Reversible Blind Image Watermarking based on Integer Wavelet Transform

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الملخص:

في هذا البحث ، تم اقتراح تقنية جديدة للعلامة المائية الرقمية لتضمينها داخل الصورة باستخدام التحويل المويجي الصحيح (**IWT**) تم تطوير تقنية العلامة المائية الرقمية وذلك لاسخدامها في بعض التطبيقات مثل التعرف على الوجوه التي تتطلب صورة عالية الجودة ليكون الأداء افضل الأداء. لهذا الهدف ، يتم تطبيق **IWT** على الصورة لتحليلها إلى نطاقات فرعية مختلفة. اعتمادًا على القوة المرغوبة للعلامة المائية ، يتم تحديد النطاق الفرعي للموجة. وبالتالي ، يتم تضمين العلامة المائية في زوج من قيم المويجات. أخيرًا ، يتم إعادة بناء الصورة ذات العلامة المائية من خلال تطبيق **IWT** المعكوس. حيث يتم استخراج بيانات العلامة المائية من الصورة المتضمنة العلامة المائية. بعد ذلك ، يتم استعادة الصورة الأصلية باستخدام العلامة المائية المستخرجة. النتائج العملية اثبتت أن تقنية العلامة المائية المقترحة لا تتمتع فقط بقوة اخفاء البيانات ولكن لديها أيضًا القدرة على كمية بيانات كبيرة.

الكلمات المفتاحية: العلامات المائية للصورة الرقمية ، العلامة المائية القابلة للانعكاس ، التحويل المويجي الصحيح ، العلامة المائية العمياء ، العلامة المائية العكسية.

Abstract:

In this paper a new reversible (also known as invertible) blind image watermarking technique is proposed based on Integer Wavelet Transform (IWT). This lossless image watermarking technique is developed for some applications like face recognition that a high perceptual quality image is required in order to preserve the performance. For this aim, IWT is applied on an image to decompose it to different sub-bands. Depending on the desired robustness of the watermark, the wavelet's sub-band is selected. Thus, a lossless function is used to embed the watermark into pair of wavelet's values. Finally, watermarked image is

reconstructed by applying inverse IWT. At receiver side, watermark data is extracted from the watermarked image. Then, the original image is recovered by using extracted watermark. Experimental results reveal that the proposed watermark technique not only has proper invisibility but also it has high payload.
Keywords: Digital image watermarking, reversible watermark, integer wavelet transform, blind watermark, invertible watermark.

1. Introduction

Nowadays, there is special attention to digital watermarking due to its wide applications such as fingerprinting, copyright control and protection, authentication, etc. Embedding extra information into the original content makes a slight difference between original content and watermarked content. Majority of the available watermarking techniques are irreversible which the original content cannot be recovered [1]. Distribution and transmission the watermarked version cannot be always acceptable by some applications such as biometric recognition [2], military investigation, space exploration, and medical diagnosis. In these applications, the security of the content as well as quality of the content must be satisfied. Thus, another kind of watermarking known as reversible watermarking is applied to satisfy both of them. Reversible (or also called lossless or invertible) watermarking does not have any degradation on original content [3]. All of the reversible watermarking are fragile or semi-fragile which can easily be destroyed if any modification is taken place [4]. Figure 1 illustrates two major categories of reversible watermarking techniques.

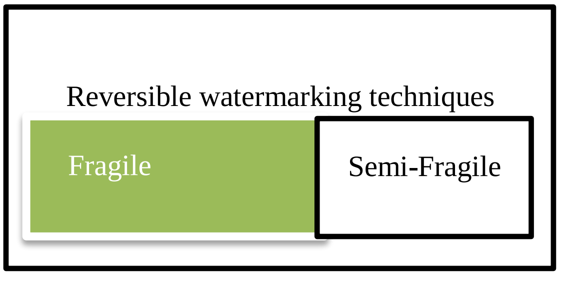

Figure 1. Two main classes in reversible image watermarking techniques.

In this paper, a novel reversible image watermarking technique is proposed by using IWT. The main reason is the ability of IWT for transforming an image to some sets of integer. Furthermore, applying lossless functions for watermark embedding and watermark extraction are broadening the application of this technique for wide range of applications.

The rest of this paper is organized as follow: first, related works in reversible image watermarking are discussed; second, the proposed reversible image watermarking technique is explained; third, an experimental result on the proposed reversible image watermarking technique is provided; fourth, the proposed algorithm is compare with other techniques; and finally, conclusions and future trends are presented.

2. Related Works

Majority of reversible image watermarking techniques have been classified into two main techniques including semi-fragile and fragile watermarking techniques. Figure 2 presents available reversible image watermarking techniques.

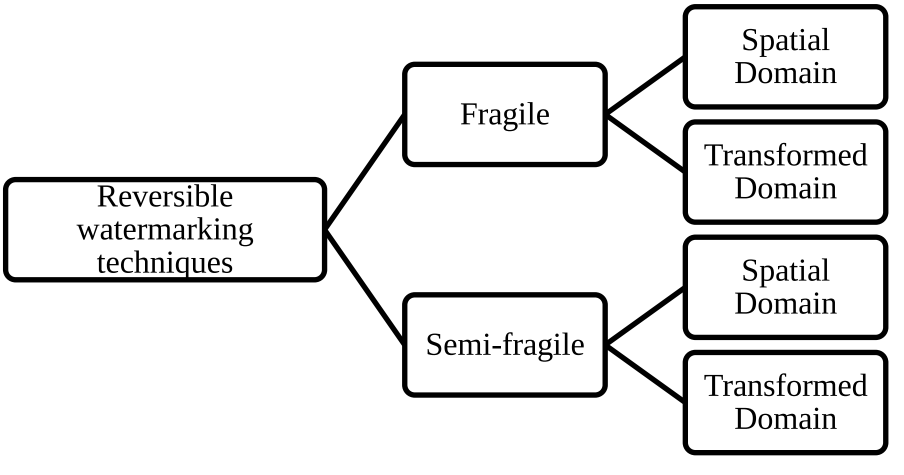

Figure 2. Available techniques for reversible image watermarking techniques.

Fragile reversible image watermarking based on spatial domain: The first technique for fragile reversible image watermarking has been presented based on differences among the neighborhoods pixels [5]. Although this technique can provide high amount of payload, the invisibility of the watermark can be degraded.

Fragile reversible image watermarking based on transform domain: A technique has been developed that apply a transformation functions like DCT in order to embed the watermarking bit bases on ZRX (Zero-Replacement Extraction), CA (Confusion Avoidance), or ZRE (Zero-Replacement Embedding) [6]. Although this technique can provide reasonable watermark invisibility, the low embedding capacity is the main problem of this approach. Another algorithm has been used based on substitution scheme for color images watermarking using Fourier transform [7]. Although the low capacity is the main issue of this study.

Semi-fragile reversible image watermarking based on spatial domain: A investigation has been developed based on modifying histograms of two sets [8]. For this purpose, two sets of regions in the image are selected. Then, watermark bit is inserted by changing the histograms' bins.

Semi-fragile reversible image watermarking based on transform domain: A study in [9] has been developed based on Weighted Quantization Method (WQM) by using two functions such as F and L. L is consisted of different quantization steps but F is the main quantization function. Another method has been presented based on LBP operators by using the local pixel contrast for the embedding and extraction of watermarks [10]. However, this technique can provide high amount of payload, the invisibility of the watermark can be degraded.

3. Proposed Watermarking Algorithm

Apart from watermark types, every watermarking algorithm has two common aspects including watermark embedding and watermark extraction. In the following, both of these aspects are explained in the details.

3.1 Watermark Embedding

The watermark embedding process is described as following:

1- Read the original image from input.
2- Apply one level two dimensional IWT on original image to decompose it four sub-bands including *cA*, *cH*, *cV*, and *cD*.
3- Rearrange details coefficients of the wavelet (*cD*) to a matrix with size of $2\times N$ ($A_{2\times N}$).
4- For each watermark bit, select pair of values (X, Y) from $A_{2\times N}$.
5- Compute the amount of L and H based on equation (1):

$$L = \left\lfloor \frac{X+Y}{2} \right\rfloor, \quad H = X - Y \tag{1}$$

6- Check the condition as in Equation (2)

$$|2 \times H + W_i| \le \min(2 \times (255 - L), 2 \times L + 1) \tag{2}$$

7- Embed the binary watermark (W_i) data as in Equation (3):

$$\widehat{H} = 2H + W_i \tag{3}$$

8- Compute the modified amount as in Equation (4):

$$\widehat{X} = L + \left\lfloor \frac{\widehat{H}+1}{2} \right\rfloor, \quad \widehat{Y} = L - \left\lfloor \frac{\widehat{H}}{2} \right\rfloor \tag{4}$$

Reconstructed the modified wavelet's details coefficients ($\widehat{cD}$) from the modified matrix ($\widehat{A_{2\times N}}$).

9- Replace $\widehat{cD}$ instead of *cD* and apply inverse one level two dimensional IWT to reconstruct the watermarked image.

3.2 Watermark Extraction

The watermark extraction process is described as following:

1- Read the watermarked image from input.
2- Apply one level two dimensional IWT on watermarked image to decompose it four sub-bands including *cA*, *cH*, *cV*, and *cD*.
3- Rearrange details coefficients of the wavelet (*cD*) to a matrix with size of $2\times N$ ($A_{2\times N}$).
4- For each watermark bit, select pair of values (X, Y) from $A_{2\times N}$.
5- Compute the amount of $\widehat{L_{org}}$ and $\widehat{H}$ based on equation (5):

$$\widehat{L_{org}} = \left\lfloor \frac{\widehat{X}+\widehat{Y}}{2} \right\rfloor, \quad \widehat{H} = \widehat{X} - \widehat{Y} \tag{5}$$

6- Extract the binary watermark ($\widehat{W_i}$) data as in Equation (6):

$$\widehat{W_i} = \widehat{H_{org}} \ \% \ 2 \tag{6}$$

7- Compute the new amount of $\widehat{H}$ before watermarking as in Equation (7)

$$\widehat{H_{org}} = \frac{\widehat{H} - \widehat{W_\iota}}{2} \quad (7)$$

8- Compute the original amount of image as in Equation (8):

$$\widehat{X_{org}} = \widehat{L_{org}} + \left\lfloor \frac{\widehat{H_{org}} + 1}{2} \right\rfloor, \quad \widehat{Y_{org}} = \widehat{L_{org}} - \left\lfloor \frac{\widehat{H_{org}}}{2} \right\rfloor \quad (8)$$

9- Reconstructed the modified wavelet's details coefficients ($\widehat{cD}$) from the modified matrix ($\widehat{A_{2\times N}}$).

10- Replace $\widehat{cD}$ instead of cD and apply inverse one level two dimensional IWT to reconstruct the original image.

In order to describe the proposed algorithm more clearly, Figure 3 presents the pseudocode for watermark embedding and extraction processes.

Img: input image
Img_wm: watermarked image
Img_org: constructed original image from the watermarked image
cA, cH, cV, cD: wavelet coefficients
N: size of cD
A: Revised matrix from cD
BB: Modified matrix
Floor(): floor function
Reshape(): matrix reshaping function
IWT(): Integer wavelet transform function
Inverse LWT: Inverse integer wavelet transform function
Min: find minimum among between two values

1. Read original image (img) from input.
2. [cA cH cV cD]=IWT(img).
3. A = reshape(cD,2,N);
4. For i=1:N
x=B(1,i).
y=B(2,i).
l=floor((x+y)/2).
h=x-y.
5. If abs(2*h+ wi)<=min(2(255-l),2*l+1)
hh=2*h+w_i.
xx=l+floor((hh+1)/2).
yy=l-floor(hh/2).
B(1,i)=xx.
B(2,i)=yy.
6. End of If
7. End of for
8. AA = reshape(B).
9. img_wm =inverse IWT(cA,cH,cV,AA).
	1. Read watermarked image (img_wm) from input.
	2. [cA cH cV cD]=IWT(img_wm).
	3. A = reshape(cD,2,N);
	4. For i=1:N
	xx=B(1,i);
	yy=B(2,i);
	lll=floor((xx+yy)/2);
	hhh=xx-yy;
	ww_i= mod(double(hhh), 2);
	h_real=(hhh-ww(i))/2;
	xx=lll+floor((h_real+1)/2);
	yy=lll-floor(h_real/2);
	BB(1,i)=xx;
	BB(2,i)=yy;
	5. End
	6. BBB = reshape(BB);
	7. img_org= inverse IWT(cA,cH,cV,BBB,liftscheme);

Figure 3. Pseudocode for the proposed embedding and extraction processes

4. Experimental Results

In this part, the performance of the proposed invertible image watermarking technique based on IWT is evaluated. For this purpose, five images were selected including Lena, baboon, cameraman, Barbara,

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

(f)	(g)	(h)	(i)	(j)
39.53 dB	41.01 dB	40.55 dB	42.44 dB	40.43 dB

Figure 4. Original images of (a) Lena (b) baboon (c) cameraman (d) Barbara (e) pepper and the watermarked images of (f) Lena (g) baboon (h) cameraman (i) Barbara (j) pepper.

Table 1 presents the major criterion for the proposed image watermarking technique. As seen, the invisibility and capacity can fully meet. However, due to fragility nature of the proposed reversible watermarking technique, the watermark data always extracted with random nature.

Table 1. various watermarking factors for the developed image watermarking technique.

Image	PSNR (dB)	Capacity (b)	Avr BER (%)
Lena	39.53	6272	49

Baboon	41.01	6272	44
Cameraman	40.55	6272	54
Barbara	42.44	6272	59
Pepper	40.43	6272	55

Table 2 presents amount of different criterion for the developed reversible image watermarking technique. As seen, Mean Square Error (MSE) revealed that when there was no attack, the constructed images were exactly similar to original images. In addition, the amount of Peak to Signal Noise Ratio (PSNR) between original and constructed images were infinity which show prefect recovered images. However, under attacks, the proposed reversible image watermarking was behaved like fragile which can be inferred from the amount of Bit Error Rate (BER). Apart from these criterion, it can easily infer that the reversible image watermark is only applying for environment without any attack.

Table 2. Different factors for the developed reversible image watermarking technique.

Attack	**MSE**	**BER**	**PSNR**
No attack	0	0	∞
Salt and pepper noise	1.2397e+04	43	29.54
AWGN	1.1586e+04	45	23.23
JPEG	1.2386e+04	62	31.43
Rotation and scaling	1.2586e+04	23	33.34
Cutting	1.2576e+04	33	24.54
Filter	1.0126e+04	51	26.65

5. Discussion

Digital image watermarking induces undesired noise into the image. Therefore, some applications like face recognition cannot use

watermarking technology for its security. Although image enhancement techniques may have some improvements for the performance of face recognition for noisy face images, the facial and other important components of the image also be affected. Therefore, developing invertible image watermarking for these types of applications is required. In this paper, a novel invertible image watermarking technique is proposed that not only can carry the watermark but also, the original image can be retrieve from the watermarked image blindly. This algorithm can support multimodal biometric systems that are based on facial and watermarked data. For this purpose, fingerprint biometric information is embedded as a watermark data which is not degrade the facial biometric information due to invertibility feature in the nature of the proposed watermark.

6. Conclusions and Future Trends

This paper has been discussed the reversible image watermarking framework which is based on IWT and some reversible functions. To achieve this aim, couple of pixels have been used to carry the watermark data. Although watermarking can provide reasonable watermark's capacity and invisibility, it may degrade under intentional and unintentional attacks. Experimental results reveal that the proposed algorithm can properly compute the original image from the watermarked image when no attacks are taken place. Future trends in this work can be apply other transformation techniques such as DCT, FFT, and multi-resolution transformation to improve watermark invisibility and improve capacity.

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