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The Halftone Image Watermarking Algorithm Based on Error Diffusion

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Abstract. Halftone image watermarking is an important direction of research and application in the field of information hiding now. This paper proposed a halftone image watermarking algorithm based on error diffusion. It is an effective measure to copyright protection of printed matter, source authentication and prevented forgery etc. This algorithm embedded watermarking image information as an error signal into the pixels adjacent to this location by error diffusion algorithm. Information embedding was completed synchronously with halftone. So watermarking extraction is simple and fast. Experiments show that this algorithm can embed a binary watermarking image into the halftone image with the same size. This algorithm has a good performance in resistance to a variety of attacks (such as noise jamming, fouling, and rotation etc.).So it has certain practical value.

Introduction

Halftone is also called gray level. It is the technical index that reflects image brightness level and the change of monochrome contrast. Halftone image is to quantize a continuous tone image (such as gray image) to a special binary image by halftone adjustment technique, which is used in image output such as newspapers, magazines etc. currently. Because the visual resolving power of human is limited, the visual effect of halftone image is similar to the original image beyond a certain range, namely human feel that it still is a continuous tone image. At present, there are many watermarking algorithms based on gray image. They are the main measures of digital copyright protection. But these algorithms can not be directly applied to halftone image[1]. The main reason is the halftone image is still the binary image. Pixel has only two states of black and white for grayscale image, the image grayscale are showed with the density of black spots by halftone algorithm. It is synthesized by the CMYK four colors for color image. Each color is binary. So the information hiding ability of halftone image is much smaller than grayscale image and color image. For example,(1) The algorithm based on space domain transform "0" and '1' directly. It only embeds watermarking on the image boundary in order not to produce the obvious trace of modification. The watermarking capacity is limited greatly.(2) The embedding strength of watermarking produces a large change when the algorithm based on common transform domain(such as DCT etc.) transform to the space domain and then image binaryzation, which results watermarking will be affected strongly or even unable to be extracted. Actually, many watermarking algorithms based on gray image (such as space domain, transform domain, compressed domain, based on biometric model watermarking algorithm etc.) are not applicable for halftone image[2,3].

Halftone image watermarking is an important direction of research and application in the information hiding field now. There are some problems such as the embed capacity is smaller[4,6], the resolution of watermarking image is only the half size of the carrier binary image[6] etc. So this paper proposed a halftone image watermarking algorithm based on the error adjustment by the error diffusion. It can embed a binary watermarking image with the same size of halftone image into the halftone image. It improves the information hiding capacity of halftone image greatly. The image carried watermarking has a certain ability of anti-noise jamming, fouling, and rotation.

The halftone technology based on error diffusion algorithm

The common halftone technology of digital image includes ordered dither algorithm and error diffusion algorithm. The ordered dither compares the input image with a periodic threshold matrix（ or called screening matrix）. This screening algorithm compares in the original gray image by a fixed size threshold matrix. The output pixel is 0 or 1, which is decided by the threshold. It outputs different halftone images with different designs of the threshold matrix. This ordered dither algorithm with threshold matrix lost the details of continuous tone image mostly. So the obtained halftone image exist a big distortion compared to the original continuous tone image.

The error diffusion algorithm is recognized as one of the most ideal halftone algorithms. It is the halftone technique that distributes the error produced in procession of image quantization to the surrounding pixels according to proportion through the filter, namely diffuses the error to the surrounding pixels. Halftone image dealt with the error diffusion algorithm has rich color and good visual effect compare to the ordered dither algorithm[7]. Figure 1 is a schematic diagram of error diffusion algorithm, h_{mn} is error transfer operator, namely diffusion kernel.

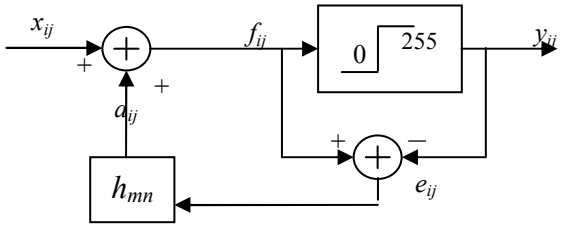


Fig.1 The schematic diagram of error diffusion algorithm

The process of the error diffusion can be described by the following equation:

$$f_{ij} = x_{ij} + \sum_{(m,n)\in R} e_{(i-m)(j-n)} \times h_{mn} \tag{1}$$

$$y_{ij} = \begin{cases} 0 & f_{ij} < T/2 \\ T & f_{ij} \geq T/2 \end{cases} \tag{2}$$

$$e_{ij} = f_{ij} - y_{ij} \tag{3}$$

Among them，T is image gray level. T=255 when the bit depth of gray image is 8. The white pixel is 255 and the black pixel is 0 in the resulting halftone images. R is the region units need to pass the error to the back pixel in the procession of the scanning. The different error transfer operators are choice for image binaryzation. There are three common error transfer operators, namely Floyd-Steinberg operator (or call Steinberg kernel), Jarvis operator,Stucki operator. The different error transfer operator can produce the halftone image of different quality.

The watermarking algorithm based on halftone

The halftone technology can spread the embedded content as noise to more than one point. The image embedded watermarking has no obvious visual distortion by the corresponding balance process. Because the halftone image is generally printed on white paper with black image, The thinking of hidden watermarking algorithm based on halftone is : (1) When the information to be embedded is white, the corresponding position of the halftone image without watermarking and the halftone image with watermarking are both white point ;(2) When the information to be embedded is black, the corresponding position of the halftone image without watermarking and the halftone image with watermarking has at least one black point. In addition,in order to maintain better visual

imperceptibility, if the corresponding position of the halftone image without watermarking is black, the algorithm should change the corresponding position of the halftone image with watermarking into white in the procession of embedding the black point. Its purpose is to maintain the balance of black and white pixels and improve the visual quality. The embedding algorithm is shown in Figure 2.

When watermarking is extracted, the algorithm makes the halftone image without watermarking P and the halftone image with watermarking Q to have melanin Summation according to pixels(AND operation of the bits according to pixels). The resulting image will show the embedded watermarking. If the image p and image q are printed on the transparent slide, then they are stacked by alignment and watermark is showed. Watermarking detection is simple and fast.

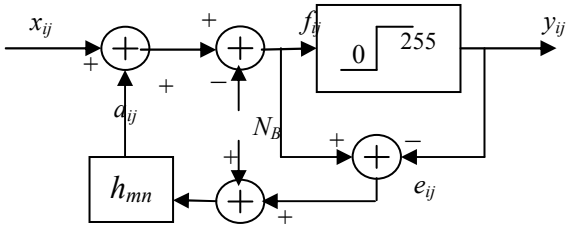


Fig.2 The embedding algorithm based on error diffusion

Hypothesis original image is $I = \{x(i, j), i = 1, \cdots N, j = 1, \cdots M\}$,namely the size of original image is $N \times M$, the watermarking that is ready to embed is $W = \{w(i, j), i = 1, \cdots N, j = 1, \cdots M\}$, $w(i, j) = \{0,1\}$. If the size of watermarking image and the original image is inconsistent, the size of watermarking image has the same size of the original image by the scaling. The standard halftone image is $P = \{p(i, j), i = 1, \cdots N, j = 1, \cdots M\}$ after the original image is processed by formula (1), formula (2), formula (3). The halftone image with watermarking is $Q = \{q(i, j), i = 1, \cdots N, j = 1, \cdots M\}$. Before watermarking is embedded, the original image is processed by halftone and then become the halftone image P. Then takeout the each pixel of the watermarking image and embed according to the order from left to right and from top to bottom. The embedding rules are as follows:

(1) If $w(i, j) = 1$, $p(i, j) = 1$, then deal according to (1),(2)and(3);

(2) If $w(i, j) = 1$, $p(i, j) = 0$, or if $w(i, j) = 0$, $p(i, j) = 1$,then modify (1) and (3) to (4) and (5), and deal according to (4),(2) and (5).

$$f_{ij} = x_{ij} + \sum_{(m,n) \in R} e_{(i-m)(j-n)} \times h_{mn} - N_B \tag{4}$$

$$e_{ij} = f_{ij} - y_{ij} + N_B \tag{5}$$

(3) If $w(i, j) = 1$, $p(i, j) = 0$,then modify (1) and (3) to (6) and (7),and deal according to (6),(2) and (7).

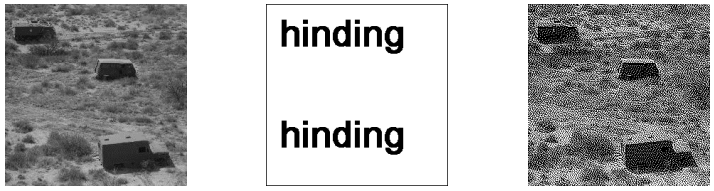
$$f_{ij} = x_{ij} + \sum_{(m,n) \in R} e_{(i-m)(j-n)} \times h_{mn} + N_B \tag{6}$$

$$e_{ij} = f_{ij} - y_{ij} - N_B \tag{7}$$

The halftone image Q dealt by the above halftone processing is the image with watermarking. The value of N_B control the embedded depth of watermarking. The image watermarking is clearer when the value of is N_B higher. But image distortion increases.

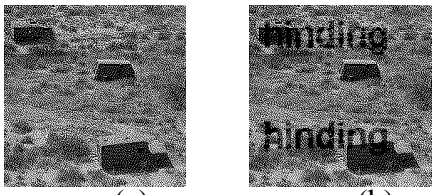
Simulation Experiment

The original image selected by experiment is 512×512×8bit. In order to observe the result of watermarking extraction conveniently, watermarking image use the binary bitmap with "hinding" and its size is 512×512×1bit. Figure 2(a) is the original image. Figure 2(b) is the watermarking image that ready to be embedded. Figure 3(a) is the halftone image with watermarking. Figure 3(b) is the result of stacking figure2(c) and figure 3(a) according to black point.



(a) (b) (c)

Fig.2 The original image,the embedded image and the halftone image

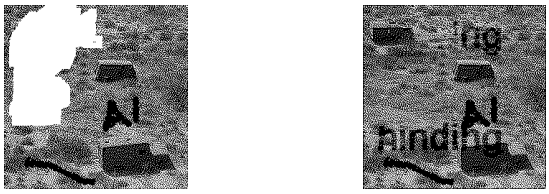


(a) (b)

Fig.3 The halftone image with watermarking and the experiment result of watermarking extraction

We can see from this experiment that the watermarking capacity is better when the embedded information is 512×512bit. Peak signal to noise ratio(PSNR) is used in the evaluation of gray scale image distortion commonly and it is not suitable for halftone binary image etc. The visual imperceptibility is satisfied when VDSF>40.5 using the objective evaluation methods proposed by literature[8] in order to evaluate the distortion of halftone image embedded watermarking objectively. VDSF of figure 3(a) is 41.3 compared to figure 2(c). We can see this algorithm can extract the watermarking effectively on the premise of meeting the visual imperceptibility.

In order to test the situation that this algorithm resist related attacks,(1) Doodle the halftone image with watermarking and detect watermarking. Figure 4(a) is the image with watermarking after it is doodled. Figure 4(b) is the result of watermarking detection. We can see doodle does not affect the watermarking detection. The part that not to be cut can detect the embedded information well in the clipping attack.(2) Detect the noise and rotation attack for halftone image with watermarking, then detect watermarking after 5% salt-pepper noise is added. The result is shown in Figure 5.Detect watermarking after it is rotated 15 degrees. The result is shown in Figure 6.We can see this algorithm has better attack tolerant for cutting, doodle, adding noise and rotation etc. and it has better robustness.



(a) (b)

Fig.4 The detection after doodled

Fig.5 The detection after watermarking image is added noise

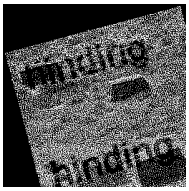


Fig.6 The detection after watermarking image is rotated

Conclusions

This paper proposed an algorithm that embeds the digital watermarking with same size of the carrier image in the halftone image. The Characteristics of this algorithm are (1) Solve the problem that the embedded capacity of most watermarking algorithm is small;(2) The embedding of watermarking and the halftone carry out simultaneously, and the extraction of watermarking is simple;(3) The experimental results verify that the visual imperceptibility of the embedded watermarking by this algorithm is good and the extracted watermarking is clear. And the image with watermarking can extract the watermarking still after it is attacked by doodle, noise and rotation. The Shortcoming of this algorithm is that watermarking extraction still need halftone image. It does not realize the blind detection. However, if the halftone image of the original image is outputted on transparent film, transparent film is superimposed on the image to be tested and can show the hidden watermarking (copyright information) in practical application. So the protection of copyright is achieved.

All the analysis shows it is an important method of copyright protection and anti-counterfeiting that the Digital watermarking is added in halftone image. This algorithm can be applied on all image based on halftone.For example, the copyright protection and anti-counterfeiting of documents, newspapers, currency, checks, magazines, and confidential document etc. It has the certain practical value.

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