A NOVEL METHOD TO EMBED WATERMARK IN DIFFERENT HALFTONE IMAGES: DATA HIDING BY CONJUGATE ERROR DIFFUSION (DHCED)

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ABSTRACT

In this paper, we propose a novel way called DHCED to hide invisible patterns in two or more visually different halftone images (e.g. Lena and Harbor) such that the hidden patterns would appear on the halftone images when they are overlaid. Conjugate Error Diffusion is used to embed the binary visual pattern in the two distinct halftone images. Simulation results show that the two halftone images have good visual quality, and the hidden pattern is visible when the two distinct halftone images are overlaid.

1. INTRODUCTION

Image data hiding is the hiding or embedding of invisible data in an image without affecting its perceptual quality such that the hidden data can be extracted with some procedure. The study of data hiding techniques is commonly called watermarking [1] or steganography [2].

In this paper, we are concern about data hiding for halftone images. Halftone images [3] contain only 2 tones and are generated by a procedure called halftoning from multi-tone images. Although there are only 2 tones, halftone images look like the original multi-tone images when viewed from a distance. Halftone images are widely used in the printing of books, magazines, and newspapers and in computer printers. It is often desirable to hide visual patterns within the printed halftone images such that the hidden patterns can be viewed when some appropriate images are overlaid. Some visual pattern examples include short messages with large font size, logos, graphics or clip arts which can be used for authentication, and conveying secret messages or product related information.

There are only a few existing techniques for halftone image data hiding. They can be divided into two classes. One class of techniques embed invisible digital data into halftone images [3] such that the data can be read by scanning the halftone images and applying some extraction algorithms on the scanned image. images [4]. A second class of techniques embed hidden visual patterns into two or more halftone images such that when the two images are overlaid, the hidden image can be viewed directly on the halftone images. The hidden data must be visual patterns and they are meant to be visually inspected on the halftone images.

Some used stochastic screen patterns [5] and conjugate halftone screens [6] to embed the hidden patterns in ordered dithered halftone images. In [7], Data Hiding by Stochastic Error Diffusion (DHSED) was proposed to embed hidden visual patterns in two or more error diffused halftone images. The hidden patterns can be visually inspected when the images are overlaid. However, it is only limited to embedding a watermark pattern into two or more visually identical images.

In this paper, we propose a method call Data Hiding by Conjugate Error Diffusion (DHCED). It applies pixel-wise artificial noise [8] to embed tri-level watermark to two visually different halftone images.

2. DATA HIDING BY CONJUGATE ERROR DIFFUSION

In this section, we propose a novel algorithm called Data Hiding by Conjugate Error Diffusion (DHCED) to hide invisible watermarking patterns in two visually different error diffused halftone images such that the hidden patterns can be visually detected when the images are overlaid.

DHCED uses two $M \times N$ halftone images, B_0 and B_1, to hide some binary image H which can be visually detected by overlaying B_0 and B_1. Note that B_0 and B_1 may come from two visually different images, such as Lena and Harbor. Let X be the original $M \times N$ multi-tone image from which B_0 and B_1 are obtained. We will use $x(i,j)$ and $b_i(i,j)$ to represent the pixels at location (i,j) of X and B_i respectively. In general, all quantities associated with B_i would have a subscript i. The hidden binary pattern H is assumed to have the same size $M \times N$ as B_0 and B_1. In the case that the desirable hidden patterns have size smaller than $M \times N$, they can be enlarged and padded to $M \times N$. The black pixels in H can carry meaningful foreground patterns such as text, logo, graphics or clip arts while the white pixels can carry the background.

The first image B_0 is generated by regular error diffusion with no hidden visual patterns. Error Diffusion is a halftoning technique, which can generate high quality halftone image. Error Diffusion is a causal single-pass sequential algorithm. The 2-D multi tone image is halftoned line-by-line sequentially. In this algorithm, the past error is diffused back to the current pixel. The relationship between input and output of error diffusion can be described by the following equations :

$$u_{m,n} = x_{m,n} - \sum h_{k,l} e_{m-k,n-l} \quad (1)$$
$$b_{m,n} = Q(u_{m,n}) \quad (2)$$
$$e_{m,n} = \beta b_{m,n} - u_{m,n} \quad (3)$$
$$Q(u_{m,n}) = \begin{cases} 1, & u_{m,n} \geq T_0 \\ 0 & u_{m,n} < T_0 \end{cases}$$

$x_{m,n}$ = original gray-scale image
$b_{m,n}$ = binary halftone image
$e_{m,n}$ = quantization error
$u_{m,n}$ = state variable
β = dynamic range of the image, usually 255
$h_{k,l}$ = error diffusion kernel
$Q(.)$ 1-bit quantization, $T_0 = 128$ used

The error diffusion kernel controls the feedback weighting of past errors. In this paper, a typical kernel, the Jarvis[8] kernel, is used.

The second image B_1 is generated by applying Data Hiding by Conjugate Error Diffusion (DHCED) to *X* with respect to B_0 to hide *H*. In DHCED, the hidden tri-level binary image *H* is used to define the synchronization or conjugate regions on a pixel-by-pixel basis. Let H_B be the collection of the locations of all the black pixels in *H*. Similarly, let H_W be the collection of all the white pixel locations in *H* and H_g be the collection of all the gray pixel locations in *H*. For $(i,j) \in H_W$, the pixel $b_1(i,j)$ in B_1 is 'favored' to be identical to the co-located pixel $b_0(i,j)$ in B_0. For H_B, the pixel $b_1(i,j)$ in B_1 is 'favored' to be conjugate to the co-located pixel $b_0(i,j)$ in B_0. For H_g, the pixel $b_1(i,j)$ in B_1 is unbiased to the co-located pixel $b_0(i,j)$ in B_0. This can be achieved through the following equations.

Fig. 1 is the block diagram of DHCED diffusion. The structure DHCED is similar to the normal error diffusion. The major difference is the Noisy Function block *N(.)* in which the binary output is adaptively toggled.

In Fig. 1, $b_{m,n}$ is the "normal" output without DHCED according to error diffusion. If its characteristic follows *H*, no change is applied. And if it gives the wrong watermark, $b_{m,n}$ should be toggled to give the correct watermark. However, this can introduce a huge distortion causing undesirable visual artifacts. As a result, the change would be performed only if the change is acceptable.

The change can be controlled by realizing that forced toggling of $b_{m,n}$ is equivalent to adding a distortion $\Delta x_{m,n}$ to the original image pixel $x_{m,n}$ in Eqn. (1) to distort $u_{m,n}$ such that the quantized output in Eqn. (2) is reverted.

$$x'_{m,n} = x_{m,n} + \Delta x_{m,n}$$
$$u'_{m,n} = x'_{m,n} + \sum h_{k,l} e_{m-k,n-l} = u_{m,n} + \Delta x_{m,n}$$
$$b'_{m,n} = Q(u'_{m,n}) = Q(u_{m,n} + \Delta x_{m,n})$$

If $u_{m,n} \geq 128$, the minimal distortion $\Delta x_{m,n}$ required to achieve forced toggling is $128 - u_{m,n} - 1 < 0$. Otherwise, the minimal $\Delta x_{m,n}$ required is $128 - u_{m,n} > 0$.

In DHCED, if $|\Delta x_{m,n}| < T_1$ for some appropriate threshold T_1, the pixel-wise distortion associated with the forced toggling is considered to be acceptable and thus the toggling would be performed. Otherwise, it would not be performed. Apart from the *N(.)* block, DHCED is the same as regular error diffusion.

The Noisy Function is equivalent to adding noise of bounded magnitude to the input image. The parameter T_1 provides the trade-off between visual quality and contrast of hidden pattern. A large T_1 allows more pixels to be used to hide hidden pattern *H*. But a large T_1 means that the magnitude of the additive noise is large which would translate to large image degradation or lower visual quality.

The noisy multi-tone image *x'* is a good estimator to quantify the quality of halftone image by PSNR.

When B_0 and B_1 are overlaid, the regions corresponding to the different regions of *H* should have different intensity.

3. SIMULATION RESULTS

The proposed DHCED is simulated using the 512x512 Lena and Harbor images. The corresponding error diffused halftone images using Jarvis kernel are shown in Fig. 3 and Fig 4. In this simulation, the image in Fig.4 is selected as B_0. The hidden pattern *H* contains tri-level 2 alphabets "HK" as shown in Fig. 2.

The image B_1 with *H* embedded by DHCED is shown in Fig. 5. Compared with halftone image in Fig. 3 with no hidden pattern. They look identical to each other. Fig. 6 is the equivalent noisy estimator *X'*. The distortion is 40.0 dB, bounded by the threshold T_1=20, compared with the original image.

When B_0 and B_1 are overlaid in Fig. 7, which is equal to AND Boolean operation, the hidden image is revealed in the halftone image. Before overlapping, the intensity of halftone image is 0.48. After overlapping, the intensity of H_g is 0.25. The intensity of H_W is 0.45. The intensity of H_B is 0.04. Consequently, the difference in intensity reveals the hidden pattern *H* in the halftone image. The other way to extract *H* is applying NXOR (Not Exclusive OR) operation, to B_0 and B_1 as shown in Fig. 8. The hidden pattern *H* is clearly displayed.

4. CONCLUSION

In conclusion, DHCED can embed hidden pattern in two visually different halftone images. The pattern is visible through overlaying or Boolean operations such as NXOR. It overcomes the limit of DHSED, which can only embed hidden pattern in two visually identical images. By the pixel-wise operation of DHCED, the hidden pattern and halftone image can be merged seamlessly without degrading the visual quality of halftone image.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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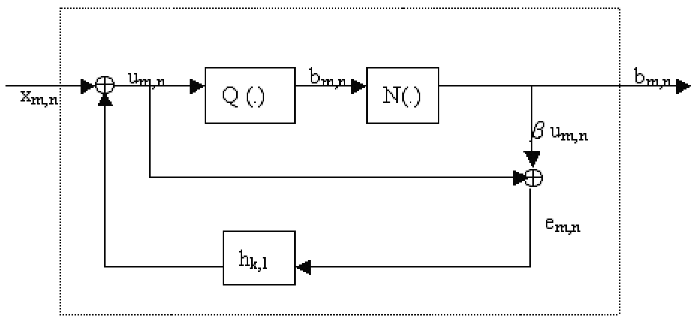

Fig. 1 Block diagram of DHCED

Fig. 2 Tri-level pattern *H* to be hidden

Fig. 3 Halftone Lena

Fig. 4 Halftone Harbor

Fig. 5 B_0 Halftone Lena with H hidden

Fig. 6 Estimator X' of Y_1 (40.0 dB)

Fig. 7 B_0 and B_1 overlaid showing the hidden H

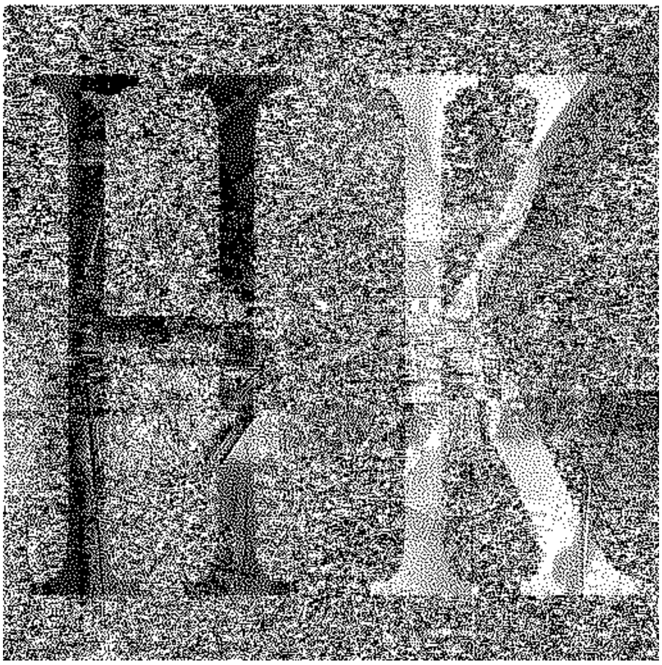

Fig. 8 B_0 and B_1 under NXOR showing the hidden H