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A Contourlet-Based Image Watermarking Scheme with Removal and Geometrical Attacks

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Abstract – We propose a new multiresolution watermarking method for still images based on the contourlet transform (CT). In our approach, the watermark is a grayscale image which is embedded into the highest frequency sub band of the host image in its contourlet domain. We demonstrate that in comparison to other methods, this method enables us to embed more amounts of data into the directional subbands of the host image without degrading its perceptibility. The experimental results show robustness against several common watermarking attacks such as compression, adding noise, filtering, and geometrical transformations. Since the proposed approach can embed considerable payload, while providing good perceptual transparency and resistance to many attacks, it is a suitable algorithm for fingerprinting applications.

Key Words: Demonstrate, Multiresolution, Fingerprinting

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INTRODUCTION

Recent rapid growth of distributed networks such as Internet enables the users and content providers to access, manipulate, and distribute digital contents in high volumes. In this situation, there is a strong need for techniques to protect the copyright of the original data to prevent its unauthorized duplication. One approach to address this problem involves adding an invisible structure to a host media to prove its copyright ownership. These structures are known as digital watermarks. Digital watermarking is performed upon various types of digital contents such as images, audio, text, video, and 3D models. It is applied to many applications, such as copyright protection, data authentication, fingerprinting, and data hiding [1]. Current methods of watermarking images, depending on whether the original image is used during watermark extraction process or not, could be divided into two categories: blind and non-blind methods. Schemes reported in [2, 3] are nonblind methods, while the methods in [4–9] are categorized as blind methods.

REVIEW OF LITERATURE

Most of the reported schemes use an additive watermark to the image in the spatial domain or in frequency domain. Recent works on digital watermarking for still images are applied on frequency domain.

Among the transform domain techniques, discrete wavelet transform-(DWT-) based techniques are more popular, since DWT has a number of advantages over other transforms including space-frequency localization, multiresolution representation, superior HVS modeling, linear complexity, and adaptivity [10]. In general, the DWT algorithms try to locate regions of high frequency or middle frequency to embed information, imperceptibly [11]. Even though DWT is popular, powerful, and familiar among watermarking techniques, it has its own limitations in capturing the directional information such as smooth contours and the directional edges of the image. This problem is addressed by contourlet transform (CT) [12]. The contourlet transform was developed as an improvement over wavelet where the directional information is important. In addition to multiscale and time-frequency localization proprieties of wavelets, CT offers directionality and anisotropy.

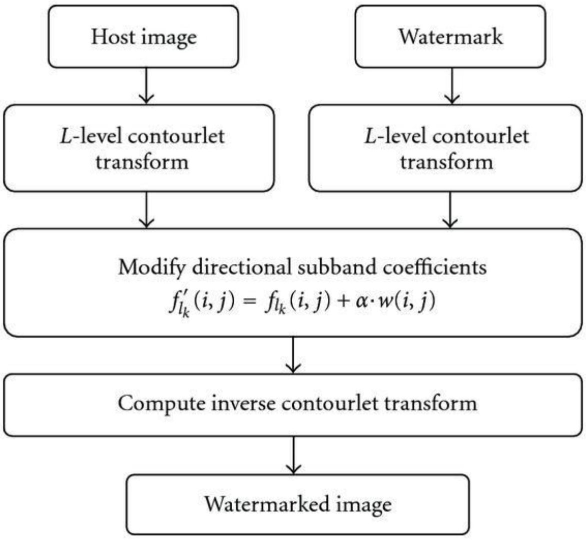
Zaboli and Moin [2] used the human visual System characteristics and an entropy-based approach to create an efficient watermarking scheme. It decomposes the original image in CT domain in four hierarchical levels and watermarks it with a binary logo image which is scrambled through a well-known PN sequence. They showed adding a scrambled watermark to high-pass coefficients in an adaptive way based on entropy results in a high performance detection capability for watermark extraction.

MATERIAL AND METHOD

Watermark Embedding Technique

In the proposed algorithm, the watermark which is a grayscale image, with as much as 25% of the host image size, is embedded into the gray level host image of size $N \times N$. The host image and the watermark are transformed into the contourlet domain. Then, the CT coefficients of the last directional subband of the host image are modified to embed the watermark. The steps involved in watermark embedding are shown in Figure. We use $f(i,j)$ to denote the host image, $f'(i,j)$ the watermarked image, and $w(i,j)$ the watermark. The technique is comprised in three main steps as discussed below.

Figure Embedding algorithm.



The host image $f(i,j)$ of size $N \times N$ and the watermark $w(i,j)$ of size $N/2 \times N/2$ are transformed into the CT domain. An "n" level pyramidal structure is selected for LP decomposition. At each level l_k, there are 2^{l_k} directional subbands, where $k = 1,2,3,\ldots,n$. The highest frequency subband of the host image is selected for watermark embedding. Watermark decomposition results in two subbands w_1, w_2 and a lowpass image. Since w_1 and w_2 have the same resolution, therefore we choose one of them, in addition to the lowpass image for watermark embedding.

The coefficients of the selected subband are modified as follows [17]:

$$f'_{l_k}(i,j) = f_{l_k}(i,j) + \alpha \cdot W(i,j), \quad (2)$$

Where $f'_{l_k}(i,j)$ represents lth level, kth directional subband coefficients, and α is a weighting factor which controls robustness and perceptual quality. Inverse contourlet transform (ICT) is applied by considering the modified directional subbands to obtain the watermarked image.

Watermark Extraction Process

For retrieving the watermark, we need a copy of the original image as a reference. By using the inverse embedding formula (3), we can extract the embedded watermark

$$w'(i,j) = \frac{f'_{l_k}(i,j) - f_{l_k}(i,j)}{\alpha}, \quad (3)$$

The extraction process consists of the following steps.

Both watermarked and original images are transformed into CT domain.

The directional subband and the lowpass image of the embedded watermark will be retrieved by subtracting the highest frequency subbands of the original and the watermarked image by using (3).

For reconstructing the watermark, Laplacian Pyramid requires both directional subbands (W_1,W_2) and the lowpass image (L). Instead of inputting (L,W_1,W_2) we input (L,W_1,W_1) into the LP.

The watermark extraction process is summarized in Figure 7.

Figure Extraction algorithm.

By increasing the levels of decomposition, the watermarking capacity is also increased, and the quality of extracted watermark is improved. In order to achieve this goal, after selecting a subband, we can use other directional subbands which have the highest level of energy. The watermarked image quality is measured by the PSNR between f and f', formulated by

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{255^2}{\mathrm{MSE}}\right)(\mathrm{dB}),$$

$$\mathrm{MSE} = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j) - f'(i,j))^2. \quad (4)$$

To evaluate the performance of watermark retrieval process, normalized correlation (NC) is used. Here, W_1 and W_2 are the original and recovered watermark signals, respectively. The normalized correlation is calculated by

$$NC = \left(\frac{\sum_{i=0}^{M} \sum_{j=0}^{N} w_1(i,j) \cdot w_2(i,j)}{\left(\sqrt{\sum_{i=0}^{M} \sum_{j=0}^{N} w_1(i,j)^2} \right) \cdot \left(\sqrt{\sum_{i=0}^{M} \sum_{j=0}^{N} w_2(i,j)^2} \right)} \right). \quad (5)$$

We have performed experiments with various watermarks and popular host images such as Lena, Barbara, Baboon, Cameraman, City, Couple, Man, Boat, Elaine, Peppers, and Zelda of size 512×512. The watermark is a grayscale fingerprint (.bmp) of size 128×128, which contains lots of curves and significant details. Therefore, it can be a perfect criterion for measuring the performance of the proposed method. In addition, it can be used in fingerprinting applications. In (2), α was set to 0.1 to obtain a tradeoff between perceptibility and robustness. In both LP and DFB decomposition, "PKVA" filters [18] were used because of their efficient implementation. We decomposed the host image into four levels, and the watermark into one level.

WATERMARK INVISIBILITY

Figures 8(a) and 8(b) provide the comparison between the original Lena test image and its corresponding watermarked image.The original watermark and the extracted watermark are also shown in Figures 8(c) and 8(d), respectively. The results of embedding data in the highest frequency subband of the host image are shown

Figure

(a) Lena image. (b) Watermarked image. (c) Original watermark. (d) Extracted watermark.

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Our experiments on the test images showed that the 16th directional subbands have the highest priority for watermark embedding. The results of embedding the watermark in the 16th directional subbands of the host images were as follows. The watermark invisibility can be guaranteed at average PSNR value of 46.96 dB for all the test images due to their similar characteristics and the NC value of 0.9862 for all the extracted watermarks except for the Man image, for which the PSNR and NC values were 47.09 and 0.9838, respectively.

CONCLUSION

The results of hiding more amounts of data into the highest and other directional subbands of the Lena test image are shown in Table 2. The PSNR and NC values for other subbands are also shown in columns 2 and 3 of the same table, respectively. We used the 1st and the 4th directional subbands that have the highest level of energy after the 16th subband. In addition to embedding the watermark into the 16th directional subband, we hide another version of the watermark into the 1st and the 4th subband, and thus we could embed 34 KB of data into the host image without degrading its perceptual quality. Embedding the watermark in other subbands with lower energy than a given threshold will result in perceptual distortion in the watermarked image. Table 3 shows the results of embedding data in the Lena test image with different sizes. The size of the watermark is 25% of the size of the host image.

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