

# WATERMARKING-BASED INPAINTING UNDER DATA TRANSMISSION ENVIRONMENT

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## ABSTRACT

This study proposes a novel image inpainting technique based on watermarking and halftoning. This technique use LSB method to embed error diffusion halftone image into original image for protecting the image. In image repair process, we use LSB method to extract the halftone information, and the reference image is achieved from LUT inverse halftone. Finally we use the reference image to finish the image inpainting work. Experiment shows the performance of our method is very excellent in image inpainting.

**key words:** Watermark, Inpainting, Halftone Image, Inverse Halftoning

## 1. INTRODUCTION

Image inpainting technique aims to fill in the damaged region of an image with new information so that it is hard to find that the image has once been damaged. The technique can be used in Image restoration, (e.g., scratch removal), zooming, image coding, wireless image transmission (e.g., recovering lost blocks), and special effects (e.g., removal of objects) [1]. In recent years, this technology has received extensive attention, and researchers have developed some different theories and techniques to deal with this complex image processing task. Although several early image inpainting methods have been proposed in space dimension to repair the damaged image including Partial Differential Equations (PDE) [2], fast image inpainting [3], and radial basis inpainting [4], these inpainting methods are implemented directly and simply. Other researchers transform the image from spatial domain to frequency domain or multi-resolution domain so that the repaired results can be improved by enhancing the diversity of information analysis [5-7]. For the multi-resolution domain, wavelet transform decomposes the complex texture components into different directive sub-bands in different frequency layers. Therefore, the image complexity will be reduced in each sub-band of the decomposed image and the similarity relationship of the image components will be better, leading to a better inpainting work. But they still need

sufficient data to analyze for image inpainting. In the wavelet transform, the repaired result is still good to the image with dot points, but it is unsatisfactory to the line image signals with high-frequency composition [8][9]. Hung et al.[10] Proposed an inpainting algorithm based on bandelet transform, which utilizes the geometrical flow of the neighboring texture of the damaged regions as the basis of restoration. And it transforms the textural variation into the nearing domain axis utilizing the bandelet decomposition method to decompose the non-relative textures into different bands, and then combines with the affine search method to perform image restoration.

However, these methods above even can be achieved good results in a certain type of image, but that are not suit for each case and cannot work well while dealing the large damaged regions including important independent features. Therefore, we proposed a novel image inpainting technique based on data hiding and inverse halftoning. This technique uses LSB method to embed error diffusion halftone image into original image for protecting the image. In image repair process, we use LSB method to extract the halftone information, and the reference image is achieved from LUT inverse halftone. Finally we use the reference image to finish the image inpainting work. Experiment shows the performance of our method is very excellent in image inpainting.

The remainder of this chapter is organized as follows: Section 2 describe the methods we use about LSB, halftoning and inverse halftoning. Section 3 refers to our proposed method. Section 4 reports the experimental results and evaluation. Section 5 concludes this paper. 2. Tables, Figures and Equations

## 2. LOOK-UP-TABLE INVERSE HALFTONING

Inverse halftoning is the process of retrieving a gray-scale image from a given halftone. This has a wide range of applications such as compression, printed image processing, scaling, and enhancement. In these applications, operations cannot be done on the halftone image directly so that inverse halftoning is mandatory. Many good studies in inverse halftoning have been

available in the literature, such as Gaussian Filtering[11], Nonlinear Filtering[12], Wavelet-Based technique[13-14], Shape-Adaptive DCT[15], Look-Up-Table (LUT)[16] and Edge-Based Lookup Table(ELUT)[17]. We adopt LUT algorithm for inverse halftoning because it is general and practical. We describe LUT algorithm as follow:

A Look-Up-Table (LUT) based algorithm proposed by Mese and Vaidyanathan [16] produces very good results with low computational complexity. However, the LUT method uses the mean of corresponding contone values of existent binary input patterns to predict the contone value of non-existent binary input patterns. In other words, the LUT method creates the reconstructive function according to the training images.

The first step is to choose the neighborhood or template for the pixels to be used in the prediction. Author used two different templates as shown in Fig. 1. In Fig. 1(a), a rectangular template is shown, and this template is abbreviated as "Rect" in comparison tables later. "O" denotes the estimated pixel. All of the pixels are used in the prediction. In Fig. 1(b) another template is shown. This pattern consists of a symmetric part and some additional pixels. In the 16-pixel pattern the "a" pixels and the "O" pixel are used in the prediction of the contone value of pixel "O." This template is denoted as "16pels" in comparison tables. Another example of a template is obtained by adding "b" pixels to the "16pels" template and this template is referred to as "19pels" template.

Authors assume that there are pixels (including the pixel being estimated) in the neighborhood and that they are ordered in a specific way. They call the pixel values as  $p_0, p_1, \dots, p_{N-1}$ . where  $p_i \in \{0,1\}$  for  $i = 0, 1, \dots, N-1$ . Note that there are  $2^N$  different patterns since for  $i = 0, 1, \dots, N-1$ . If the original image is an 8 bit gray image, LUT should return a value for each pattern, i.e.,  $T(p_0, p_1, \dots, p_{N-1}) \in \{0, 1, \dots, 255\}$ . During the inverse halftoning phase, the pixels in the template will be arranged in a specific order, and the contone value will be obtained from the LUT.

The design of LUT describe as follows: Author first obtained the expected contone value for each template pattern. Then this contone value would be assigned to the corresponding LUT position for that pattern. They denoted the number of occurrences of pattern  $(p_0, p_1, \dots, p_{N-1})$  in the sample halftone images as  $K(p_0, p_1, \dots, p_{N-1})$ . Thus,  $K(p_0, p_1, \dots, p_{N-1})$  is the histogram value of the pattern  $(p_0, p_1, \dots, p_{N-1})$ . They denoted the contone values in the original images corresponding to patterns  $(p_0, p_1, \dots, p_{N-1})$  as  $C(p_0, p_1, \dots, p_{N-1})$ , for  $i = 0, 1, \dots, K(p_0, p_1, \dots, p_{N-1}) - 1$

If ,  $K(p_0, p_1, \dots, p_{N-1}) > 0$ , The LUT value for the pattern would be the mean of the corresponding contone values, i.e.

$$T(p_0, p_1, \dots, p_{N-1}) = \frac{\sum_{i=0}^{K(p_0, p_1, \dots, p_{N-1})-1} C(p_0, p_1, \dots, p_{N-1}, i)}{K(p_0, p_1, \dots, p_{N-1})} \quad (4)$$

If  $K(p_0, p_1, \dots, p_{N-1}) = 0$ , then the pattern  $(p_0, p_1, \dots, p_{N-1})$  does not exist. The contone values for nonexistent patterns should be estimated from the existent patterns. The best linear estimator was proposed for nonexistent pattern estimation [16]. In this method, a linear model is used to estimate the contone values in terms of halftone values inside the template.

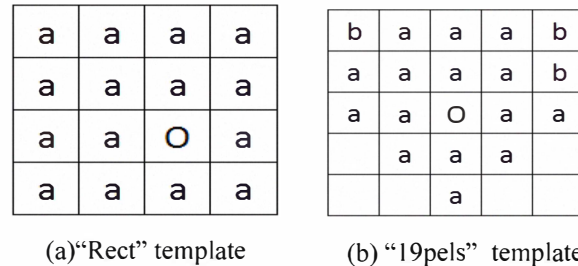


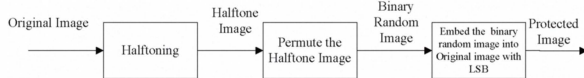
Fig. 1 LUT template[16]

### 3. PROPOSED METHOD

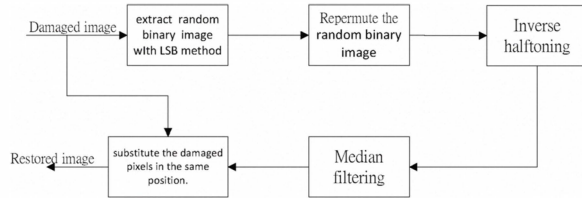
Based on the key basic techniques shown in section 2, this study proposed a novel image inpainting algorithm which combines the related techniques about watermarking, halftoning and inverse halftoning. The proposed image inpainting system was divided into two phases: watermark embedded phase and inpainting phase.

In watermark embedded phase, we first converts original image into halftone image with halftoning algorithm. Then we permute the halftone image in order to increase the robustness to local attacks. Finally, we embed the permuted random binary image into the original image with Least Significant Bit Substitution method. The process of watermark embedded phase is shown as Fig. 2.

In inpainting phase, we first extract the random binary damaged image from the damaged image with least significant bit substitution method, and then repermute the random binary damaged image to obtain the damaged halftone image, and convert the damaged halftone image to the reference image with inverse halftoning algorithm. Finally, after enhancing reference image with median filter, we substitute the pixels of attacked area in damaged image with the enhanced reference image in the same position. The process of inpainting phase is shown as Fig. 3.



**Fig. 2** the process of watermark embedded phase.



**Fig. 3** the process of inpainting phase

#### 4. EXPERIMENTAL RESULTS

The process of proposed image inpainting system is divided into two phases: watermark embedded phase and inpainting phase. There are three steps in watermark embedded phase as follows:

- Step1:** Converts original image into halftone image.
- Step2:** Permute the halftone image.
- Step3:** Embed the permuted random binary image into the original image with LSB method.

In our experiment, we convert original image into halftone image with error diffusion algorithm, because of the performance of error diffusion algorithm is better than order dithering. We permute the halftone in order to increase the robustness against local attacks. For the good results of imperceptibility and capacity, we adopt LSB method for data embedding. The PSNR of the protected image Lena to original image is 54.14db.

In inpainting phase, there are five steps as follow:

- Step1:** Extract the random binary damaged image from the damaged image with LSB method.
- Step2:** Repermute the random binary damaged image to obtain the damaged halftone image.
- Step3:** Convert the damaged halftone image to the reference image with LUT inverse halftoning algorithm.
- Step4:** Enhance the reference image with median filter
- Step5:** Substitute the pixels of attacked area in damaged image with the enhanced reference image in the same position.

We adopt LUT algorithm for inverse halftoning because it is general and practical. Fig. 4 is an example of inpainting phase. Fig. 4(a) is the damaged Lena image attacked in both eyes. Because the both eyes are the important independent features, there could not be found similar reference areas or textures in the neighborhood

within the image. Other published inpainting algorithms cannot work well while dealing the large damaged regions including important independent features like Fig. 4(a). The restored image is shown as Fig. 4(b), and the PSNR to original image is 48.82. This experiment shows the performance of the proposed algorithm is very excellent. We also test the results of inpainting for different damaged rate as shown in Fig. 5.

Finally, we use the common image “Barbara” as the test image for inpainting. This test mainly focuses on the texture part of image, because this type of damaged regions cannot be repaired well using the current image inpainting methods. In Fig.6(b), we can easily find the errors of the repairing result using the PDE method. However, based on Fig.6(c) and (d), which are implemented by PII [7] method and our proposed method, respectively, it’s hard to distinguish the difference in visual. We use the zoom-in images to compare these two repairing results, which are shown in Fig.7(b) and (c). We can clearly find that the repairing result of our proposed method is more precise than that of PII method in texture variation. Fig.6 and Fig.7 show that the proposed method is better than others.

#### 5. CONCLUSIONS

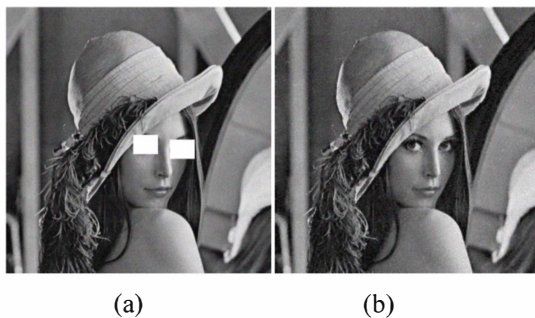
This study proposes a novel image inpainting techniques which integrate algorithms of halftoning, inverse halftoning and watermarking. This technique use LSB method to embed error diffusion halftone image into original image for protecting the image. In image repair process, we use LSB method to extract the halftone information, and the reference image is achieved from LUT inverse halftone. Finally we use the reference image to finish the image inpainting work. Experiment shows the performance of our method is very excellent in image inpainting. In future, we will continue our study on the technique of multiple watermarking for image inpainting.

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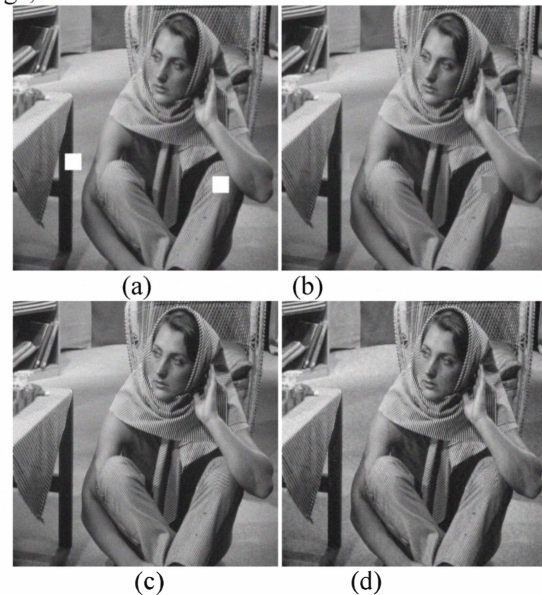
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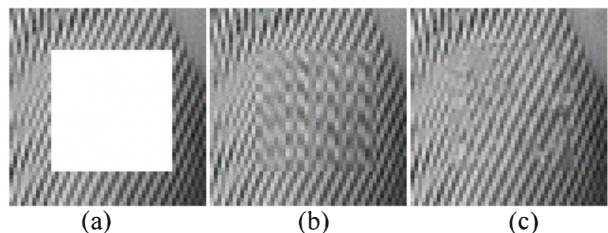
**Fig. 4** an example of inpainting phase (a)the damaged Lena image attacked in both eyes from the protected image (b)the restored image.



**Fig. 5** (a) Damaged rate is 1.76% for Lena; (b) Restored image, PSNR=47.80



**Fig. 6** Experimental results from utilizing different methods: (a)The damaged image; (b) The PDE method[2].; (c) The PII method[7]. ;(d) Our proposed method.



**Fig. 7** Zoom-in inpainting result of Fig. 15 (a), 15 (c) and 15(d): (a) The damaged region; (b) The PII method[7]; (c)The proposed method.