Image Watermarking using CRT through Gradient Magnitude of Laplacian Filter

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***Abstract*— Novel watermarking model is developed on this paper using laplacian filter from two previous watermarking models that use CRT algorithms. The first model is embedding the watermark on the random pixel on each single block which can degrade the homogeneous areas. The second model use the canny edge detection to determine the edges as embedding locations within binary representation without considering the gradient magnitude that causes less optimal result. The proposed model is developed from the laplacian filter to generate the gradient magnitude of the image regions as embedding locations. The higher gradient magnitude represents the better location for embedding. Bits of watermark are embedding from the location with the highest gradient magnitude to the lower gradient magnitudes according to the number of watermark bits. The proposed model has higher imperceptibility with average SSIM of 0.9996 than the conventional CRT with average SSIM of 0.9985. In compression test, the proposed model has higher robustness with average NC value of 0.6746 than the previous models that have NC average values of 0.6618 and 0.6616 correspondingly. Temporarily, in noise test, all of the models have the similar average NC values. The model has better visual quality of the watermarked image than the previous models that use block division and canny edge detection algorithm. It also has better robustness against compression.**

Keywords—image proccessing; watermarking; laplacian filter; gradient magnitude; chinese remainder theorem

I. Introduction

This paper proposed a new watermarking scheme from the previous model that used Chinese Remainder Theorem (CRT) as the embedding algorithm. The original CRT [1], use the block based embedding which is divide the host image into such block according to the bits number of watermark. The embedding location is randomly selected ignoring the gradient magnitude. This model is robust against additive noise attack, but the visual quality is significantly reduced if the embedding lies on the homogeneous block.

The further research [2], using canny operator to generate the edges of images as the embedding locations. It is able to determine the heterogeneous areas which have large gradient magnitude as value of one and the homogeneous area as zero. The model is able to overcome the previous CRT problem of embedding on homogeneous areas which in turn improve the imperceptibility. However, the edge based CRT represents the gradient magnitude as binary value using thresholding. The value above the threshold represents as one and the rest as zero. It is simplify the representation of the edge areas but ignoring the value of gradient magnitude, whereas it is important factor in determining the proper location for embedding.

Some of watermarking model are developed based on the transformation/frequency domain such discrete cosine [3], discrete wavelet [4], integer cosine [5], and integer wavelet [6]. They are transformed the host image into such coefficient which represent the frequency as region magnitude. The transformation algorithm has large computational complexity to improve the robustness and imperceptibility. But the improvement is not proportional to the computational cost. Nowadays, the watermarking model is widely used on online and a real-time system which is required the low complexity.

A new model is proposed to determine the proper location for embedding the watermark bits. Laplacian filter is used in convolution process of host image to generate the gradient magnitude of image region. The gradient magnitude is represented in uint8-bit value which is corresponding with the host image and has low complexity as well. It is used as embedding locations within descending order. The watermark bits are embedding from the location with the highest gradient magnitude to the lower gradient magnitudes in accordance with bits number of watermark. The proposed model has better performance in term of imperceptibility than the previous models that use block division and canny edge detection algorithm.

II. Laplacian Filter

Laplacian filter is a high pass filter that use single kernel to compute the second derivatives within single pass. The filter is used to get the difference between single pixel and its neighboring pixel value. The difference is called as gradient magnitude. The higher gradient magnitude represents the better location for embedding the watermark. Implement laplacian operator to the pixel value $I(x,y)$:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (1)$$

The default kernel size is 3 by 3 with the alpha of 0.2. It is used to control the shape of the laplacian and must be within the range of 0 and 1. The larger kernel will increase the size of surrounding pixel involved.

III. CRT ALGORITHM

Chinese Remainder Theorem is able to perform a factorization of large number of integer into several of smaller paired value which co-prime each other based on the modulus operator[7]. It represents as series of remainder when the moduli are co-prime as well [8]. In the field of image watermarking, the CRT is growing rapidly [9]. The embedding process is done by altering the paired co-prime value. Let:

$$y \equiv r_j \left(\bmod z_j\right) \tag{2}$$

y is bottom 6 bit of pixel value and r_i represents the j-th residues which is:

$$y \equiv \left(\sum_{j=1}^{s} r_j \frac{b}{z_j} k_j \right) \bmod b \tag{3}$$

z_j are paired co-prime values of s number series and b represents the modulo of:

$$b = z_1 \cdot z_2 \cdot \ldots \cdot z_s \tag{4}$$

and k_j as follows:

$$\left(k_j \frac{b}{z_j} \right) \equiv 1 \quad \left(\bmod z_j\right) \tag{5}$$

In original CRT algorithm, the y is modified based on the binary value of watermark. The paired co-prime values of z_1 and z_2 are used to get the residues of r_1 and r_2 as showed in (3). The paired co-prime values are used on binary condition to insert the bits by modifying the value of y as shown in (4) and (5). The preceding models use the CRT as an embedding scheme without considering the gradient magnitude as embedding location, hence they are result is less optimal result neither in robustness nor the visual quality. The proposed model is developed from the laplacian filter (1) to insert the bits from the location with the largest gradient magnitude to the smaller gradient magnitudes according to the number of watermark bits.

IV. THE PROPOSED METHOD

The embedding of watermark bits is done on such number of large gradient magnitude of the image. The proposed model is described in Fig. 1 as follows:

A. Embedding

The value of 66 which has paired co-prime value of 11 and 6 is used to generate the residues of r_1 and r_2. The values are based on the previous research and it able to load the maximum 6-bit value.

1) Use the Laplacian filter to generate the gradient magnitude
2) Load the number watermark binary
3) Define such number of large gradient magnitude

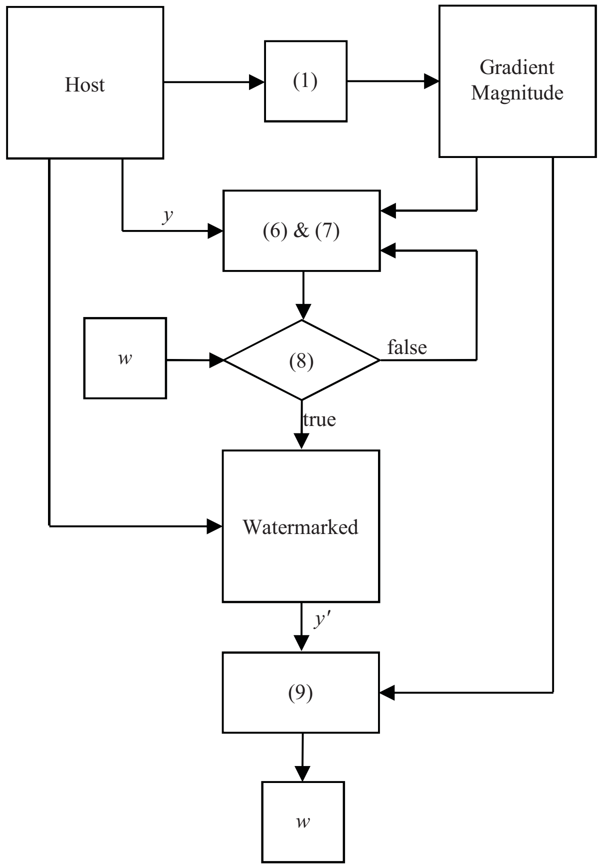


Fig. 1. Embedding and Extraction Model

4) Sort the defined gradient magnitude in descending order
5) Read y
6) Calculate the residues r_1 and r_2 using the paired co-prime:

$$r_1 = y \bmod 6 \tag{6}$$

$$r_2 = y \bmod 11 \tag{7}$$

7) Modify y until it meet the condition for embedding the watermark bit w as follows:

$$r_1 \begin{cases} \geq r_2 & , w = 1 \\ < r_2 & , w = 0 \end{cases} \tag{8}$$

8) Repeat the previous steps to embeds the entire watermark binary

B. Extraction

The 3rd step of embedding is used to locate the pixels for extraction like this:

1) Sort the gradient magnitude in descending order
2) Read the bottom 6 bit of y'
3) Compute the paired residues r_1 and r_2 using the paired co-prime using (6) and (7)
4) Get the binary value of watermark using the paired residues:

$$w = \begin{cases} 1 & , r_1 \geq r_2 \\ 0 & , r_1 < r_2 \end{cases} \quad (9)$$

5) Repeat the previous steps to extract the entire watermark binary.

V. Results and Discussions

This experiment uses the same dataset from precedent research to get a fair comparison. The proposed model is compared with the previous models from [1] and [2]. Fig.2 shows the dataset that contains ten host images in grayscale or 8-bit color depth and has rows and columns size of 512. For the watermark image, an image in black and white color with rows and columns size of 128 is used. The seed value from zero to nine is used on image from Baboon to Truck respectively. The seed value is used to randomize the embedding location and generate the additive noise based on previous researches. To give better representation the results are showed in table and chart.

Fig. 2. The host and watermark images

A. Image Quality

To get a better image quality meassurements, this experiment use the Strucutral Similarity or SSIM [10] instead of PSNR. The SSIM is able to meassure the imperceptibility according to human visual system.

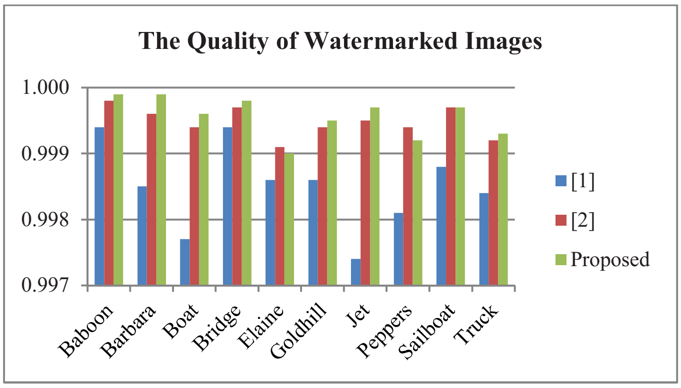


Fig. 3. Structural Similarity

Fig. 3 shows that the model has higher imperceptibility with average SSIM of 0.9996 than the conventional CRT with average SSIM of 0.9985.

B. Robustness

In next experiment the default JPEG2000 with 1:3 of compression and the 'salt & pepper' additive noise with 1/20 of density are used. The watermark image is then extracted and measured using NC or Normalized Correlation. In compression test, the proposed model has higher robustness with average NC value of 0.6746 than the previous models that have NC average values of 0.6618 and 0.6616 respectively as shows in Fig. 4 and Table I. Meanwhile, in noise test, the entire models have the similar average NC values as shows in Fig.5 and Table II.

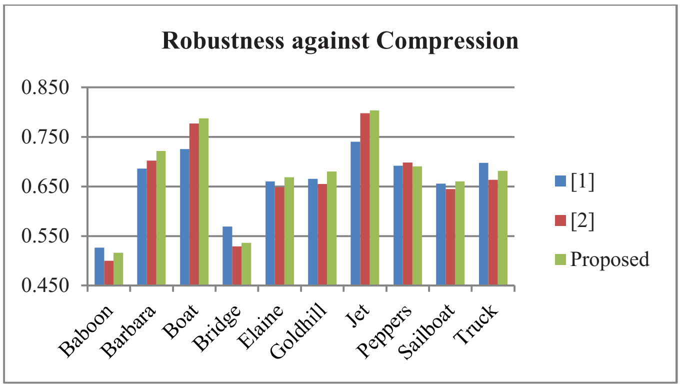


Fig. 4 Robustness against JPEG2000 Compression

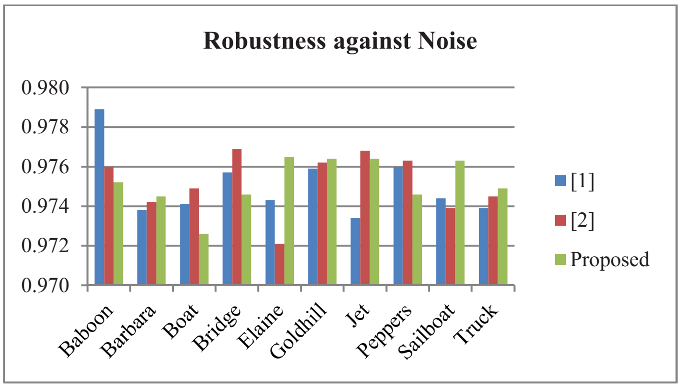


Fig. 5 Robustness agains Aditive Noise

TABLE I. ROBUSTNESS AGAINST COMPRESSION

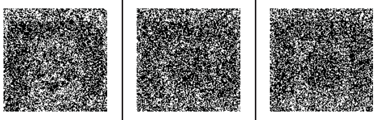
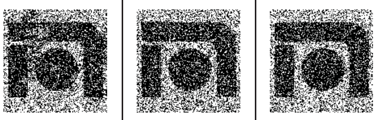
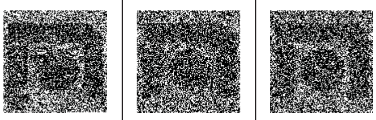
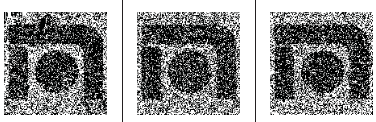
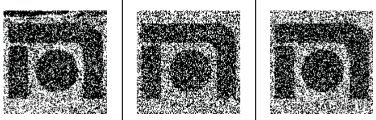
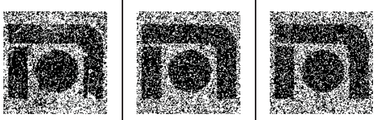
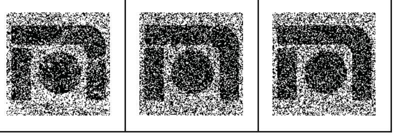
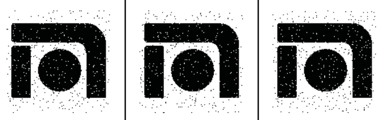
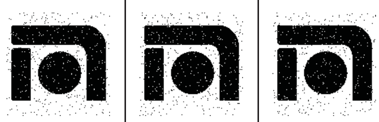
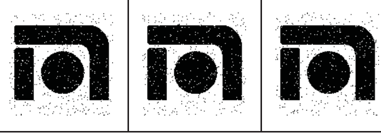
Images	[1]	[2]	Proposed
Baboon			
Barbara			
Boat			
Bridge			
Elaine			
Goldhill			
Jet			
Peppers			
Sailboat			
Truck			

TABLE II. ROBUSTNESS AGAINST ADDITIVE NOISE

Images	[1]	[2]	Proposed
Baboon			
Barbara			
Boat			
Bridge			
Elaine			
Goldhill			
Jet			
Peppers			
Sailboat			
Truck			

VI. CONLUSION

The novel embedding model is presented, it based on the two previous models that use block division and canny edge detection algorithm. They are ignoring gradient magnitude as embedding location. The proposed model determines the proper location for embedding the watermark bits. Laplacian filter is used to compute the gradient magnitude. The watermark bits are embedding from the location with the highest gradient magnitude to the lower gradient magnitudes according to the watermark bits number.

The proposed model has higher imperceptibility with average SSIM of 0.9996 than the conventional CRT with average SSIM of 0.9985. In compression test, the proposed model has higher robustness with average NC value of 0.6746 than the previous models that have NC average values of 0.6618 and 0.6616 correspondingly. Meanwhile, in noise test, all of the models have the similar average NC values. The proposed model has higher imperceptibility of the watermarked image than the previous models that use block division and canny edge detection algorithm. It also has better robustness against JPEG2000 compression.

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