DIGITAL WATERMARKING IN WAVELET TRANSFORM DOMAIN

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Abstract

This paper presents a technique for the digital watermarking of still images based on the wavelet transform. The watermark (binary image) is embedded into original image in its wavelet domain. The original unmarked image is required for watermark extraction. The method of embedding of digital watermarks in wavelet transform domain was analysed and verified on grey scale static images.

Keywords

Wavelet transform, digital watermarking

1. Introduction

Digital representations of copyrighted material such as movies, songs, and photographs offer many advantages. However, the fact that an unlimited number of perfect copies can be illegally produced is a serious threat to the rights of content owners. Until recently, the primary tool available to help protect content owners' rights has been encryption. Encryption protects content during the transmission of the data from the sender to receiver. However, after receipt and subsequent decryption, the data is no longer protected and is in the clear. Watermarking complements encryption. A digital watermark is a piece of information that is hidden directly in the media content, in such a way that it is imperceptible to a human observer, but easily detected by a computer. The principal advantage of this is that the content is inseparable from the watermark [1].

They are some ways to watermark embedding into image information. One of the possible method is using of discrete wavelet transform for watermark embedding into an image. In this paper is presented an algorithm of digital watermarking in wavelet domain.

2. Digital Watermarking

A watermark is hidden information within a digital signal. For the watermarking several techniques have been developed. Watermarking technique can be divided into two main groups:

- spatial domain watermarking,
- frequency domain watermarking.

Techniques that work in spatial domain can suffer from signal compression and hostile attacks [2]. Frequency domain techniques are much more robust against compression and geometrical transformations than spatial domain techniques. Nevertheless, one weakness for may spatial frequency approaches is that the human visual system is not taken into account when selecting positions to insert the watermark. Because of the invisibility constraint of a watermark, these techniques have to use signals of relatively lower power than would otherwise be possible, to avoid degrading the image quality, inevitably limiting the robustness of the watermark [2].

Proposed properties were shown that for watermarked media several requirements must be satisfied [6],[7]:

- Imperceptibility – the watermark should be imperceptible, not to affect the viewing experience of the image or the quality of signal.
- Undeleting – the watermark must be difficult or even impossible to remove by a hacker, at least without obviously degrading the host signal.
- Statistically undetection – A pirate should not be able to detect the watermark by comparing several watermarked signals belonging to the same author.
- Robustness – The watermark should be survive by the using of the lossy compression techniques and signal processing operations (signal enhancement, geometric image operations, noise [8], filtering [9], etc.).

Robustness is crucial to the success of watermark embedding. To achieve an imperceptible watermarking is not difficult by minor modification of the host data. Making the watermark indestructible, however, is not a trivial problem.

The process of image watermarking can be represented by the addition of a noise term that is a function of the watermark signal, *w*, and possibly of the original image, *I*. Watermarked image, *I'*, can be created in wavelet transform domain. When an image undergoes wavelet decomposition, its components are separated into bands of approximately equal bandwidth on a logarithmic scale much as the retina of the eye splits an image into several components. It is, therefore, expected that use of discrete wavelet transform will allow the independent processing of the resulting components much like the human eye.

The algorithm of embedding of digital watermark in frequency domain, in generally is shown on Fig. 1.

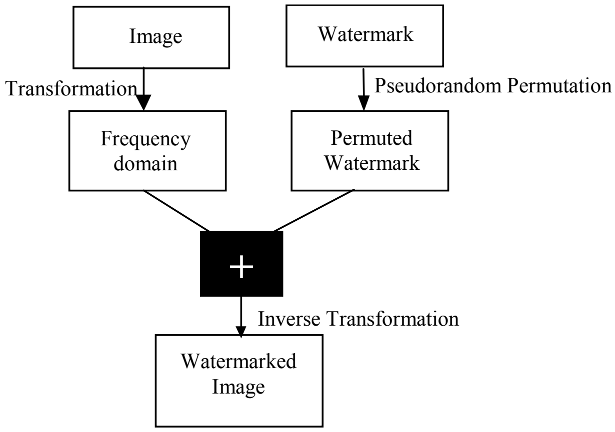

Fig. 1 Process of digital watermarking in frequency domain

For watermark extraction is needed watermarked image and also the original image. Than the process of watermark extraction can be realized by following Fig. 2.

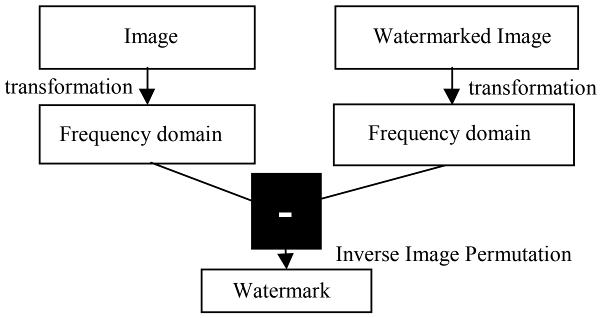

Fig. 2 Process of watermark extraction

3. Wavelet transform

Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. The idea is not new. Approximation using superposition of functions has existed since early 1800's , when Joseph Fourier discovered that he could superpose sines and cosines to represent other functions. However, in wavelet analysis, the scale that we use to look at data plays a special role. Wavelet algorithms process data at different scales and resolutions. If we look at a signal with a large "window", we would notice gross features. Similarly, if we look at a signal with a small "window", we would notice small features. The result in wavelet analysis is to see both the forest and the trees.

The wavelet transform is a linear transform that generalizes the properties of the Haar transform. A wavelet, in the sense of the Discrete Wavelet Transform (DWT), is an orthogonal function, which can be applied to a finite group of data [4]. Wavelets are functions that satisfy certain requirements [5]

- localized in time and frequency,
- integrate to zero,
- quick and easy calculation of the direct and inverse wavelet transform.

They are various wavelets: Haar, Coiflet, Daubechie, etc. Whereas the basis function of the Fourier transform is a sinusoid, the dyadic wavelet basis is a set of function which are defined by a recursive difference equation

$$\phi(x) = \sum_{k=0}^{M-1} c_k \phi(2x-k) , \tag{1}$$

where M is the number of nonzero coefficients. The value of coefficients is determined by constraints of orthogonality and normalization.

Wavelet transform uses wavelets as basis and is a tool that cuts up data or functions or operation into different frequency components, and then studies each components with a resolution matched to its scale [5].

The discrete representation of fast wavelet transform is used for image processing. DWT is defined by

$$F(j,k) = 2^{-\frac{j}{2}} \sum_{\forall i} f(i)\phi\left(2^{-j} i - k\right) \tag{2}$$

inverse DWT is defined by

$$f(i) = \sum_{\forall j} \sum_{\forall k} F(j,k) 2^{-\frac{j}{2}} \phi\left(2^{-j} i - k\right) \tag{3}$$

where $i, j,$ and k are integers.

The 2D algorithm is based on separable variables leading to prioritising of x and y directions, and scaling function is defined by

$$\phi(x,y) = \phi(x)\phi(y) . \tag{4}$$

The wavelet decomposition of original image I is shown on the Fig. 3.

The original image is decomposed by the lowpass (LP) and highpass (HP) filters followed by downsampling first of rows and then of columns. The result of wavelet decomposition is approximation of original image and three detail signals (horizontal, vertical and diagonal). Process of wavelet decomposition can be expressed in the following form

$$cI_j = cI_{j+1} + cD_{j+1}^{(h)} + cD_{j+1}^{(v)} + cD_{j+1}^{(d)} \tag{5}$$

The next step is decomposition of cI_{j+1} and so on. After j decomposition steps we obtain decomposed image in the next form ($j=2$, see Fig. 4).

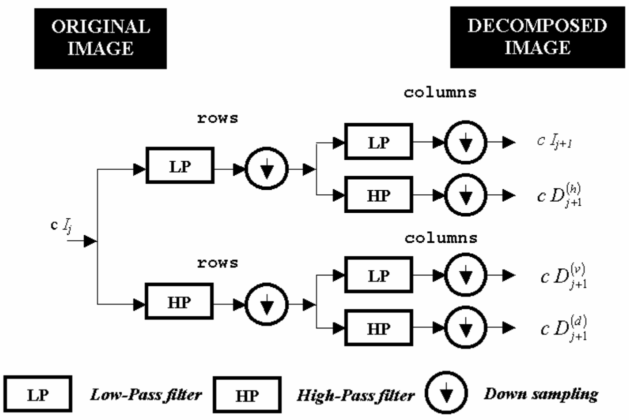

Fig. 3 Wavelet decomposition of image

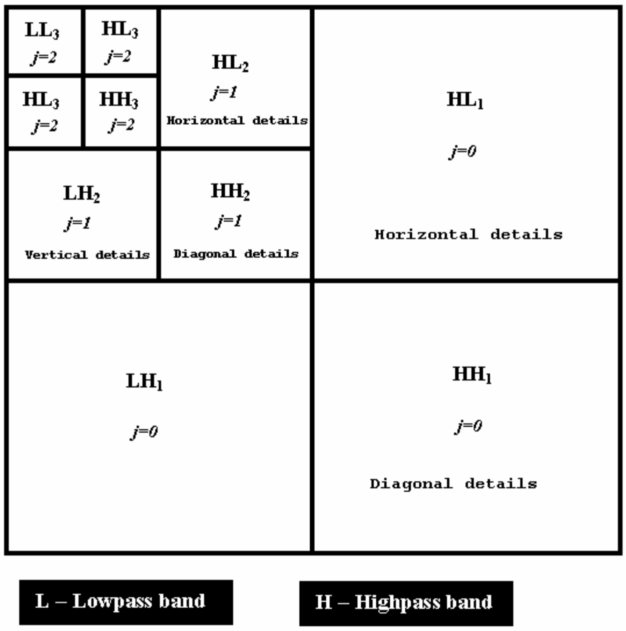

Fig. 4 Example of wavelet decomposed image

The process of image reconstruction is shown in Fig. 5.

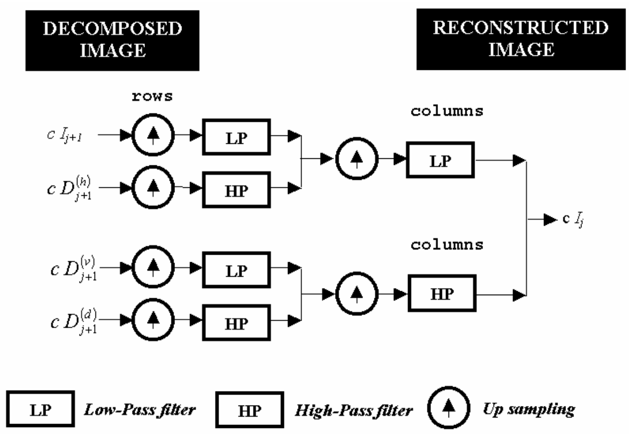

Fig. 5 Image reconstruction

4. Wavelet based Watermarking

Watermarking in the DWT domain consists of encoding and decoding parts.

In the encoding part, we first decompose an image into wavelet frequency domain and we obtain decomposed image. Image permuted watermark we add to obtained image decomposition. The watermark permutation is reversible and it is key for correct watermark extraction. For each coefficient within the wavelet domain, the key has a corresponding value of one or zero (if watermark is an binary image) to indicate if the coefficient is to modify or not. Note that watermarks are not inserted into the LH1, HL1 and HH1 bands (where L denotes the lowpass band and H denotes the highpass band), because the energies in these bands are relatively small.

In decoding part, we then take the two-dimensional (2D) inverse DWT (IDWT), obtaining the watermarked image *I'*.

5. Experiments

Our experiments we have realized on static gray-scale image Einstein in *.pgm format. As a watermarks were employed binary images that are shown in following figures (Fig. 6, Fig. 7).

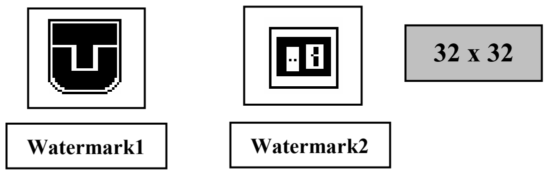

Fig. 6 Employed watermarks

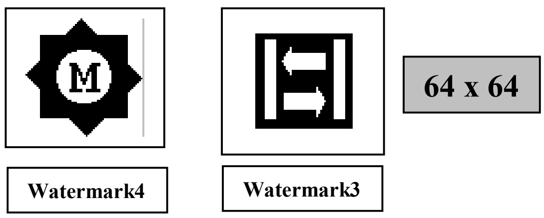

Fig. 7 Employed watermarks

In our experiments, the two-level DWT is employed for watermarks with size 64x64, in which an image is decomposed into 7 subbands, and for watermarks with size 32x32 was used three-level DWT, in which an image is decomposed into 10 subbands.

Quality of watermarked image was analyzed with objective and subjective criteria of image quality. As objective criteria of image quality was used Peak –Signal –to – Noise Ratio defined as following relation (6)

$$PSNR = 10\log_{10}\frac{255^2}{\left(\frac{1}{N_1.N_2}\right)\sum_{i=1}^{N_1}\sum_{j=1}^{N_2}\left(I(i,j)-I'(i,j)\right)^2} \quad (6)$$

Experimental results are shown in following Tab. 1, and an example of watermarked image is shown on Fig. 8.

	PSNR [dB]
Watermark1 (32 x 32)	60,33
Watermark2 (32 x 32)	55,97
Watermark3 (64 x 64)	50,89
Watermark4 (64 x 64)	50,36

Tab. 1 Experimental results

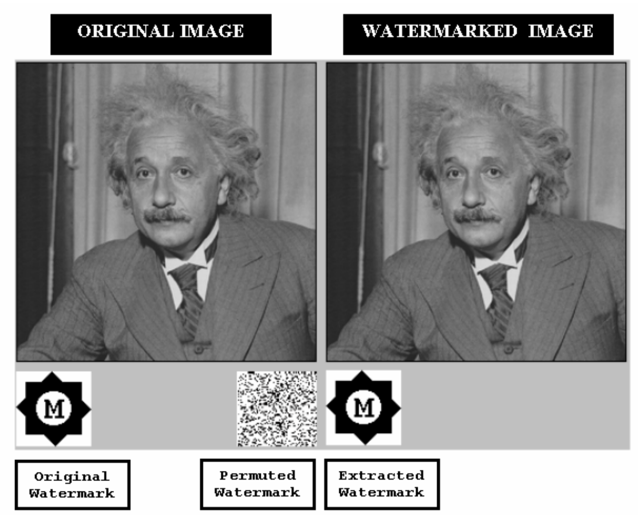

Fig. 8 Example of watermarked image

6. Conclusions

Digital watermarking of still images based on the wavelet transform is a good method for authentication of image materials. The using of wavelet transform satisfies requirements for watermarked media. We demonstrate the investigation of image distortion on the relation between the original image and watermarked image. In proposed algorithm the original unmarked image is required for watermark extraction.

References

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