Hiding Visual Patterns in Halftone Images

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Abstract

To get higher contrast between the hidden visual pattern and the background of decoded image is one of the most important objectives in the visual cryptography research for halftone images. *Pei* and *Guo* proposed a noise-balanced error diffusion method ($NBED$) for hiding visual patterns in halftone images and had a nice experimental result. But in their method, since the noise-balanced value influences the quality of images apparently, it is tuned and decided by the user. In this paper, we propose a method named "Automatic Noise-Balanced Error Diffusion" ($ANBED$) which determines the noise-balanced values automatically. Our method generates two images: the traditional error diffusion image (TED) and a hidden visual pattern image (HVP). When the TED is superimposed by the HVP, the hidden visual pattern can be seen by human eyes. Simulation result shows that our automatic method is very close to *Pei* and $Guo's$ method with the best tuned noise-balanced value.

1 Introduction

The digital halftoning technique that used to change the gray-level images into bi-level images is trying to exploit the characteristic of low keen in human eyes. The halftone image is composed by black and white pixels and it almost looks like the original multi-tone image. The digital halftoning technique can be used for print newspaper, magazine, cartoon etc.

Many digital halftone algorithm have been proposed by Refs.[1] -[5]. There have three common methods for generating digital halftoning images namely error diffusion, ordered diffusion, and patterning [1][5][6]. Error diffusion introduced by *Floyd* and *Steinberg* is one of the best approaches to generate halftone image but more complicated than others.

The halftoning error is using a particular kernel to diffuse adjacent neighbors so that the error splits in a few components. Then it added to the gray level values of the neighbors. Tab. I, II and III show the different halftone filters to carry out error diffusion respectively. They are $Floyd - Steinberg's$ filter, $Stucki's$ filter and $Javis's$ filter. In this paper, we used the $Jarvis's$ filter to carry out error diffusion.

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0	0	0
0	X	7/16
3/16	5/16	1/16

Tab. I $Floyd-Steinberg's$ filter

0	0	X	8/42	4/42
2/42	4/42	8/42	4/42	2/42
1/42	2/42	4/42	2/42	1/42

Tab. II $Stucki's$ filter

0	0	X	7/48	5/48
3/48	5/48	7/48	5/48	3/48
1/48	3/48	5/48	3/48	1/48

Tab. III $Javis's$ filter

Recently, there have several data hiding techniques for error diffused halftone images are proposed (Pei and Guo, 2003a; Pei and Guo, 2003b, Fu and Au, 2003a, Fu and Au, 2003b; $Tseng$ and $Chang$, 2005; $Chao$, Ho and Chu, 2008) [6][7][8][9][10][11]. Pei and Guo proposed a noise-balanced error diffusion method ($NBED$) for hiding bi-level visual pattern into two or more error diffusion images. They exploited the traditional error diffusion method to have the first image and the others are obtained by applying the noise-balanced error diffusion method to the original gray-level image. When the two or more error diffusion images are overlapped, the visual pattern may realize directly by the human eyes without any computation. In fact, if the noise-balanced value is tuned improperly, the decoded visual pattern will mix up with the background of decoded image and that make the visual pattern unclear.

In this paper, in order to avoid the messy work of tuning the noise-balanced value, we propose an Automatic Noise-Balanced Error Diffusion method ($ANBED$) for hiding visual patterns in halftone images. In our method, the noise-balanced values are determined automatically. When the two output images including the traditional error diffusion image (TED) and a hidden visual pattern image (HVP) are overlapped, the hidden visual pattern can be seen by human eyes without any computation. Our simulation result is as good as Pei and $Guos$ method with the best tuned noise-balanced value.

The rest of the paper is organized as follows. In Section 2, we explained the $NBED$ which is proposed by Pei and Guo in 2003. In section 3, we described our proposed method $ANBED$ which concerned on solving the problem of the visual pattern will be unclear after overlapped. In section 4, we will show some simulation results. In section 5, we made our conclusion.

2 Noise-Balanced Error Diffusion Review

Pei and Guo proposed the noise-balanced error diffusion ($NBED$) method in 2003. Using their method, when the two or more error diffusion images are overlapped, the visual pattern may realize directly by the human eyes. Thus, it is one kind of visual cryptography. The traditional error diffusion flowchart is shown in Fig. 1. Let X be an input gray-level image, with the pixel value is $x_{i,j}$, and suppose the size of image is HW. The scanning order is from top to bottom and from left to right and adding the error value $e'_{i,j}$, then $x_{i,j}$ becomes $x'_{i,j}$. The $e'_{i,j}$ is produced by $e_{i,j}$ operate the error diffusion by kernel k. The $e_{i,j}$ is difference between the modified gray-level value output and binary output. The method can be described in the following steps:

Step 1: Produce the first halftone image using the traditional error diffusion.

A- Compute the prior error $x'_{i,j}$.

$$x'_{i,j} = \sum_{k=0}^{2} \sum_{l=-2}^{2} e(i+k, j+l) ker(k,l) \quad (1)$$

where $e_{i,j}$ is the halftoning error and the $ker(k,l)$ is the $Javis$ filter coefficients.

B- Renew the pixel value $x_{i,j}$.

$$v_{i,j} = x_{i,j} + x'_{i,j} \quad (2)$$

C- Compare the renewed gray-level pixel value $v_{i,j}$ with a threshold $T(T = 128)$ and determine the output halftoned pixel value $b_{i,j}$.

$$b_{i,j} = \begin{cases} 0 & \text{if } v_{i,j} < T, \\ 1 & \text{if } v_{i,j} \geq T. \end{cases} \quad (3)$$

D- Compute the halftoning error $e_{i,j}$.

$$e_{i,j} = v_{i,j} - b_{i,j} \quad (4)$$

All the steps completed then output a tradition error diffusion image (TED).

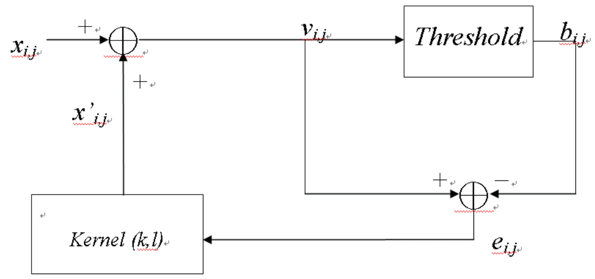

Fig. 1. Traditional error diffusion flowchart

Step 2: Produce the second halftone image using $NBED$ method.

A- If the visual pattern $x_{i,j}$ is black pixel and $TED_{i,j}$ is white, using the $NBED$ method to produce the $NBED_{i,j}$.

$$v_{i,j} = x_{i,j} + x'_{i,j} - Nb \quad (5)$$

$$e_{i,j} = v_{i,j} - b_{i,j} + Nb \quad (6)$$

B- If the visual pattern $x_{i,j}$ and $TED_{i,j}$ are all black pixels, using the Traditional error diffusion to produce the $NBED_{i,j}$.

C- If the visual pattern $x_{i,j}$ is white pixel, then $NBED_{i,j} = TED_{i,j}$.

Step 3: Decoded hidden visual pattern.

When the TED is overlapped the $NBED$, then we can see the hidden visual pattern directly by eyes.

In $Guo's$ research, the Nb value is the fixture which decided by user. If we increased the Nb value, the quality of $NBED$ image will be degraded but we can get better decoded hidden visual pattern. Maybe their advantage is to adjust the Nb value freely but it is unable to select a suitable Nb value automatically. In order to solve this problem, we make a description of the improvement method in next section.

3 The Proposed Method

In this section our proposed method called "Automatic Noise-Balanced Error Diffusion ($ANBED$)". This method could select a suitable Nb value automatically in every different position when embedding the visual pattern in halftone image. The advantage of this method can obtain the better contrast between the hidden visual pattern and the background of the decoded image. We made a brief description in the following steps:

Step 1: Produce the first halftone image using the traditional error diffusion. The same steps as mentioned in section 2 to produce the TED image.

Step 2: Produce the second halftone image using the $ANBED$ method.
A- To adjust the visual pattern pixels value, causes it to become the black, the white or the gray.
B- Divide the visual pattern image into 3*3 blocks.
C- If the visual pattern $x_{i,j}$ is black pixel and $TED_{i,j}$ is white, using the $ANBED$ method to produce the $ANBED_{i,j}$.
(a) Calculates the random Nb value.
(b) Decided the Nb value and it maximum value is 18.
(c) Let $x_{i,j}$ as a center of 3*3 block and let N denoted as the number of black pixel in this block. So the Nb value will be $2N$. For example, if a 3*3 block has two black pixels, then its Nb value is four. With such computing mode, it will decide the Nb value of each position automatically.

Step 3: If the visual pattern $x_{i,j}$ and $TED_{i,j}$ are all black pixels, using the Traditional error diffusion to produce the $ANBED_{i,j}$.

Step 4: If the visual pattern $x_{i,j}$ is white pixel, then $ANBED_{i,j} = TED_{i,j}$. This method increases the low-complexity computation by selecting a suitable Nb value automatically in every different position when embedding the visual pattern in halftone image. When the two halftone images are overlapped, we do not have to try for which Nb value can offer better visual quality. It can save more time for decide the Nb value and get the same visual pattern quality.

4 Simulation Results

The quality of images are depending by the vision of human eyes. Because the complexity of composition order, there have different $PSNR$ for different images. There only need low $PSNR$ value for the simple images which usually are black, white or gray to get good visual quality. For the complex images like color images, there need higher $PSNR$ values to get the better visual quality.
From the simulation result, the $PSNR$ value of our proposed method is higher than the $PSNR$ value of $NBED$ method. Even the difference of $PSNR$ value between them is less than 0.5 percent and the visual quality still almost the same. But since our method can determine the noise-balanced values automatically and this will save more time if compare to the $NBED$ method.
In this section, we compare the $PSNR$ value between the images which used the $NBED$ or

$ANBED$ method in Tab. IV. The hidden visual pattern is shown in Fig. 2. The original images are shown in Fig. 3. The traditional error diffusion halftone image using $Javis's$ filter images are shown in Fig. 4. The $Guo's$ method simulation results with $Nb = 5$ are shown in Fig. 5. The overlapped version of TED and $NBED$ images are shown in Fig. 6. We use the proposed method $ANBED$ to simulate the 400*400 $Lena$ and $Deep$ images to embed the hidden visual pattern are shown in Fig. 7. The overlapped version of TED and $ANBED$ images are shown in Fig. 8. Although our method increases the black pixels of $ANBED$ image, but it does not affect the quality of decoded visual pattern.

	$NBED$	$ANBED$
$Lena$	15.0169	15.2742
$Deep$	23.1876	24.3180

Tab. IV The $PSNR$ values.

The table IV shows that the $PSNR$ value of our proposed method($ANBED$) is higher than the $NBED$ method. There are two images for the simulation purpose, the Lena and Deep image. Another two images generated from the Lena and Deep image, the first image is the TED image superimposed by the HVP and the second image is the TED image superimposed by the $TED2$ image. The $PSNR$ values in first row of table IV are the simulation result from the comparison of the first and second image from Lena image to $NBED$ and $ANBED$ respectively and the $PSNR$ values in second row are from the comparison of the first and second image from Deep image to $NBED$ and $ANBED$ respectively. From the simulation result in table IV,even the visual quality from two methods are almost the same, but since our proposed method has higher $PSNR$ value than $ANBED$ method, we still can conclude that $ANBED$ is better than $NBED$.

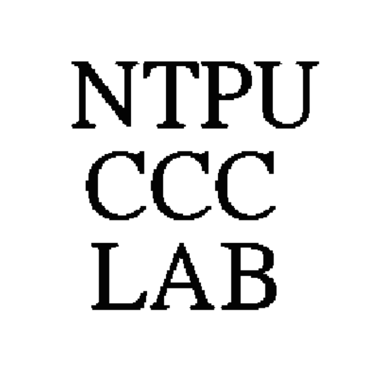

Fig. 2. Hidden visual pattern

Fig. 3(a). Original *Lena* image

Fig. 3(b). Original *Deep* image

Fig. 4(a). $LenaTED$

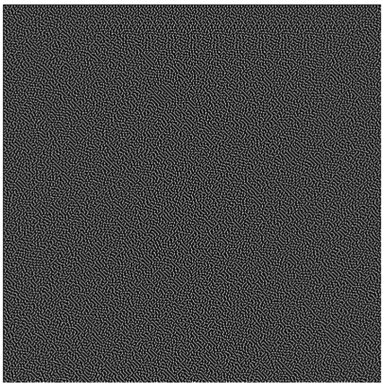

Fig. 4(b). *DeepTED*

Fig. 5(a). *LenaTED*2 Nb5

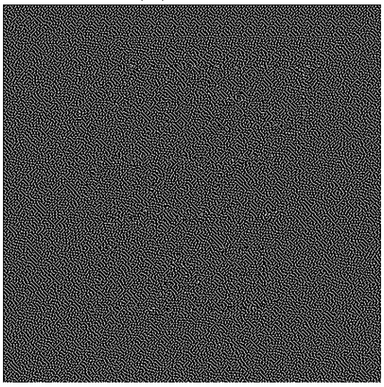

Fig. 5(b). *DeepTED*2 Nb5

Fig. 6(a). *Lena* decoding image

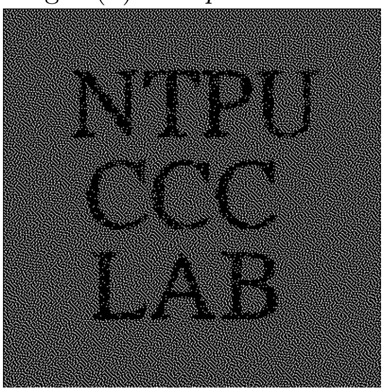

Fig. 6(b). *Deep* decoding image

Fig. 7(a). *LenaANBED* image

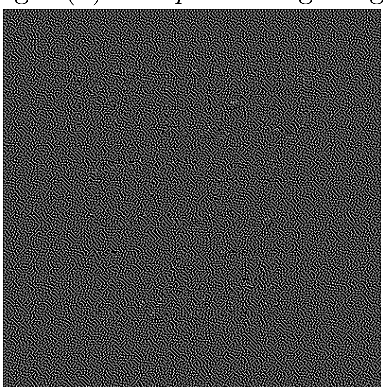

Fig. 7(b). *DeepANBED* image

Fig. 8(a). *Lena* decoding image with *ANBED*

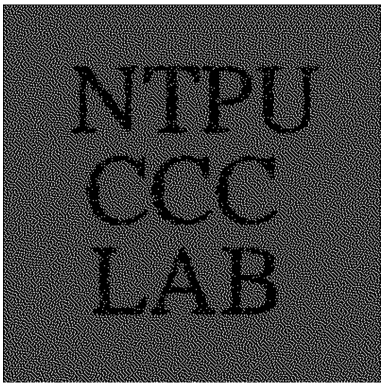

Fig. 8(b). *Deep* decoding image with $ANBED$

5 Conclusions

In this paper, we propose a method named "Automatic Noise-Balanced Error Diffusion" ($ANBED$) for hiding visual patterns in halftone images which will determine the noise-balanced values automatically. Our method generates two images: the traditional error diffusion image (TED) and a hidden visual pattern image (HVP). When the TED is superimposed by the HVP, the hidden visual pattern can be seen by human eyes. Simulation result shows that our automatic method is very close to *Pei* and $Guo's$ method with the best tuned noise-balanced value.

Furthermore, our method is very efficient. Since it only needs an extra scan of the visual pattern when compared with *Pei* and $Guo's$ method, the computation complexity is still linear, that is, $O(n)$, where n is the number of pixels.

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