A REVERSIBLE DATA HIDING SCHEME TO INVERSE HALFTONING

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Keywords: Halftone image, Inverse halftoning, Reversible data hiding, Look-up table (LUT), Gaussian filtering.

Abstract: A new inverse halftoning algorithm based on reversible data hiding techniques for halfton images is proposed in this research. The proposed scheme has the advantages of two commonly used methods, the look-up table (LUT) and Gaussian filtering methods. We embed a part of important LUT templates into a halfton image and restore the image lossless after these templates been extracted. Then a hybrid method is performed to reconstruct a gray-scale image from the halfton image. In the image reconstruction process, the halfton image is scanned pixel by pixel. If the scanned pattern surrounding a pixel appeared in the LUT templates, a gray value is directly predicted using the LUT value, otherwise, it is predicted using Gaussian filtering. Experimental results show that the reconstructed gray-scale images using the proposed scheme own better quality than both the LUT and Gaussian filtering methods.

1 INTRODUCTION

Inverse halftoning is a process which transforms halftone images into gray-scale images. Halftone images are binary images that provide a rendition of gray-scale images and consists of '0" and '1". It has been widely used in the publishing applications, such as newspapers, e-documents, magazines, etc. In halftoning process, it need to use a kernel to carry out the conversion, and the common kernel is such as Floyd-Steinberg kernel, and is difficult to recover a continuous-tone image through halftone manipulation, conversion, compression, etc. In the past few years, many efficient inverse halftoning algorithms have been proposed, but there is no way to construct a perfect gray image from the given halftone image. There exist several inverse halftoning methods, including kernel estimation (Wong, 1995), wavelet (Xiong, Orchard, & Ramchandran, 1996), filtering (Fan, 1992; Kite, Venkata, Evans, & Bovik, 2000), and set theoretic approaches (Chang, Yu, & Lee, 2001). Most of these methods can obtain good reconstruction image quality but require relatively high computational complexity.

The halftoning and inverse halftoning processes can be regarded as the encoding and decoding processes of vector quantization. Therefore, the codebook design methods can be applied to build the inverse halftoning lookup tables (Mese & Vaidyanathan, 2001, Chung & Wu, 2005). The content of a table entry is the centroid of the input samples that are mapped to this entry. The results are optimal in the sense of minimizing the MSE for a given halftone method. Although the table lookup method has the advantages of good reconstructed quality and fast speed, it faces the empty cell problem in which no or very few training samples are mapped to a specific halftone pattern.

In this paper, a reversible data hiding scheme for halftone images is proposed. We embed a part of important LUT templates into a halfton image and restore the image lossless after these templates been extracted. Then a hybrid method is performed to reconstruct a gray-scale image from the halfton image.

Lee J., Wu H. and Wu M. (2009).
A REVERSIBLE DATA HIDING SCHEME TO INVERSE HALFTONING.
In *Proceedings of the International Conference on Signal Processing and Multimedia Applications*, pages 86-89
DOI: 10.5220/0002237500860089

2 REVERSIBLE DATA HIDING FOR BINARY IMAGES

Reversible data hiding can embed secret message in a reversible way. Relatively large amounts of secret data are embedded into a cover image so that the decoder can extract the hidden secret data and restore the original cover image without any distortion. Recent, a boundary-based PWLC method is presented (Tsai, Chiang, Fan, Chung, 2005). This method defines the same continuous 6 edge pixels as an embeddable block through searching for binary image edges. And then one can embed data in the pair of the third and fourth edge pixels. A reversible data hiding method for error diffused halftone images is proposed (Pan, Luo & Lu, 2007). This method employs statistics feature of pixel block patterns to embed data, and utilizes the HVS characteristics to reduce the introduced visual distortion. The method is suitable for the applications where the content accuracy of the original halftone image must be guaranteed, and it is easily extended to the field of halftone image authentication. However, these two methods both have a drawback that the capacity of data hiding is still limit.

3 PROPOSED METHOD

The proposed inverse halftoning method based on reversible data hiding techniques can be divided into two phases: the embedding process and the extracting process. Figure 1 shows the diagram of the proposed method. In the embedding process, a gray-scale image is transferred into a halftone image by error diffusion process. Then pattern selection is performed to determine the pattern pairs for the use in reversible data hiding. Meanwhile, a part of LUT templates are selected to keep high quality of recovery images in the reconstruction process. These templates along with the pattern pairs will be encoded in bit streams and embedded into the halftone image. The data embedding operation is performed based on pattern substitution. In the data extracting process, the pattern pairs and LUT temples are first extracted. The halftone image can be lossless restored after the data extraction. Finally, we can reconstruct a good quality gray-scale image from the halftone one with the aid of LUT templates. The proposed scheme has the advantages of two commonly used methods, the look-up table (LUT) and Gaussian filtering methods. We embed a part of

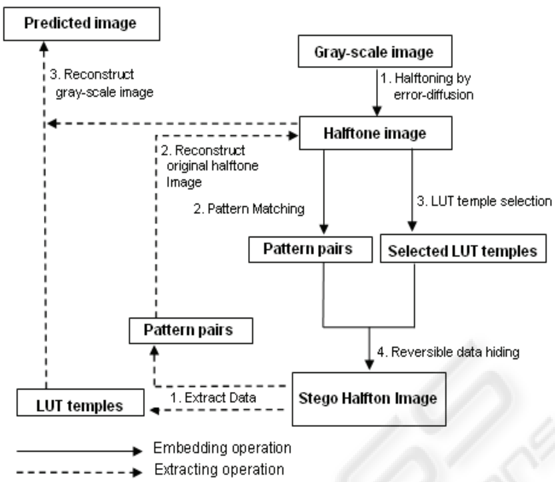


Figure 1: The embedding and extracting diagram of proposed method.

important LUT templates into a halfton image and restore the image lossless after these templates been extracted.

3.1 Data Hiding with Pattern Substitution for Halftone Images

The proposed method of reversible halftone data hiding technique uses pattern substitution method to embed and extract data into halftone images. The original image is partitioned into a set of non-overlapping 3x3 blocks. There are totally 2^9 different patterns. Therefore, each pattern is uniquely associated with an integer in the range of 0 to 511. In most cases, many patterns never appear in an image. Figure 2 is an instance to show the pattern histogram for image Lena.

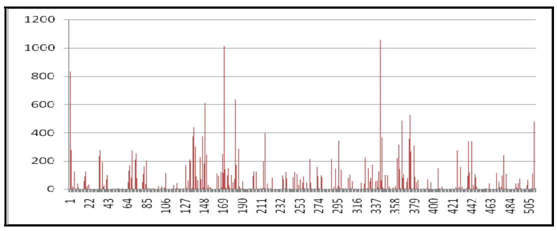


Figure 2: The pattern histogram of halftone image “Lena”.

In this study, all patterns are classified into two groups, *used* and *unused*. For each used pattern A, an unused pattern B which content is the most closest to pattern A will be selected to form a pair for data embedding. In the data embedding process, the original halfton image is partitioned into a group of 3×3 non-overlapping patterns. Then, any pattern *p* on the halfton image with the same content of A will be selected to embed 1-bit data. If a data bit “0” is embedded on *p*, then the content of *p* is remained as *A*. If a data bit “1” is embedded on *p*, then the content of *p* is updated as the content of pattern *B*. This scheme works because pattern *A*, *B* look similar. In data extraction process, the embedded message is obtained depending on the pattern *A*, *B* when the test image is scanned. To achieve a higher capacity of embedding data, more pattern pairs should be determined, whose steps can be presented as below.

1. Partition the original image into non-overlapping 3×3 blocks.
2. Compute the occurrence frequencies for all appeared patterns. Sort these used patterns decreasingly and denoted them as PH^i according to their occurrence frequencies.
3. Find out all unused patterns. Assume that there are totally *k* unused patterns, *k* pairs of patterns (PH^i, PL^i) should be constructed to perform the data embedding.
4. Search all blocks in the original image. As long as we come across a pattern in the PH^i, if a bit “0” is embedded, the block is remained as PH^i; Otherwise the block is updated as the pattern PL^i.

Figure 3 displays the top 10 patterns PH^i and 10 unused patterns PL^i from Lena image.

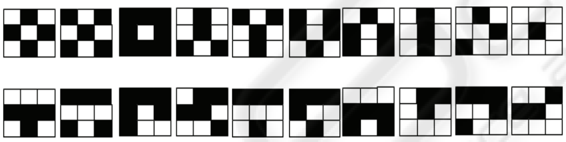
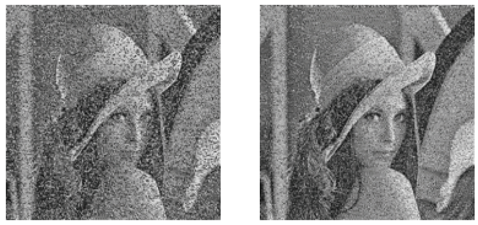


Figure 3: An example of PH^i (first row) and PL^i (2nd row) obtained from the Lena image.

However, the image quality of stego-image generated using the proposed method is not very well in the visual effect. Figure 4(a) shows the stego-image obtained using the proposed method with 26317 bits embedded into Lena.

To consider human visual effect, we should take notice about some situations which will cause “Congregation” effect of bright or dark spots. These cases are displayed bellows. To avoid these cases when a pattern replacement occurs, we adjust the weights of distance on pattern similarity computation and a better result is obtained. Figure 4(b) shows a good image quality for the stego-image.



(a) (b)

Figure 4: The stego-image generated using the proposed method; (a) without quality consideration (b) with quality consideration.

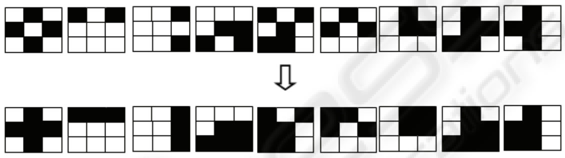


Figure 5: The cases will cause bad human visual effects.

3.2 Determine Important LUT Templates to be Embedded

The proposed method is a kind of hybrid inverse halftoning method which has the advantages of Gaussian filtering and LUT methods. Figure 6 shows the reconstruction process for these two methods. For an image block in the halfton image, if the difference of predicted value and the original real gray value using Gaussian filtering method is larger than the difference using LUT method, then the LUT template is worth to be recorded and embedded. This means the LUT template can obtain a higher image quality than using Gaussian filtering method in the image recovery process. However, only a part of important templates which save larger quality loss are selected to embed since the embedding capacity is limit for a halftone image. In

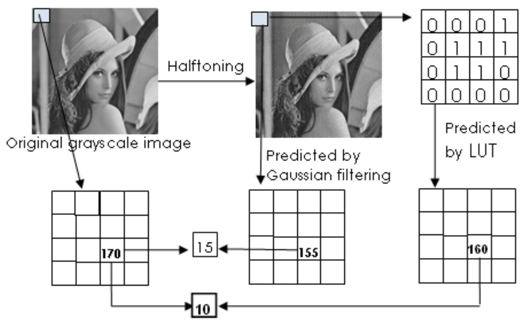


Figure 6: An instance to determine the “importance” for a LUT template.

the gray-scale image recovery process, we scan the halftone image by checking the templates. If the current template is one of the embedded templates, then LUT is used to predict the gray value; otherwise Gaussian filtering method is applied to predict the value.

4 EXPERIMENTAL RESULTS

Four 512×512 error diffused halftone images "Lena" 、"pepper" 、"Airplane" 、"Baboon" are selected to test the performance of the proposed method. These halftones are obtained by performing Floyd–Steinberg error diffusion filtering on the 8-bit gray level images. Capacities for different images are listed in Table 1. Table 2 shows the PSNR values for the recovery images using the different methods. The proposed method performs better than both Gaussian filtering and LUT method (train 10 images). Experimental results show that the reconstructed gray-scale images using the proposed scheme own better quality than both the LUT and Gaussian filtering methods.

Table 1: The embedding capacity (bits) with different images using the proposed method.

Images	template	LUT pairs	Maximum capacity(bit)
Lenna(26317bit)	4x4	995	26330
Pepper(26575)	4x4	1005	26585
Airplane(24985)	4x4	974	24999
Baboon(8315)	3x3	469	9544

Table 2: PSNR values for the reconstructed images using different methods.

Images	PSNR(dB)		
	Gaussian	LUT	The proposed method
Lenna(26317bit)	29.395483	27.203030	30.107435
Pepper(26575)	29.296406	26.871689	30.721979
Airplane(24985)	28.289963	26.350929	29.750772
Baboon(8315)	22.219963	21.400383	23.991392

Gaussian filter $\sigma = 1.41$

5 CONCLUSIONS

A new inverse halftoning algorithm based on reversible data hiding techniques for halfton images is proposed in this research. We embed a part of important LUT templates into a halfton image and restore the image lossless after these templates been extracted. Then a hybrid method is performed to reconstruct a gray-scale image from the halfton image. Experimental results show the proposed scheme outperformed than both the LUT and Gaussian filtering methods.

ACKNOWLEDGEMENTS

This work was supported by National Science Council, R.O.C., under grant 97-2221-E-390-012.

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