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Lossless Image Digital Watermarking based on Integer Wavelet and Histogram Adjustment

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Abstract

A novel distortionless image data hiding method named lossless image digital watermarking based on integer wavelet and histogram adjustment is proposed. This image data hiding method can invert the stego-image into the original image without any distortion after the hidden data are extracted. The image histogram adjustment is used to prevent grayscales from possible overflowing. This method hides data into a selected bit-plane of the integer wavelet transform coefficients in the high frequency subbands. It can embed much more data compared with the existing distiortionless data hiding techniques under imperceptibility requirement. Experimental results have demonstrated the validity of the algorithm.

Keywords: histogram adjustment, high-capacity data embedding, lossless images watermarking, integer wavelet transformation.

1. Introduction

A lossless high-capacity data embedding for image watermarking based on integer wavelet and histogram adjustment is proposed. In medical images, even small adjustments are not allowed for obvious legal reasons and a potential risk of a physician misinterpreting an image. After extracting data embedded ,the original image should be reversible from watermarked image.

The application of image digital watermarking as a new technology in the area of image archiving and communication is growing rapidly, such as software package PACS. Obviously most of current data hiding algorithms are not distortionless. Recently, some distortionless marking techniques have been reported in the literature. The concept of distortion-free data embedding appeared for the first time in an authentication method in a patent owned by Eastman Kodak was published in 1999. This method [1] is carried out in the image spatial domain. Another spatial domain technique was reported. These techniques aim at authentication, instead of data embedding. As a result, the amount of hidden data is quite limited. The first distortionless marking technique that is suitable for data embedding was presented in [2]. This amount of hidden data is still not large enough for some medical applications.

2. watermarking by integer wavelet

The lossless watermarking processed in the wavelet domain is attracted. The high compression rate obtained by de-correlation in wavelet domain is for embedding high-capacity data. The watermarked image with suitable embedding data obtained by multi-resolution is for imperceptible in vision.

The key problem for integer wavelet using in image watermarking is that the gray level should be held in given range. The dynamic range histogram adjustment on gray level is used to avoid overflow after returning space domain from wavelet domain. For example the range of histogram on gray level under 8 bit image may be compressed from 0-255 gray level to smaller range, for example 15-240. The extra histogram data can be added to the embedding data in wavelet domain. The highest resolution levels in wavelet domain are recommended. The less significant bit instead of the least significant bit (LSB) in wavelet domain is used for more data embedding. The Lifting integer wavelet and arithmetic coding are used in this paper. In addition, a secret key is used for both secure against attacks and fine adjustment of overflow avoidance.

To eliminate more redundancy to embed more data while avoiding round-off error, we propose to use the second generation wavelet transform such as IDWT , which maps integer to integer and whose CDF (2,2) format has been adopted by JPEG2000. This technique is based on the lifting scheme.

The encoding of watermarking includes five steps: (1) first histogram adjustment; (2) wavelet transformation; (3) data embedding; (4) inverse wavelet transformation; (5) second histogram adjustment forming watermarked image. The decoding of watermarking includes other five steps; (6) third histogram adjustment; (7) wavelet transformation; (8) extracting data

embedded; (9) wavelet inverse transformation (10) forth histogram adjustment for getting the original image.

Table 1 Embedding data to original image forming a stego-image

	procedure	function
1	1st histogram adjustment	keep histogram narrower to avoid from overflow
2	wavelet transformation	transformation by integer lifting wavelet
3	embedding data	embed data to fourth bit plane of highest resolution subband secret key: Hash function
4	inverse wavelet transformation	transformation by integer lifting inverse wavelet
5	2nd histogram adjustment	improve PSNR by circular shifting

Table 2 Extracting data and recovering into the original image from stego-image

	procedure	function
6	3rd histogram adjustment	inverse circular shifting
7	wavelet transformation	transformation losslessly by integer lifting wavelet
8	extracting data	extract data from fourth bit plane of highest resolution subband secret key: Hash function
9	inverse wavelet transformation	transformation by integer lifting inverse wavelet
10	4th histogram adjustment	circular shifting and recover into original image

To further enhance the visual quality of the marked image, we embed data only in the high frequency subbands LH_1, HL_1 and HH_1.

The arithmetic coding is chosen to losslessly compress middle binary bit-plane because of its high coding efficiency. The secret key is used to make the hidden data remaining in secret even after the algorithm is known [3]. The circular shifting procedures are used four times for both higher PSNR and recovering into original image.

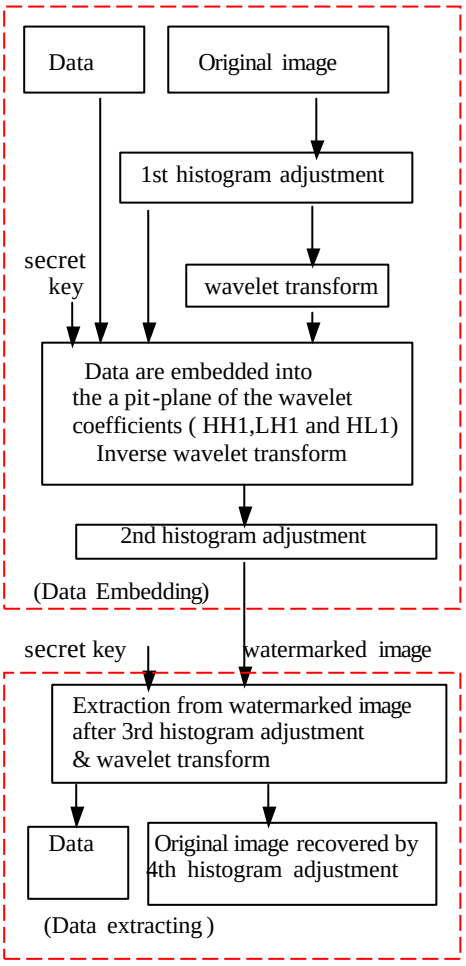


Figure 1 Distortionless watermarking algorithm

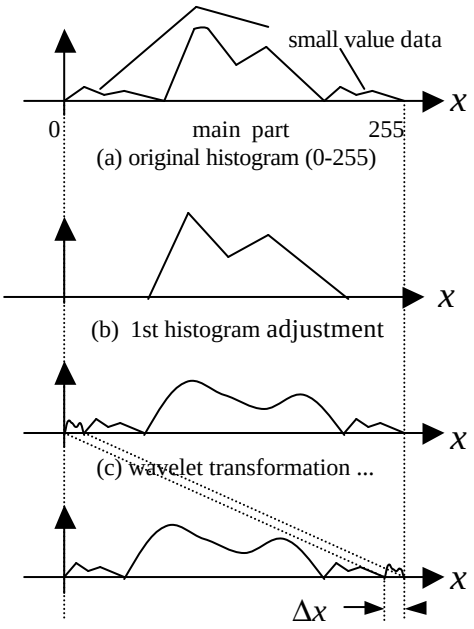


Figure 2 Digital watermarking by wavelet transformation and histogram adjustment

3. Experimental results

3.1 Example A

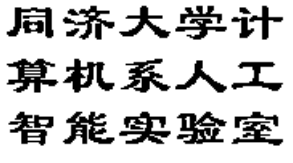
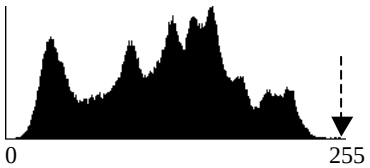


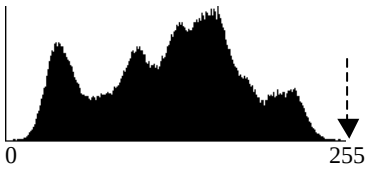
Figure 3 watermark Image

The watermark (192×120 binary image) is shown in Figure 3. The original "Lena" images and watermarked image are shown in 5. The experimental result of Lena image original with 512×512×8 images are shown in Figure 4. It is observed that the imperceptibility requirement is met. The data is embedded at 256×256 high frequency subbands LH_1, HL_1 and HH_1. The secret key is formed by Hash function.

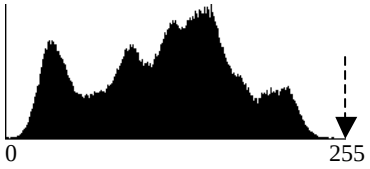


(a) original histogram with mean 118.62

(b) mean 123.62 after 1st histogram adjustment



(c) data emdedded with mean 123.62



(d) mean being recovered to 118.62 after 2nd histogram adjustment

Figure 4 Digital watermarking by histogram adjustment for Image Lena

(a) Original

(b) Watermarked (PSNR=36.64)

Figure 5 Watermarking of Image Lena

3.2 Example B

A watermarking MRI image is shown in Figure 6 (watermark binary image as embedded data is the same as Figure 2). It is observed that the imperceptibility requirement is also met.

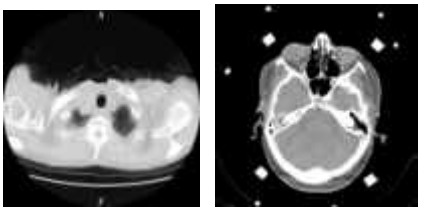
(a) Original

(b) Watermarked (PSNR=25.20)

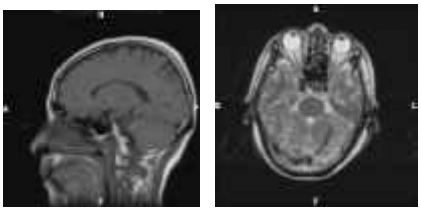
Figure 6 Watermarking of Image Mpic2

3.3 Example C

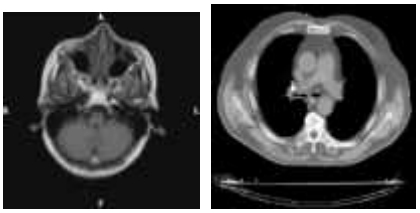
The 8 MRI and 8 common images are shown in Figure 7 and 8 respectively. The pay load of these 16 images of 512×512× 8 are listed in Table 3.



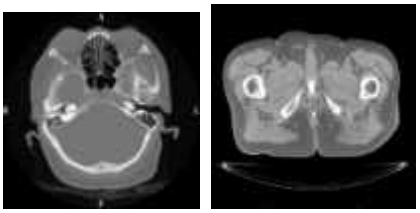
Mpic1 Mpic2



Mpic3 Mpic4



Mpic5 Mpic6



Mpic7 Mpic8

Figure7 Images of MIR

Table 3 Data Embedding

image name	pay load (bit)		image name	pay load (bit)
Mpic1	54,150		Lenna	85,507
Mpic2	70,799		Peppers	69,285
Mpic3	84,500		Tiffany	89,848
Mpic4	69,278		Couple	84,879
Mpic5	88,236		Baboon	14,916
Mpic6	35,183		Airplane	93,981
Mpic7	81,695		Sailboat	44,086
Mpic8	53,896		House	77,726

4 . Summary

The proposed invertible data embedding watermarking is able to embed about 15k to 94k bits into image of 512 × 512 × 8 imperceptibly.The pay loads of this watermarking are much more than what the existing techniques can do.

Lena Peppers

Tiffany Couple

Baboon Airplane

Sailboat House

Figure 8 Common Images

The key elements of the technique include the utilization of integer wavelet transform, histogram adjustment, arithmetic coding image compression and secret key.

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