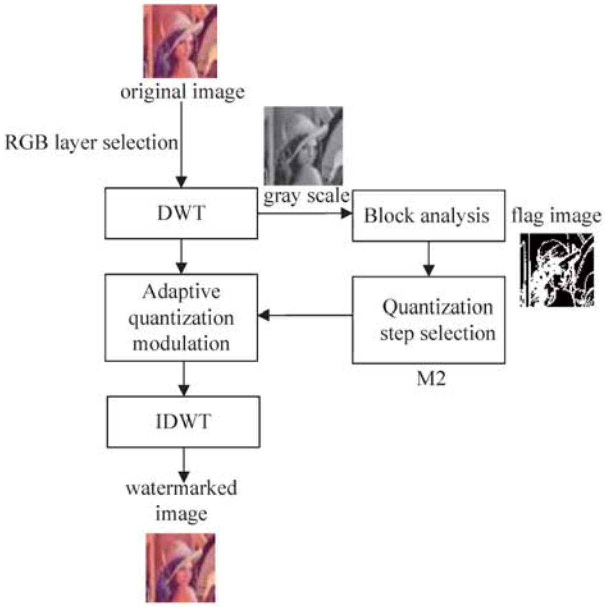

Figure. 2. Block diagram of watermark embedding process.

(a) (b) (c)

Figure3 Sample images; (a) girl, (b) sail boat, (c) pepper.

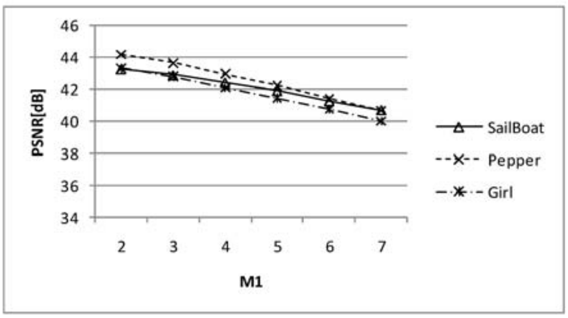

Figure4 PSNR of sample images.