Multi-Purpose Watermarking Schemes for Color Halftone Image

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Abstract: - In many printer and publishing applications, it is desirable to embed data in halftone images for copyright control and authentication purposes. However, the robustness of the geometrical attacks in halftone watermarking is still a key problem. In this paper, we proposed a multipurpose color halftone watermarking using embedding watermark into the pixel with complicated texture by wavelet transform based on the dithering technique in the halftone processing. According to properties of the color model [R,G,B], we chosen the G level for embedded our robust watermark and B level for embedded our semi-fragile watermark. The Zernike moment is adopted to detect rotation and scale of the watermarked image. Experimental results show that watermarked image with good visual quality and the robust watermark is robust to the malicious attacks such as compress, corrupting, cropping, rotating, and scaling. The semi-fragile watermark can detect the regions where attacked by corrupted and cropped.

Key-Words: - Multi-purpose watermarking, Halftone image, Wavelet transform, Zernike moment, Robust watermark, Semi-fragile watermark.

1 Introduction

Digital color halftoning is the process of transforming continuous-tone color images into images with a limited number of colors. The importance of this process is because that many color imaging systems use output devices such as color printers. The goal is to create the perception of a continuous-tone color image using the limited spatiochromatic discrimination capability of the human visual system.

With a rapid innovation of computer technology, it is often desirable to embed data into the images for copyright control and authentication purposes. In this paper, we are concerned about watermark for color halftone images. In some applications, it's desirable to hide visual patterns into color halftone images. Digital halftoning can be divided into two categories: (1) amplitude modulation (AM): ordered dithering (2) frequency modulation (FM): error diffusion. Halftone images 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, newspapers and computer printers. The digital color halftoning approach is to apply these monochrome halftoning techniques to the color [red, green, and blue].

The watermark has to withstand digital attacks such as image processing and geometric transformations. The watermark must have two most important properties: transparency and robustness. Transparency refers to the perceptual quality of the watermarked data. The watermark should be invisible over all types.

The digital watermark is still presented in the image after distortion and the watermark detector can detect it. Ideally, the amount of image distortion to remove the watermark should degrade the desired image quality to the point of becoming commercially valueless. It is called the robustness of digital watermark to image processing. The common distortions of signal processing include lossy compression (in particular JPEG), re-sampling, image enhancement, cropping, etc.

There are some existing techniques for halftone image data hiding. [1][2][3][4], in these methods, the embedded pattern cannot be recovered with only one halftone image. It can be viewed only when two halftone images are overlaid. In [5], although it can embed full size pattern, the pattern can't extracted clearly. In [6], although it doesn't need the original image, the watermark will easily damage after cropped. The watermark is not robust to geometrical attacks. In this paper, the method was adopted as the embedding method based on DWT and Zernike moment. The Zernike moment is adopted to detect rotation and scale of the watermarked image. It is robust for various attacks such as cropped, human marking, rotated and scaled and can detect the regions where were attacked.

This paper is organized as follows. Section2.1 describes Zernike Moment. Section2.2 describes one of halftoning techniques. In section 3, the proposed method is presented. The experimental results are presented in section 4. The conclusion is discussed in section5.

2 Zernike Moment and Ordered Dithering

2.1 Zernike Moment

Anm of the Zernike Moment in the watermarked halftone image is calculated to detect the watermarked halftone image is rotated, scaled or not [9][10].

2.1.1 Zernike Moment Definition

Let the set of these polynomials be denoted by Vnm(x,y) :

$$V_{nm}(x,y)=V_{nm}(\rho,\theta)=R_{nm}(\rho)\exp(jm\theta) \quad (1)$$

Rnm(ρ) is called radial polynomial, which can defined as :

$$R_{nm}(\rho)=\sum_{s=0}^{(n-|m|)/2}(-1)^s\frac{(n-s)!}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!} \quad (2)$$

where n ≧ 0, n-|m| is even , and |m| ≦ n, ρ is the length of vector from origin to pixel at (x,y), and θ is the angle between vector ρ and X axis in counterclockwise direction. For digital image, The Zernike moment of order n with repetition m can defined as :

$$A_{nm}=\frac{n+1}{\pi}\sum_x\sum_y f(x,y)V^*_{nm}(x,y) \quad (3)$$

2.1.2 Rotation Detection

Assume the original image is denoted by $f(\rho,\theta)$, α is the angle of the rotation. The rotated image is denoted by $f^r(\rho,\theta)$. The relationship between the original image and the rotated in polar coordination is:

$$f^r(\rho,\theta)=f(\rho,\theta-\alpha) \quad (4)$$

$$A^r_{nm}=A_{nm}\exp(-jm\alpha) \quad (5)$$

If m=0, $A^r_{nm}=A_{nm}$, there is no phase difference between them. If m≠0, according to equation (5), we can have

$$\arg(A^r_{nm})=\arg(A_{nm})+m\alpha \quad (6)$$

$$\alpha=\frac{\arg(A^r_{nm})-\arg(A_{nm})}{m} \quad (7)$$

We can calculate the rotation degree α by equation (7) if the image has been rotated.

2.1.3 Scaling Detection

Assume f(x/a,y/a) represent a scaled of the image f(x,y). Then the relationship of Zernike moment A_{00} of f(x,y) and A'_{00} of f(x/a,y/a) :

$$|A'_{00}|=\alpha^2|A_{00}| \quad (8)$$

$$\alpha=\sqrt{|A'_{00}|/|A_{00}|} \quad (9)$$

A'_{00} is calculated from the scaled image. And can obtained α according to the value of A_{00} .

2.2 Ordered Dithering

The dithering technique use a dither cell to produce a halftone image. Assume original image denoted by g(x,y). The dither cells with size N1xN2 (N1=N2=8) is shown in Figure 2. We should quantize g(x,y) to obtain Q(x,y) by equation(1).

17	62	51	45	4	26	18	61
50	34	5	29	55	14	36	9
19	44	13	24	38	42	49	52
60	15	54	16	58	56	10	8
43	30	20	11	7	31	12	0
57	33	21	1	37	63	27	39
46	48	6	53	28	3	22	23
32	40	25	41	2	59	47	35

Figure 2 A N1xN2 dither cell array

$$Q(x,y)=N_1\times N_2\times\left[1-\frac{g(x,y)}{255}\right] \quad (10)$$

The dither cell will be the threshold pattern. The halftone image H(x,y) will obtain by equation2.

$$H(x,y)=\begin{cases}1, & Q(x,y)>T(x,y)\\ 0, & Q(x,y)<T(x,y)\end{cases} \quad (11)$$

T(x,y)=T(x+k1*N1,y+k2*N2) (12)

where black is denoted by 1 and white is denoted by 0. T(x,y) is the threshold array. k1 and k2 are positive integers.

3 Multipurpose Watermarking Method

Decompose the color image into RGB. G level is used to embed robust watermark. B level is used to embed semi-fragile watermark. R level is halftone to regular halftone image.

3.1 Watermark Embedding

3.1.1 Robust watermark system

3.1.1.1 Scrambling robust watermark

Let Wr be the binary robust watermark with size 32x32. For the scrambling of the watermark, the pixels of the watermark are pseudo-randomly permuted to form a new watermark image Wr'.

3.1.1.2 Robust watermark embedding

For G level, after one-level wavelet decomposition, the variance of LH, HL, and HH sub-bands in coefficients by the 4x4 mask. If the average value in the 4x4 mask is bigger than the value of global average of the sub-band, the value of the binary mage is denoted to "1". Other, the value is set to "0". We can obtain a binary index image lh, hl, hh respectively. The new reference map S={lh,hl,hh}will be the index to embed the watermark.

The robust watermark is embedded by using a number of different dither cells to create a threshold pattern in the halftoning process. The original image I_g is segmented into 64x64 blocks with size 8x8. Two dither cells C0 and C1 are used as shown in Figure 3. In order to achieved robust watermark. The dither cells should produce different halftone patterns. The robust watermark will embedded when the value of the reference map "S" is equal to "1". The embedding method consists of two decision rules. The rule one for selection of the dither cell is to select C0 when the value of the S is bit'0'. The rule two for selection of the dither cell is to select C0 when the value of the watermark Wr' is 0 and select C1 when the value of the watermark Wr' is 1. The selected dither cells form a thresholding pattern with size 512x512. This pattern produces the threshold values to halftone the original image. It will produce a watermarked halftone image I_g'.

51	27	6	46	59	12	54	7
16	63	40	23	0	42	24	33
2	34	11	49	31	15	61	47
55	26	53	17	57	38	5	21
10	43	4	41	8	28	52	39
60	20	29	62	22	44	13	32
1	48	36	9	50	3	58	25
35	14	56	18	30	37	19	45

(a)

17	57	38	5	21	55	26	53
41	8	28	52	39	10	43	4
62	22	44	13	32	60	20	29
9	50	3	58	25	1	48	36
18	30	37	19	45	35	14	56
6	48	59	12	54	7	51	27
40	23	0	42	24	33	16	63
11	49	31	15	61	47	2	34

(b)

Figure 3. (a) The 8x8 dither cell C0

(b) The 8x8 dither cell C1

The detailed process of embedding robust watermark:

1. Perform DWT to decompose the host image.
2. Calculate the variance of HL, LH, HH with size 4x4 mask.
3. Obtain a binary map "S" with size 64x64 by using the higher variance of 4x4 masks.
4. Scramble the watermark and obtain a key.
5. Two dither cells of 8x8 arrays C0 and C1 are used.
6. The host image is segmented into 64x64 blocks
7. Rule one: When the value of the map is 0, the selection of the dither cell is to select C1.
8. Rule two: When the value of the map is 1, the selection of the dither cells is to select C0 for bit 0 of the watermark and select C1 for bit 1 of the watermark.
9. Using the thresholding pattern to produce a robust watermarked halftone image.

3.1.2 Semi-fragile watermark system

Let Ws be the binary semi-fragile watermark with size 64x64. The semi-fragile watermark is embedded by using a number of different dither cells to create a threshold pattern in the halftoning process. The original image I_b is segmented into 64x64 blocks with size 8x8. Two dither cells C2 and C3 are used as shown in Figure 4. In order to achieved semi-fragile watermark. The dither cells should produce similar halftone patterns. The embedding method consists of two decision rules. The rule one for selection of the dither cell is to select C2 when the value of the semi-fragile watermark Ws' is bit'0'. The rule two for selection of the dither cell is to select C3 when the value of the semi-fragile watermark Ws' is bit'1'. The selected dither cells form a thresholding pattern of size 512x512. This pattern produces the threshold values to halftone the original image. It will produce a watermarked halftone image I_b'.

51	27	6	46	59	12	54	7
16	63	40	23	0	42	24	33
2	34	11	49	31	15	61	47
55	26	53	17	57	38	5	21
10	43	4	41	8	28	52	39
60	20	29	62	22	44	13	32
1	48	36	9	50	3	58	25
35	14	56	18	30	37	19	45

(a)

51	6	27	46	59	12	54	33
16	63	40	23	0	42	24	7
2	34	11	49	31	15	61	47
55	26	53	17	57	38	5	21
4	43	10	41	8	28	52	39
60	20	29	62	22	44	13	32
1	48	36	9	50	3	58	25
35	14	56	18	30	37	19	45

(b)

Figure 4. (a) The 8x8 dither cell C2

(b) The 8x8 dither cell C3

The detailed process of embedding semi-fragile watermark:

1. Two dither cells of 8x8 arrays C2 and C3 are used.

2.Rule one: When the value of the semi-fragile watermark is bit"0", the selection of the dither cell is to select C2.
3.Rule two: When the value of the semi-fragile watermark is bit"1", the selection of the dither cells is to select C3.
4.The thresholding pattern is used to produce a semi-fragile watermarked halftone image.

The proposed watermark embedding system is shown in figure 5.

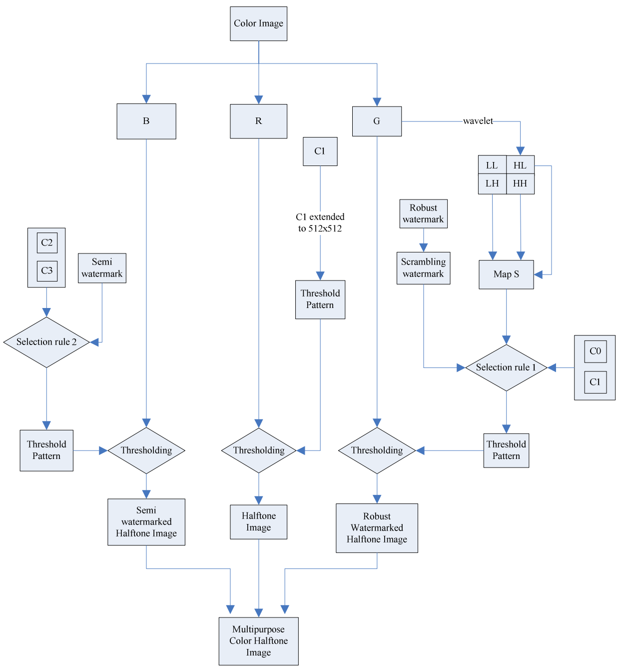


Figure 5. Block diagram of the proposed watermark embedding system.

3.2 Watermark Extracting

Transform the watermarked color halftone image to bi-level halftone image. We can use Anm not only to calculate the angle of the rotated halftone image but also the size of the scaled halftone image. Recover the rotated or scaled watermarked color halftone image. Decompose the watermarked color halftone image into RGB. G level is used to extract our robust watermark. B level is used to extract our semi-fragile watermark.

3.2.1 Robust watermark extracting

For G level, according to the map, we can find out which blocks embedded our watermark. For these blocks with size 8x8 of the watermarked halftone image, calculate the average graylevel of blocks and simulate the block with a constant colored region having this average color. Dither cells C0 and C1 are used to produce two halftone regions. The region which is similar to the original halftone region is selected as the decoding dither cell and the watermark bit.

The detailed process of extract robust watermark:

1.According to the map S, find out which blocks embedded the robust watermark.
2.Calculating the average graylevel of blocks with size 8x8 and simulate the block with a constant color region having this average color.
3.Using dither cells C0 and C1 be the threshold values to produce two halftone regions C0' and C1' respectively.
4.Comparing the two halftone regions C0' and C1' created by dither cells C0 and C1.
5.The halftone region is similar to the original halftone region is selected as the decoding dither cell and also the decoded watermark bit. (C0 for bit0, C1 for bit1)
6.According to the key of the scrambling, retrieve the watermark.

3.2.2 Semi-fragile watermark extracting

For B level, calculate the average graylevel of blocks with size 8x8 of the watermarked halftone image and simulate the block with a constant colored region having this average color. Dither cells C2 and C3 are used to produce two halftone regions. The region which is similar to the original halftone region is selected as the decoding dither cell and the watermark bit. (C2 for bit"0", C3 for bit"1")

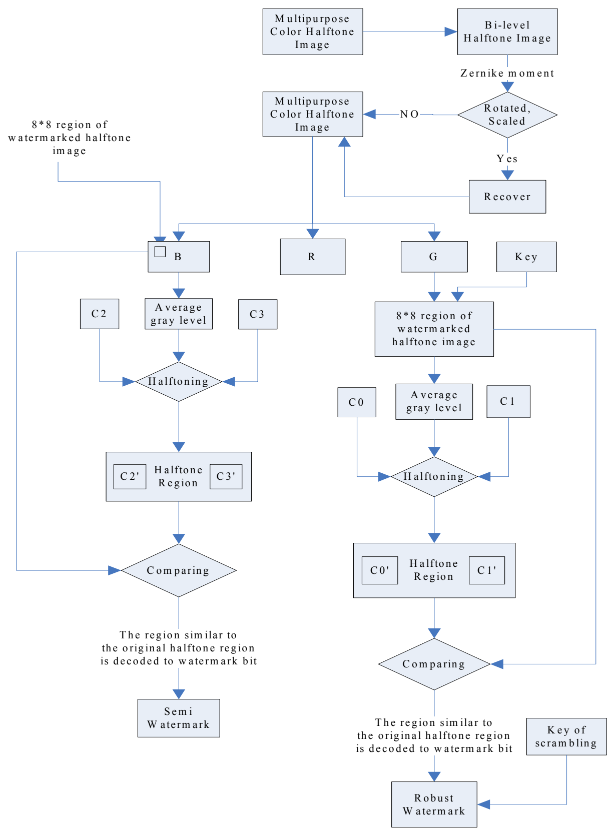


Figure 6. Block diagram of the watermark extracting system.

The detailed process of extract semi-fragile watermark:

1. Calculating the average graylevel of blocks with size 8x8 and simulate the block with a constant color region having this average color.

2. Using dither cells C2 and C3 be the threshold values to produce two halftone regions C2' and C3' respectively.

3. Comparing the two halftone regions C2' and C3' created by dither cells C2 and C3.

4. The halftone region is similar to the original halftone region is selected as the decoding dither cell and also the decoded watermark bit. (C2 for bit0, C3 for bit1)

The watermark extracting system is shown in figure 6.

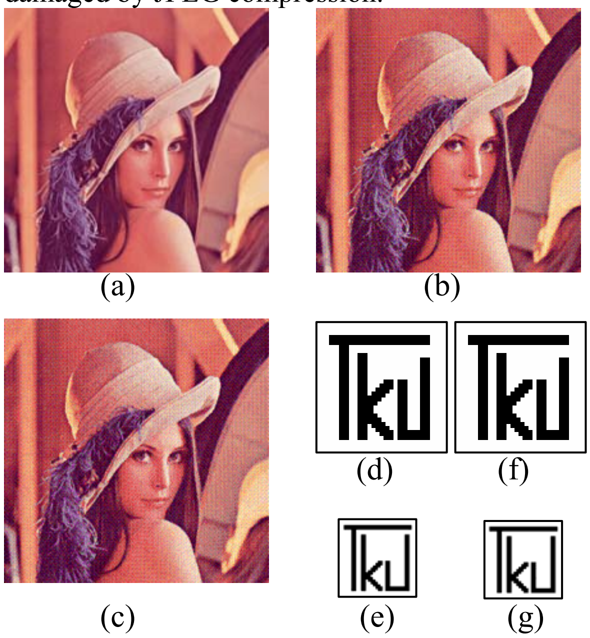
4 Experimental results

Figure 7.(a) is the original color image LENA with size 512x512. Figure 7.(b) is the halftone image using one dither cell. Figure 7.(c) is the watermarked color halftone using our method. Figure 7.(d) is the semi-fragile watermark with size 64x64. Figure 7.(e) is the robust watermark with size 32x32. Figure 7.(f) is the semi-fragile watermark extracted from (c). Figure 7.(g) is the robust watermark extracted from (c). Figure 8 are some attacks of the Lena image. Figure 8. (a), (b) and (c) are the attacks of corrupted and cropped. The robust watermarks are still clearly in Figure 9 (a), (c) and (e). The semi-fragile watermarks can show the regions where are attacked are shown in Figure 9 (b), (d) and (f). Table1 is the correlation between original watermarks and the watermarks extracted from compress images. Table2 is the comparison between the estimated α and the rotating angle and scaling. We can obtain the rotated angle of image by rounding the measured angle to integer angle and the scaling of image by rounding the measured scale to integer scale or decimal scale.

The recovery of rotated watermarked color halftone image can be obtained by Photoimpact, but the values of pixels of the recovered image are changed. Table3 is the correlation between original watermarks and the watermarks extracted from recover rotated image. Table4 is the correlation between original watermarks and the watermarks extracted from recover scaled image.

5 Conclusion

In this paper, the watermarked color halftone image has good visual quality by using ordered dithering to embedded watermark. The Zernike moment is adopted to detect rotation and scale of the watermarked image. In our method, the robust watermark is able to withstand various attacks such as cropped, corrupted, scaled, rotated and JPEG compression. The semi-fragile watermark not only detect regions where are attacked but also easily damaged by JPEG compression.



(a) Original Image (b) Halftone Image(c) Watermarked Halftone Image(d) Semi-fragile watermark (e) Robust watermark(f) Extract semi-fragile watermark(g) Extract robust watermark

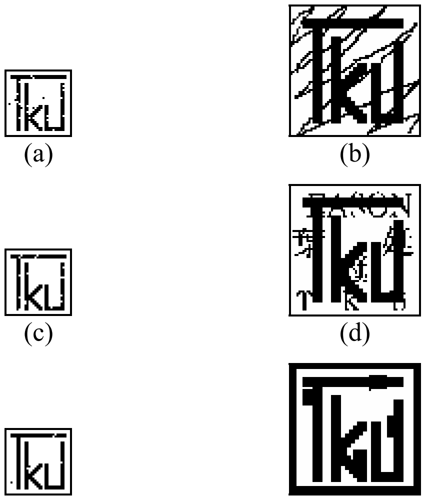
Figure 7.

(a) Corrupting

(b) Corrupting

(c) Cropping

Figure 8. Some attacks of the Lena Image.



(a) (b) (c) (d) (e) (f)

(a) Robust watermark extracted from Figure5.(a)
(b)Semi-fragile watermark extracted from Figure5.(a)
(c)Robust watermark extracted from Figure5.(b)
(d) Semi-fragile watermark extracted from Figure5.(b)
(e) Robust watermark extracted from Figure5.(c)
(f) Semi-fragile watermark extracted from Figure5.(c)

Figure 9. The extracted watermarks of the images with malicious attacks.

Table 1. The NC values of the extracted robust and semi-fragile watermarks after different quality of JPEG compression.

	90%	80%	70%	60%
Robust watermark	1	1	1	1
Semi-fragile watermark	0.4050	0.4075	0.4102	0.4082
	50%	40%	30%	20%
Robust watermark	1	0.9990	0.9990	0.9775
Semi-fragile watermark	0.3970	0.3992	0.4055	0.4207

Table 2. Estimated angle and scaling with Zernik moment

Rotated image	0°	10°	20°	30°	40°
Angle α	0°	10.449°	20.275°	30.282°	40.211°
Scaled image	0.75	1	1.5	2	2.5
Scaled α	0.7613	1	1.511	2.012	2.487

Table 3. The NC values of the extracted robust and semi-fragile watermarks after rotation operations.

	Rotated				
	0°	10°	20°	30°	40°
Robust watermark	1	0.9355	0.9209	0.9326	0.9297
Semi-fragile watermark	1	0.5789	0.5503	0.5520	0.5444

Table 4. The NC values of the extracted robust and semi-fragile watermarks after scaled operations.

	Scaled				
	0.75	1	1.5	2	2.5
Robust watermark	0.8457	1	0.9912	1	0.9834
Semi-fragile watermark	0.3950	1	0.9573	1	0.8804

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