WATERMARKING TECHNIQUE FOR COLOR HALFTONE IMAGES

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ABSTRACT

In this paper, we propose a method to hide invisible patterns in color error diffused halftone images. The hidden pattern is embedded in different color components. The hidden patterns would be revealed when the watermarked color halftone images are under Boolean operation or overlaid. Simulation results show that the watermarked color halftone images have good visual quality and the hidden pattern is visible clearly.

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 concerned about data-hiding for color halftone images. Grayscale Halftone images [3] contain only 2 tones and are generated by a procedure called halftoning from multi-tone images. Some data-hiding techniques embed invisible digital data into halftone images [4]. Some 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. For example, some used stochastic screen patterns [5] and conjugate halftone screens [6] to embed the hidden patterns in ordered dithered halftone images.

In [7], we propose a method call Data Hiding by Conjugate Error Diffusion (DHCED) to embed a watermark in halftone images. In this paper, we extend this technique to color halftoning [8]. It is called Conjugate Color Error Diffusion (CCED), which applies to two color halftone images. The hidden patterns would be revealed when two similar color halftone images are overlaid or under Boolean operation with each other. Simulation results show that the watermarked halftone images have good visual quality and the hidden pattern is visible clearly.

2. DATA HIDING BY CONJUGATE ERROR DIFFUSION

In this section, we briefly review the Data Hiding by Conjugate Error Diffusion (DHCED), which hides invisible watermarking patterns in error diffused halftone image. DHCED uses two $P \times Q$ halftone images, B and B^c, to hide a binary image *C*.

The first image B is generated by regular error diffusion with no hidden visual patterns. Error Diffusion is a halftoning technique generating high quality halftone image. It is a causal single-pass sequential algorithm. The 2-D multi-tone image is halftoned line-by-line sequentially and the current error is diffused to the future pixels.

The second image B^c is generated by applying DHCED to X with respect to B to hide C. In DHCED, the binary image C is used to define the "synchronized" or "conjugate" regions on a pixel-by-pixel basis. Let C_{black} be the collection of the locations of all the black pixels in *C*. Similarly, let C_{white} be the collection of all the white pixel locations in *C*. For $(i, j) \in C_{white}$, the pixel $b^c_{i,j}$ in B^c is "favored" to be identical to (or "synchronized" with) the co-located pixel $b_{i,j}$ in B. For $(i, j) \in C_{black}$, the pixel $b^c_{i,j}$ in B^c is "favored" to be opposite to (or "conjugate" to) the co-located pixel $b_{i,j}$ in B. To sum up, we try to make $\overline{b_{i,j} \oplus b^c_{i.j}}$ equal to $c_{i,j}$ as far as possible.

3. CONJUGATE COLOR ERROR DIFFUSION

In this section, we discuss how to extend DHCED to embed hidden pattern in two color error diffused halftone images. This is called Conjugate Color Error Diffusion (CCED).

Error Diffusion can be applied to multi-dimensional color space. Pixels are treated as vectors in a color space. The nearest attainable color is selected at each pixel, where it is computed according to some distance metric on color space. In this section, we use RGB color space in the illustration for the sake of convenience. CCED can be applied to other color component/space without loss of generality.

Let $X = \begin{bmatrix} X^r & X^g & X^b \end{bmatrix}$ be the RGB component of multi-tone color image, $B = \begin{bmatrix} B^r & B^g & B^b \end{bmatrix}$ be the RGB component of color halftone image and $f(\ )$ be the color error diffusion function such that $f(\begin{bmatrix} X^r & X^g & X^b \end{bmatrix}) = \begin{bmatrix} B^r & B^g & B^b \end{bmatrix}$. If we assume these color components are separable, it can be simplified into $f(X^r) = B^r$, $f(X^g) = B^g$ and $f(X^b) = B^b$. Using the same concept in DHCED, we can apply some bounded distortion to control the halftone output such that $f(X + \Delta) = B^c$, where B^c is a watermarked color halftone image.

Similar to DHCED, CCED uses two $P \times Q$ halftone images, B and B^c, to hide a binary image C which can be visually detected by Boolean operation on B and B^c.

The first image B is generated by regular color error diffusion to each color component separately. The second image B^c is generated by applying the proposed CCED to X with respect to B to hide C. In CCED, the binary image C is used to define the "synchronized" or "conjugate" regions on a pixel-by-pixel basis. Let C_{black} be the collection of the locations of all the black pixels in C. Similarly, let C_{white} be the collection of all the white pixel locations in C. For $(i, j) \in C_{white}$, the pixel $b^c_{i,j}$ in B^c is "favored" to be identical to (or "synchronized" with) the co-located pixel $b_{i,j}$ in B . For $(i, j) \in C_{black}$, the pixel $b^c_{i,j}$ in B^c is "favored" to be "different" from (rather then "conjugate" in DHCED) to the co-located pixel $b_{i,j}$ in B . In CCED, even though there is a favored value for the output $b^c_{i,j}$, the favored value may not be applied if the resulted distortion is excessive.

The main difference between gray scale halftone image and color halftone image is the control of distortion due to hidden image. As a color halftone image has 3 color components, it is not necessary to apply conjugate characteristics to all color components in order to embed hidden pattern. A single conjugate color component is enough to embed hidden pattern. Let us define $|\Delta x_{i,j}|$ as the magnitude of distortion. It is also a 1x3 vector containing $\begin{bmatrix} \Delta R & \Delta G & \Delta B \end{bmatrix}$. If $|\Delta x_{i,j}|$ is smaller for some appropriate threshold, the pixel-wise distortion associated with the forced toggling is considered to be acceptably small and the toggling would be performed. Otherwise, it would not be performed. It can be classified into the following two cases: -

For <u>conjugate region</u>, $(i, j) \in C_{black}$:
if $\min(\begin{bmatrix} \Delta R & \Delta G & \Delta B \end{bmatrix}) < T_c$, then $|\Delta x_{i,j}| = \begin{bmatrix} \Delta R & 0 & 0 \end{bmatrix}$, assuming $|\Delta R|$ is the min of $\Delta R,\ \Delta G,\ \Delta B$. It is the same for G and B. Otherwise, $|\Delta x_{i,j}|$=0.

For <u>synchronized region</u>, $(i, j) \in C_{white}$:
if $\max(\begin{bmatrix} \Delta R & \Delta G & \Delta B \end{bmatrix}) < T_s$, then $|\Delta x_{i,j}| = \begin{bmatrix} \Delta R & \Delta G & \Delta B \end{bmatrix}$. Otherwise, $|\Delta x_{i,j}|$=0.

It is important to note that that the distortion caused by these two cases are different. For the case $(i, j) \in C_{black}$, the distortion is usually small as there are three choices for minimizing the distortion. For case $(i, j) \in C_{white}$, since both the images B and B^c come from the same multi-tone image. The distortion is usually very small except the boundary between C_{white} and C_{black} . Usually, distortions in all

RGB values are required. Therefore, the threshold T_c and T_s are not the same.

5. SIMULATION RESULTS

Fig. 1 is a color image LENA. Fig. 2 is the hidden pattern ICASSP2004. Fig. 3 is the color halftone LENA by applying color error diffusion to CMY (Cyan, Magenta, Yellow) components separately. CMY is a subset of RGB and CMY component/space is commonly used in printing. Fig. 4 is the color halftone LENA watermarked by CCED respect to Fig. 3. It looks identical to Fig. 3. Fig. 5 is the simulation of color subtraction after overlaying of Fig. 3 & 4. The hidden pattern is revealed by the change of intensity in conjugate region. Fig. 6 is the revealed hidden pattern by using Boolean operation to compare CMY components of Fig. 3 and Fig. 4. The hidden pattern can be seen more clearly.

6. CONCLUSION

In this paper, we discussed a watermarking technique to embed hidden pattern in color halftone images. The visual quality of the watermarked images is very good and the visual pattern is visible through Boolean operation or overlaid.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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Fig.1 Color Image LENA

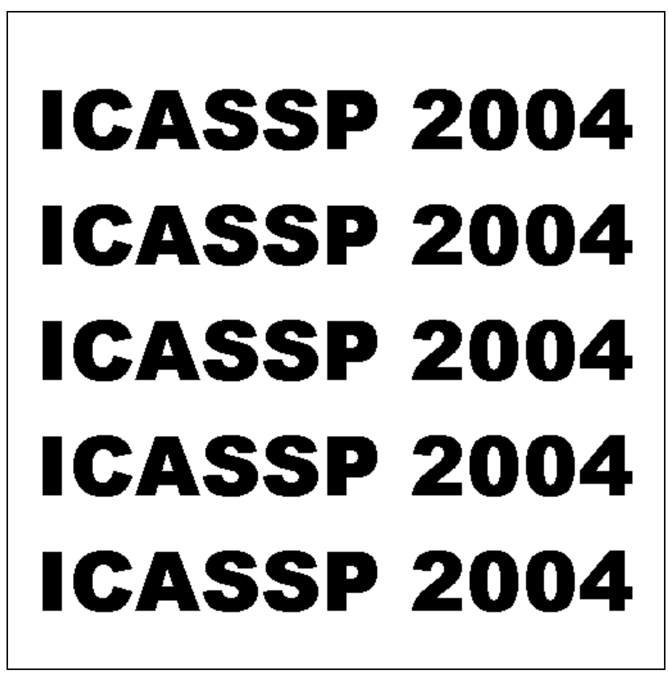

Fig. 2 Hidden Image ICASSP2004

Fig. 3 Color Halftone LENA

Fig. 4 Watermarked Color Halftone LENA

Fig. 5 Overlaying of Fig. 3 & 4

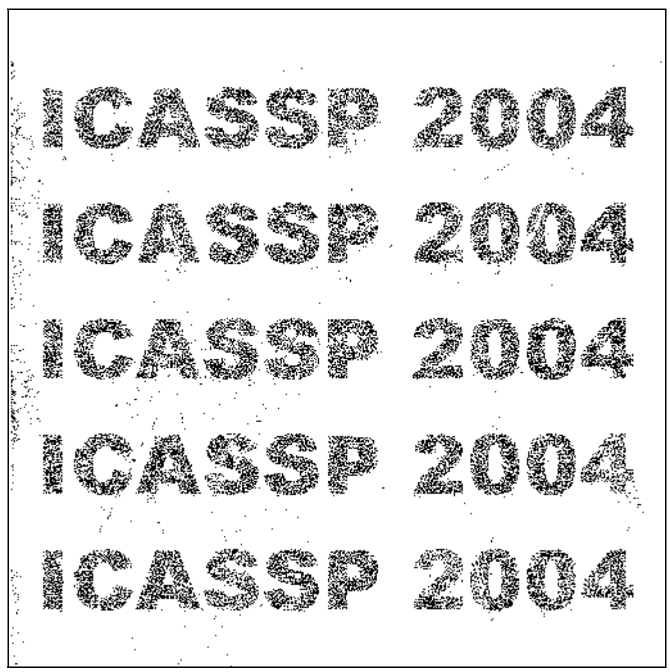

Fig. 6 Boolean operation on Fig. 3 & 4