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A New Digital Watermarking Algorithm Based On WBCT

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Abstract

The paper presents an imperceptible and robust digital watermarking algorithm using wavelet-based contourlet transform (WBCT), The WBCT can give the anisotropy optimal representation of the edges and contours in the image by virtue of the characteristics of multi-scale framework and multi-directionality. The proposed algorithm takes advantage of the significant texture information of the image to find the embedding watermarking position. Experimental results show the validity of the proposed algorithm in terms of both the watermarking invisibility and the watermarking robustness. In addition, the comparison experiments prove the high-efficiency of the proposed method . The paper presents an imperceptible and robust digital watermarking algorithm using wavelet-based contourlet transform (WBCT), The WBCT can give the anisotropy optimal representation of the edges and contours in the image by virtue of the characteristics of multi-scale framework and multi-directionality. The proposed algorithm takes advantage of the significant texture information of the image to find the embedding watermarking position. Experimental results show the validity of the proposed algorithm in terms of both the watermarking invisibility and the watermarking robustness. In addition, the comparison experiments prove the high-efficiency of the proposed method.

keywords: Digital image watermarking;Wavelet-based contourlet transform (WBCT);Multi-directionality;Texture information

1. Introduction

Image watermarking is the process of embedding the ownership imformation into host data so that intellectual copyrights can be identified. Along with the rapid growth of novel watermarking schemes,

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various attacking attempts have also been developed to destroy watermarking[1]. Such attacks as median filtering,compression, noise, and cropping, can easily make most of existing watermarking schemes ineffective. This is mainly due to the fact that slight manipulation for the marked image could desynchronize the location of the watermark and cause incorrect watermark detection. In other words, the detection or extraction of the watermark requires a synchronization step to locate the embedded mark in the content. Recent contributions have shown that image adaptive watermarking schemes can be successfully implemented by changing some coefficients of transform domain, commonly used frequency-domain watermarking schemes are the discrete cosine transform (DCT)[2], the discrete wavelet transform (DWT)[3,4,5]. These watermarking schemes embed watermark into a certain scale subbands in transform domain, thus they can resist the attack of a particular kind of image processing . But these transforms have their own limitations in capturing the directional information such as smooth contours and edges of the image. This drawback is addressed by Discrete Contourlet Transform (CT) [6] proposed by Do et al.The Contourlet transform is a directional multiresolution expansion which can represent the images that contain contours efficiently. However, due to the redundancy of the Laplacian pyramid, the contourlet transform has a redundancy factor of 4/3 ,and hence some approaches have been attempted to introduce non-redundant image transforms. Eslami and Radha proposed a new non-redundant image transform[7], the Wavelet-Based Contourlet Transform (WBCT),with a construction similar to the contourlet transform. The proposed WBCT achieves both radial and angular decomposition to an arbitrary extent and obeys the anisotropy scaling law. Compared to the aforementioned DFB-based non-redundant transforms, the WBCT can easily be realized by applying DFB on the wavelet coefficients of an image.

In this paper, in order to achieve better robustness specially against common image manipulations and geometrical attacks , we propose a novel image watermarking scheme using WBCT. The watermarking imformation is done by altering the WBCT coefficients representing the largest energy of the image ,which are carefully selected according to the directional decomposition of texture features of the image. The idea of applying WBCT is based on the fact that WBCT with capable of capturing the directional edges and contours superior to discrete wavelet transform (DWT) could favor the orientation of embedded watermarking imformation, so that effective watermarking approach could be acquire. Simulation results demonstrate that the proposed watermarking algorithm are invisible and very robust against image processing and common geometric attacks.

2. The Wavelet-based Contourlet Transform

The contourlet transform based on a multiscale and multidirectional filter bank developed by Do and Vetterli, is one of the new geometrical image transforms,which can capture nearly arbitrarily directional information of the natural images.It has been shown to be a better alternative choice than wavelets for image denoising This transform consists of two major stages: the subband decomposition and the directional transform. At the first stage, Laplacian pyramid (LP) is employed, while directional filter banks (DFB) are used for the second stage. But,the contourlet transform is a redundant image transforms due to LP.The Wavelet-Based Contourlet Transform(WBCT) developed by Eslami and Radha , with a construction similar to the contourlet is a new non-redundant image transform.It also consists of two filter bank stages:the first stage provides subband decomposition using wavelet transform rather than the Laplacian pyramid; The second stage of the WBCT is a directional filter bank (DFB), which provides angular decomposition. At each level in the wavelet transform of the first stage, the image is decomposed into LF subband and three HF subband(corresponding to the LH, HL, and HH) by wavelet transform; Then, each HF subband is decomposed into the number of direction subbands by the DFB in a given level.Start from the desired maximum number of directions on the finest level of the wavelet transform, and decrease the number of directions at every other dyadic scale when proceeded through the coarser levels.By means of this way, the anisotropy scaling law is achieved.Moreover the wavelet filters are not perfect in splitting the frequency space to the lowpass and highpass components, the scheme using fully DFB decomposition on each band could compensate for the drawbacks of the wavelet filters. Fig.1 shows the flowchart of WBCT for a 512×512 image. The HF subband images from the WT are processed by the DFB so that the directional information can be captured. The scheme can be iterated the LF subband image over. The WBCT decomposes the image into directional subbands at multiple scales.

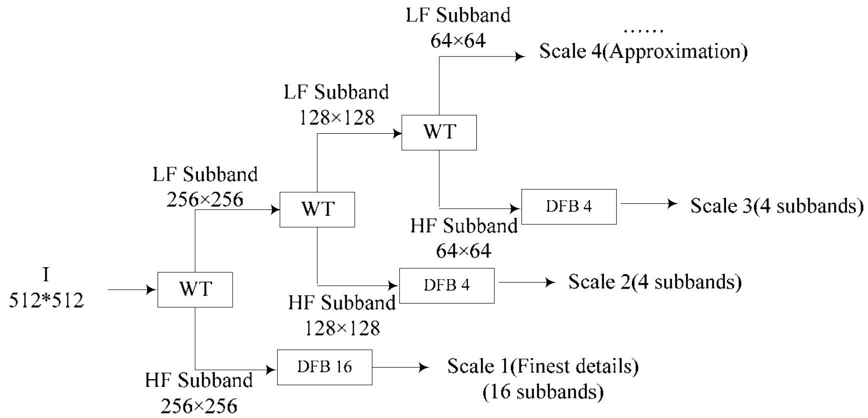

Fig. 1 Flowchart of WBCT for a 512×512 Image.

By analyzing, we find that WBCT can capture image structure features more efficiently than Discrete Wavelet Transform(DWT) and be more suitable to identify the subbands in the host image where a watermark can be embedded effectively. Considering a watermarking scheme that embeds watermark into HF subbands, which watermark will be removed easily when the watermarked image is attacked by image processing methods destroying the HF information of the image;While watermark is embedded in LF subbands which may make the scheme easily perceptible.In order to ensure the visual quality and robustness of the image which watermark is embedded into, the watermark should be embedded into the low-middle frequency subbands in our scheme. It is well known that even after the wavelet decomposition, there still exists some correlation between the wavelet coefficients, especially those corresponding to the same spatially local region at the same scale. This correlation between the coefficients corresponding to different frequencies but the same spatial location could be removed based on the Directional Filter Banks (DFB) technique and the energy of the image could be further concentrated, leading to an embedding domain that permits the embedding of larger watermark energy, which in turn lead to better perceptual transparency and getting improved robustness.

In the paper, applying 3 directions of DFB to all the HF subbands in the 1st and 2nd levels , a 2×2 block coefficients of one direction subband in the first level correspond to one coefficient in the same spatial location in the second level subbands.Embedding watermark is carried out by modifying coefficients in second level according to the energy of texture features of the image.This approach makes the watermark less visible and more robust to some common image processes than embedding watermark in only Wavelet or Contourlet domain.

3. Watermark Embedding and Extraction

3.1. Embedding Procedure

The WBCT provides a multiscale and multidirectional representation of an image. It is easily adjustable for detecting fine texture detail in any orientation at various scale level. Imperceptibility of the watermarking algorithm is commonly achieved by exploiting the weaknesses of the HVS. For this purpose, We firstly apply DFB8 to each HF subband, then calculate the energy of the coefficients of all the 2×2 blocks in each directional subband of the finest scale, we choose the position in the second scale corresponding to 2×2 block with the highest energy in all the directional subbands of the first level to embed watermark. By this way, we can hide the watermark information into the most significant direction of the position.

Steps of embedding algorithm are as follows:

- The host image is carried out two-dimensional decomposition of two layers DWT, namely it is first decomposed into LL_1, HL_1, LH_1 and HH_1,Secondly, LL_1 is decomposed into LL_2, HL_2, LH_2 and HH_2;
- DFB 8 is performed on the six subbands in the first and second level ($HL_1, LH_1, HH_1, HL_2, LH_2, HH_2$).Then, each subband is decomposed into 8 directional subbands by DFB.Notice that one coefficient in the second level correspond to a 2×2 block in the first level;
- The watermark w can be arranged as a set of matrices $w(i, j)$ with the pseudo-random binary values $\{-1, 1\}$ and the size $M \times M$;
- Calculate the energy of each 2×2 block in the first level, and choose the $M \times M$ highest energy blocks. Depending on these blocks, we can modify the corresponding coefficients in the second level based on the following strategy (Eq.(1))to embed the watermark w;

$$C'_{i \times M + j} = \begin{cases} C_{i \times M + j} \times f_1(i, j) & \text{if} \quad w(i, j) = 1 \\ C_{i \times M + j} \times f_0(i, j) & \text{else} \quad w(i, j) = -1 \end{cases} \qquad (1)$$

where $\boldsymbol{f_0(i,j)}, \boldsymbol{f_1(i,j)}$ are strength functions which are selected to be monotonous exponentially functions, $\boldsymbol{C_{i \times m+j}}$ represents the $\boldsymbol{i}^{th}$ row and $\boldsymbol{j}^{th}$ col coefficient selected to embed watermark bit. To get the best performance, we modified Eq.(9) and Eq.(10) in reference [8] as follows:

$$f_1(i, j) = -0.5e^{-0.3|C_{i \times M+j}|} + 1.5 \qquad (2)$$

$$f_0(i, j) = 0.25e^{-0.3|C_{i \times M+j}|} + 0.75 \qquad (3)$$

$\boldsymbol{f_0(i,j)}$ is the exponentially descending function for $\boldsymbol{w(i,j)}<0$ which is smaller than one and $\boldsymbol{f_1(i,j)}$ is the exponentially ascending function for $\boldsymbol{w(i,j)}>0$ which is larger than one. These functions are selected exponentially in order that larger coefficients changes more than smaller ones during the watermarking procedure, as the larger coefficients are related to the strong edges in the supposed directional subband.

- Apply inverse DFB 8 on the modified DFB subbands to obtain the changed wavelet coefficients;
- Inverse WT is applied to the modified subbands and the final watermarked image is achieved.

3.2. Extraction Procedure

The watermark extraction is the inverse process of watermark embedding. The test image is 2-levels WT decomposed, then DFB 8 is applied, the procedure is described in details as the following steps:

- Perform WT on the test image to decompose it into six nonoverlapping multiresolution subbands:$HL_1, LH_1, HH_1, HL_2, LH_2, HH_2$;
- Apply 8 directional DFB to each subband which is $HL_1, LH_1, HH_1, HL_2, LH_2$ and HH_2;
- Calculate the energy of each 2×2 block in the first level;and choose the $M \times M$ highest energy blocks.

- Compare those coefficients in the position which is related to those larger energy blocks. For the two coefficients, calculate with Eq.(4) to achieve watermark *w'*.

$$w'(i,j) = \begin{cases} 1 & \text{if} \quad (|C_t| - |C_o|) \le \sigma \\ 0 & \text{else} \end{cases} \tag{4}$$

where σ is a very small threshold, C_t represents the coefficient of the test image, C_0 express the coefficient of the host image.

- Compute by Eq.(5) the similarity between the original and extracted watermarks.

$$\rho(w, w') = \frac{\sum_{i=0}^{M}\sum_{j=0}^{M} w(i,j) * w'(i,j)}{\sqrt{\sum_{i=0}^{M}\sum_{j=0}^{M} w(i,j)}\sqrt{\sum_{i=0}^{M}\sum_{j=0}^{M} w'(i,j)}} \tag{5}$$

4. Experimental Results

To validate the invisibility and the robustness of our proposed scheme, we perform several experiments on three images with size of 512×512 (Barbara ,Baboon and GoldHill) and simulated some image processing operations, which may remove the embedded watermark. The 9/7 bi-orthogonal filters are used for 2 levels multiresolution filtering , every directional subband of each scale are decomposed eight directional subbands by DFB. In the paper, 1024 watermark bits are embedded into the coefficients selected in the host image. The performance of the watermarking methods under consideration is investigated by measuring their imperceptible and robust capabilities. For the robust capability, the correlation values (ρ) measures the difference between an original watermark *w* and the corresponding extracted watermark *w'*.

Table 1. Comparison of Correlation Coefficient Value(ρ) of Various Attacks for Different Algorithms

Attack	Ref [4]	Ref [9]	The proposed method	Attack	Ref [4]	Ref [9]	The proposed method
JPEG compression 30	0.9072	0.9564	0.9918	Rotation(5°)	0.6548	0.7371	0.8964
JPEG compression 60	0.9153	0.9428	0.9656	Rotation(10°)	0.5413	0.6758	0.8365
Low pass filtering 3×3	0.9393	0.9549	0.9786	Rotation(20°)	0.5548	0.6598	0.6744
Gaussian filtering 3×3	0.9199	0.9466	0.9711	Scaling(0.9)	0.6285	0.7621	0.7747
Median filtering 3×3	0.3557	0.4302	0.5545	Scaling(1.1)	0.5346	0.6156	0.6328
Weiner filtering	0.2119	0.3691	0.3076	Cropping(20×20)	0.9326	0.9782	0.9867
Alpha mean	0.8949	0.9019	0.9132	Cropping(200 col)	0.9532	0.9895	0.9961
Salt and pepper noise (0.01)	0.9193	0.9745	0.9807	Random cropping(20×20)	0.5324	0.5378	0.5125
Gaussian noise(10)	0.9087	0.9491	0.9657	Row column copying	0.9674	0.9899	0.9983
Sharpening	0.3418	0.6309	0.6137	Translation(10 ×10)	0.9932	0.9915	0.9982
Blurring	0.2186	0.4736	0.3485	Gamma correction	0.5302	0.5010	0.3411
Dilation	0.3684	0.5451	0.4500	Histogram equalization	0.9565	0.9386	0.9236

The correlation values (ρ)of extracted watermarks are shown in Table.1. All the results are obtained by averaging over 3 runs with 3 different host images. Various attacks used to test are JPEG compression, low pass filtering, Gaussian filter ,median filtering, Weiner filtering , Alpha mean , salt & pepper noise, gaussian noise sharpening, blurring, dilation, cropping, rotating, scaling,row column copying, gamma correction and histogram equalization. We tested and compared the robustness to various attacks of the proposed method with other watermarking schemes, We can see that the robustness of our method against 17 attack are considerably better than Wavelet-based method (reference [4]) and Contourlet-based method (reference [9]).

5. Conclusion

This paper describes a new adaptive digital watermarking method based on the wavelet-based contourlet transform(WBCT). For the WBCT has a high potential for texture analysis application,and concentrates the image's energy in the limited number of edge coefficients, this method can take advantage of the significant texture information of an image to find the embedding watermarking position.The Experimental results show that the proposed method is an excellent robustness to various attacks and preserves high perceptual quality of the watermarked image.

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