Wavelet Packet and Hybrid Filter Based Digital Watermarking

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Abstract

In this paper, a new watermark algorithm that based on wavelet packet transform and hybrid filter is proposed for watermark of digital images, which include many high frequency components. The proposed watermark algorithm is used in the high frequency component of image and applies watermark to the overall subband that include the lowest frequency band. And the watermark is embedded on input image and hybrid filtering concept has been adopted to remove the noise that was added to the original image in watermark embedding stage. The quality of the watermarked image has been analyzed with PSNR. From the simulation results, the proposed algorithm shows better invisibility and robustness performance compare with conventional watermark methods. Especially, it demonstrates better robustness for high image compression in the remote sensing images application.

Keywords: watermarking, wavelet packet transform, hybrid filter

1. Introduction

Digital watermark denotes information that is imperceptibly and robustly embedded within still images or moving pictures to protect the copyright of digital multimedia data [1]. So watermarking in the wavelet domain allows precisely to control the location of the watermark, it is very useful in the invisibility and robustness aspect. In the wavelet transform based watermark technique, the watermark is embedded in the subband except the lowest frequency band [2]. However, because the image compression is usually lossy compression that eliminates all the high frequency components, the techniques that the watermark is embedded in the lowest frequency band for high image compression. But this elastic change by the watermark embedding in the lowest frequency band causes damages of the original image.

Because the high altitude images such as an aerial photograph and a satellite photograph are mainly composed by high frequency components, a new watermark algorithm, inserts watermark into all subband that include the lowest frequency band, is needed for robustness and invisibility [3-5].

To resolve this problem, wavelet packet based digital watermark algorithm is suggested in this research. So wavelet packet transform analyze adaptively signal of each frequency band contrary to wavelet transform which is recursively decomposed in the low frequency band, it is more suitable for non-stationary signal analysis such as texture image that is easily recognized in the remote sensing images. The wavelet packet transform shows better performance than the conventional wavelet transform in texture images. Because the large coefficients are abstracted from the lowest frequency band as well as high frequency bands after the wavelet packet transform, watermark can be embedded in the overall band without any quality loss of image and keep its robustness against lossy image compression.

In this paper, a new watermark that based on wavelet packet transform is proposed for satellite photograph or other images, which include many high frequency components.

This paper is organized as follows; In Section 2, a new algorithm for creating, embedding and detecting watermark is explained. The improvements of the proposed algorithm over the conventional algorithm are demonstrated by the experiment result in Section 3. Finally Section 4, the results are summarized, some technical issues are discussed, and some suggestions and further studies are discussed.

2. Proposed Technique

2.1. Watermark Creation

A binary image is used for watermark in this research. In general, a logo, seal or signature is used for watermark to prove copyright and these are presented as a binary image.

For the prevention of deformation or detection of watermark, a watermark is scrambled using pseudo-random sequence that has deterministic random characteristics and statistical measurements such as Equation (1).

$$w = \{w(k), k = 1, 2, \dots, L, L = M \times N\}$$
(1)

Where k is relocated by pseudo-random sequence and L is the size of binary image and w is binary image sequence for watermark.

2.2. Watermark Embedding

Early watermarks are embedded in the perceptually insignificant coefficient region for preventing recognition of their existence [4]. But these watermarks are easily damaged or eliminated by image compressions or other image processing techniques. On that account, watermark has to be embedded in the perceptually significant coefficient region and the significant coefficient selecting process has to be concerned for watermark embedding. Moreover, this watermark has to be embedded over full bands within the limit of original image quality for robustness. In the proposed algorithm in this research, watermark embedding process is composed as following sequences; the wavelet packet transform of original image, selecting the perceptually significant coefficients, watermark embedding and inverse wavelet packet transform.



Figure 1. Watermark Embedding Process

2.2.1. Wavelet Packet Transform of Original Image: First of all, input image is decomposed into wavelet packet using 9-7 tap biorthogonal filter and first-order entropy [6].

Figure 2 shows the 3-level wavelet packet decomposed boat image. In Figure 2, the image in low frequency subband is quite similar to original image because it is approximation of original image. The images in high frequency subband are edges in vertical, horizontal, diagonal direction and similar figures.

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Figure 2. Wavelet Packet Decomposition of Boat Image

Figure 3 shows the wavelet decomposed boat image.



Figure 3. Wavelet Decomposition of Boat Image

2.2.2. Watermark Embedding: Watermark is embedded to wavelet packet coefficient using Equation (2). Equation (2) is used for embedding watermark adaptively based on the selected wavelet packet coefficient. That is, in case of large wavelet packet coefficients, a large α value is embedded and in case of small wavelet packet coefficient, a small α value is embedded. The reason for this watermark embedding, generally, large value is insensible to quantity of addition compare with the small value.

$$\mathbf{v} = \mathbf{v}(1 + \alpha \mathbf{w}) \tag{2}$$

v is a selected coefficient to embedding watermark, w is a watermark and α is an embedding weight. The embedding weight for coefficient of the lowest frequency band, α , is set 0.04 and coefficient of other band is started form 0.01 and doubled. As a next stage, after watermark embedded coefficient is transformed by inverse wavelet packet transform, watermark embedded image is accomplished. Contrary to in the dyadic wavelet transform, the significant coefficients locate in each subband including high frequency band, so embedding this coefficients prevents the quality of the original image from degrading and brings a robust watermarking.

2.3. Watermark Detection

To detect the watermark is a reverse process of embedding process. That is, after wavelet packet transforms the watermark embedded image, watermark information is analyzed and abstracts watermark by pseudo-random sequence [7-8]. We use hybrid filter to extract the noise distortion that was added to the image in watermark embedding stage. This hybrid filter consists of the median filter and the wiener filter to reduce white Gaussian noise and impulse noise respectively. It efficiently removes Gaussian and impulse noise from digital images while preserving thin lines and edges in the original image [9-11].



Figure 4. Structure of Hybrid Filer

The criterion of detection is defined by comparing similarity between pre-abstract watermark and post-abstract watermark such as Equation (3).

$$Similarity(w, w^*) = \frac{w \times w^*}{\sqrt{2} + \sqrt{2}}$$
(3)

In the equation (3), w is watermark image, w* is abstracted watermark.

Especially, because a noise is not intensely inserted into logo or signature image as a watermark, after similarity between abstracted watermark and original watermark is smaller than 0.95, median filter is applied to abstracted watermark and recalculates similarity between two images.

3. Experimental Results

The proposed method has been tested with different gray-scale images, standard natural images and aerial photograph images. Figure 5 shows the original boat image of size 512 x 512 and Figure 6 shows satellite image (Carolina) of size 512 x 512 collected from www.spaceimaging.com web site. Satellite images are usually composed simplified and recursive geometrical structures such as rectangular, circles, lines and groups of points by high altitude view. Two-dimensional separable length 9-7 biorthonormal wavelet filters are used for wavelet packet decomposition. After apply coefficient-partitioning scanning order, wavelet packet coefficients are selected for watermark embedding.

Invisibility and robustness of watermark is used for measurement of performance in this research. PSNR is used for performance of the invisibility after embedding watermark. Similarity using Equation (3) is used for performance of the robustness. Other watermark algorithms, such as Xia [2] and Cox [6] are also used for comparing performance at the same condition with proposed algorithm.

International Journal of Multimedia and Ubiquitous Engineering Vol.10, No.10 (2015)



Figure 5. Boat Image



Figure 6. Satellite image (Carolina)

3.1. Invisibility

As shown in the two figures, it is impossible to distinguish in perceptually whether watermark is embedded in these images.



Figure 7. Watermark Embedded Boat Image



Figure 8. Watermark Embedded Carolina Image

After embedding watermark to original images, PSNR are calculated for observing image distortion as shown in Table 1. From PSNR in the Table 1, damages of image qualities are not recognized after applying the proposed algorithm for watermark.

3.2. Robustness

JPEG and conventional wavelet image compression are applied to proposed watermark-embedded image for robustness check against image compression.

$$PSNR(I,I2) = 20 \log_{10}\left(\frac{255}{MSE}\right) \tag{4}$$

Where *MSE* is the Mean Squared Error given by:

$$MSE = \frac{1}{N^2} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} [I(i,j) - I_2(i,j)]^2$$
(5)

Where N is width and height of compared images.

	boat	carolina
Cox	40.01	38.78
Xia	41.33	38.97
Proposed method	43.16	42.65

Table 1. The PSNR (dB) of Watermark Embedded Images

JPEG is used for image compression in this experiment. Experimental result of robustness is shown in Table 2. As shown in Table 2, over 90% of watermark image is survived from high image compression.

JPEG	boat	carolina
15%	0.941858	0.904107
25%	0.974293	0.961222
50%	0.993020	0.981180
75%	1.000000	0.996113

Table 2. Similarity of JPEG Lossy Compression

4. Conclusions

In this paper, a new watermarking algorithm is proposed using wavelet packet transform and hybrid filter. The proposed watermark algorithm is used in high frequency component of image and apply watermark to the overall subband that include the lowest frequency band. And the watermark is embedded on original image and hybrid filtering has been adopted to remove the noise.

From the experimental result, the proposed algorithm shows better invisibility and robustness performance with comparing with conventional watermark methods. Especially, it demonstrates better robustness for high image compression in the remote sensing images such as aerial photos.

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International Journal of Multimedia and Ubiquitous Engineering Vol.10, No.10 (2015)