Watermarking Hiding in Halftoning Image

Zifen He [1, a], Yinhui Zhang [1,b*]

[1]Kunming University of Science and Technology,Faculty of mechanical and electrical engineering, Kunming, 650500，China

[a]zyhhzf1998@163.com, [b*]yinhui_z@163.com

Keywords: Watermarking; Halftoning; Wavelet coefficients; Arnold transformation processing; Weighted least-squares

Abstract. This paper proposes a novel approach but efficient algorithm for the edge details and regional characteristics preserving halftoning. While the gray image turns to halftone image using proposed algorithm, binary watermark is embedded in the edge position. In order to enhance the ability to resist cropping attack and smearing attack, the watermark image is pre-treated with Arnold transformation processing. The proposed method is effective, because the halftone image is embedded as a watermark sequence in the halftone process. Experiment results show that this algorithm does not cause significant distortion of the image and is good resistance to cropping, daub, JPEG compression and noise attacks.

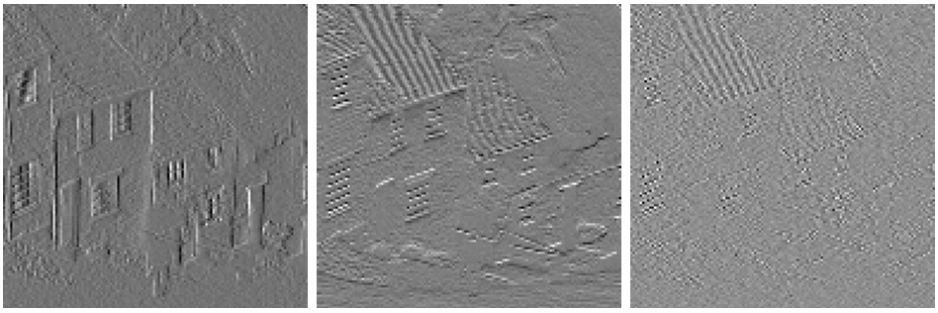
Introduction

Binary halftoning would try to compute a pattern of binary dots to achieve the illusion of a multi-bit image. The halftoning algorithms can be further classified through various properties and features, including point based methods, such as screening [1], neighborhood based methods, such as error diffusion [2], iteration-based scheme such as Direct Binary Search (DBS) [3].

Since the halftoning is widely used, halftone-based watermarking methods have been studied in recent years. These methods include using the concept of vector quantization to embed watermark into the most or least significant bit of an error-diffused image [4]. In [5], different dither cells were exploited to create a threshold pattern in the halftoning process, in which each dither cell represents the corresponding information bit of the watermark. In [6], the modified data-hiding error diffusion method was employed to embed data into an error-diffused image. In [7], the DBS was employed to achieve halftoning and watermarking simultaneously.

Scales Correlation Coefficients Fusion

For an input represented by a list of 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum.Since most of the wavelet coefficients have small values while only a few wavelet coefficients have large values. Upon the assumption that the wavelet coefficients are mutually independent, they are normalized. The boundary information of the image target is fused by the wavelet coefficients of the correlation between wavelet transform layer, which to increase the pixel resolution scale. We apply the inter-scale fusion method to gain fusion coefficient of the fine-scale, which take into account the detail of the image and approximate information. The fusion information of wavelet coefficients inter-scale are shown in Fig. 1.



(a) (b) (c)

Fig.1 The fusion information of wavelet coefficients inter-scale for HL,LH and HH sub-band (a)HL (b)LH (c)HH

We will use the term contrast sensitivity here, since we have used this terminology throughout Mannos and Sakrison proposed a model of the human contrast sensitivity function, which found the following filter frequency response to be good for predicting the subjective quality of coded images.

$$H_r(f_r) = 2.6(0.0192 + 0.114 f_r)\exp\left\{-(0.114 f_r)^{1.1}\right\} \tag{1}$$

fr in equation (1) is the spatial frequency of the visual stimuli given in cycles/degree.

Least-squares model-based(LSMB) halftoning attempts to produce an optimal halftoned reproduction[8]. In this article, we will use the following notation. Suppose we are given a gray-scale image $[x_{i,j}]$, where $x_{i,j}$ denotes the pixel located at the *i*-th column and the *j*-th row of a grid. The gray level of each pixel varies from 0 equal to white to 1 equal to black. We are also given a printer model with the sliding-window form and an eye model of the form with a memory-less nonlinearity *n*(.) followed by an FIR filter with impulse response $[h_{i,j}]$. In the LSMB approach we seek the halftone image that minimizes the squared error.

$$E = \sum_{i,j} (z_{i,j} - w_{i,j})^2 \tag{2}$$

where $z_{i,j} = n(x_{i,j}) * h'_{i,j}$, $w_{i,j} = n(p_{i,j}) * h_{i,j}$, $p_{i,j} = P(W_{i,j})$, Wi,j is composed of bi,j and its neighbors and * indicates convolution. The boundary conditions assume that no ink is placed outside the image borders.

Weighted least squares model-based regression is useful for estimating the values of model parameters when the response values have differing degrees of variability over the combinations of the predictor values. Optimal results that minimize the uncertainty in the parameter estimators are obtained when the weights used to estimate the values of the unknown parameters are inversely proportional to the variances at each combination of predictor variable values $\lambda_i \propto \frac{1}{\sigma_i^2}$.

In the proposed approach, we seek the halftone image that minimizes the weighted squared error. The related descriptions are formulated as below

$$E_{i,j} = \left\{\sum_{l=1}^{4} (LH, HL, HH)\right\} \sum_{i,j} (z_{i,j} - w_{i,j})^2 \tag{3}$$

The * indicates convolution. The halftoning image is show as Fig.2.

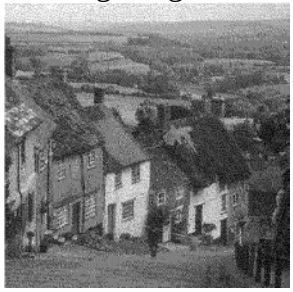


Fig.2 The halftone image

Watermark embedding and detection scheme

In this paper, it used Arnold transformation to encrypt the watermark image, then inserted the watermark image into the important coefficients from different orientations of the wavelet transformation.

Arnold scrambling times n is a “secret parameter”. This means that receiver will not be able to generate original information if he do not know this parameter. Watermark and scrambling image are shown in Fig 3.

(a) (b)

Fig. 3 Arnold transformation (a)32×32 original image (b) n=10 Arnold transformation

The watermark is embedded the edge of halftone image during the halftone processing, which are the optimal positions for watermark embedding. They are referred to as the key to the receiver. Ultimately embed watermark halftone image is shown as Fig 4.

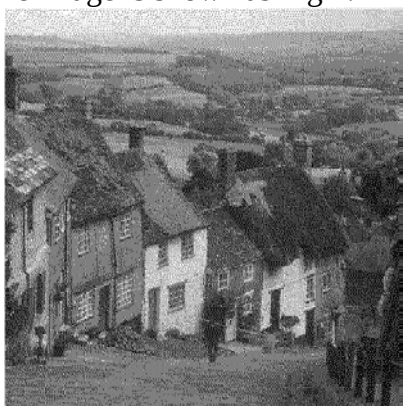


Fig. 4 Embedded watermark halftone image

Firstly, our watermark detection scheme uses watermark key to determine watermark embedding position and extract the watermark value. Secondly, The extract watermark image is Arnold transform using watermark key and Arnold periodic table. Lastly, the embedded watermark in the halftone image become multitone image after the JPEG compression and add Gaussian noise. The embattled image is must binarization (choose threshold is 128) before extracting the watermark.

Experimental results and discussions

We embed the watermark in the perceptually highly edge region, so the embedded watermark is less visible. Besides, the MSEv(mean square error value) and PSNR(peak signal-to-noise ratio) is used to measure the visual quality of the watermark halftone image. The visual quality valuation is show as Table 1.

Table 1. MSEv and PSNR between watermarked halftone image and original halftone image

Test image	MSEv	PSNR(dB)
goldhill	0.14	40.98

Tables 2 summarize the detection results against several attacks. In this paper, we use the term “normalized cross-correlation，NC” to denote it. The NC value are 0.768, 0.991,0.891,0.984 and 0.935 between the extraction and original watermark, respectively.

Tables 2 NC of detected watermark under several attacks

Attacks	NC
noise addition	0.768

JPEG compression	0.991
cropping	0.891
daub	0.984
rotations	0.935

The experimental results show that the image of errors are spread out using Arnold transform. After the watermark pre-processing by Arnold, watermark can be able to resist clipping and daubing attack, the robustness of watermark is better. In the case of halftone image quality significantly decreased, extraction watermark can identify. Use proposed algorithm for edge enhance, invisibility of watermark is better in the edge position of the embedded watermark.

Summary

In many applications, it is desirable to embed data in halftone images. But the existing halftone image watermarking have the shortcomings of being not able to guard against attacks caused by cropping, daubing, noise and rotation, etc. In this paper, we proposed a digital method with Maximal Father-Child Node Dependence Coefficients in Wavelet Domain for halftone image with good visual quality. Experimental results show that the proposed scheme is robust against several attacks. At the edge of the halftone image position watermark has good invisibility.

Acknowledgments

This work was supported by Project 61302173 and 61461022 of the National Science Foundation of China. Kunming university of science and technology talent training fund(14118777)

References

[1] B.E. Bayer: IEEE 1973 International Con$ on Communications, 26,p. 11
[2] R.W.Floyd,L. Steinberg: in Proc. Soc. Inf. Display 1975, p. 36
[3] J. P. Allebach,Q. Lin: in Proc. IEEE Int. Conf. Image Process 1996,1,p. 549
[4] J. R. Goldschneider, E. A. Riskin, and P. W. Wong: in Proc.IEEE Int. Conf. Image Process., vol. 1 (1996) p. 565
[5] Z. Baharav,D. Shaked: in Proc. Int. Conf. Security Watermark. Multimedia Content, May 1999,p. 307
[6] M. S. Fu ,O. C. Au: Proc. SPIE Vis. Commun. Image Process., vol. 4067(2000), p. 1671
[7] D. Kacker,J. P. Allebach: IEEE Trans. Signal Process., vol. 51, no. 4, (2003)p. 1054
[8] N. Pappas,David L. Neuhoff: IEEE Trans. Image Process1999, 8 , p. 1102