WATERMARKING IN IMAGE USING SLANTLET TRANSFORM

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Abstract

A watermarking scheme based on slantlet transform, an orthogonal discrete wavelet transform with two zero moments and with improved time localization, is presented in this paper. The watermark is embedded into mid band frequencies of slantlet coefficients in the transform domain, which leads to very small distortion and guarantees the visual quality of the watermarked image. The performance of the proposed algorithm is compared with embedding watermarking system using wavelet transformation the result show promising performance of the proposed system where the increasing in PSNR is approximately 20 dB.

العلامة المائية في الصورة باستعمال تحويلة المويّل

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الخلاصة

العلامة المائية المعتمدة على التحويلات من نوع مويلة (slantlet)، تحويلة المويل تعتبر تحويلة مويجة متعامدة مع تحسين في تمركز الوقت. العلامة المائية يتم حشرها ضمن الحزمة الوسطية لترددات معاملات المويل والتي تقودنا الى تشويهات صغيرة جدا وتضمن جودة بصرية عالية للصورة ذات العلامة المائية. أداء الخوارزمية المقترحة تم مقارنته مع نظام العلامة المائية باستخدام المويجة (wavelet) والنتائج اظهرت اداء واعد للخوارزمية المقترحة بفارق(20dB).

Key Words: Discrete Slantlet Transform (DST), watermarking, copywriting protection.

1. Introduction

Watermarking is currently at the forefront of research worldwide. As far as the space of embedding is concerned, two main alternatives do exist; the *spatial* and the *frequency* (transform) domains. The spatial domain techniques have become less popular because they are not robust even to the simplest of removal or altering efforts (*attacks*). Most of the research has been focused on the transform domain techniques and almost all of the known transforms have been used, as for example the DCT, DFT, wavelets, Fourier-Mellin, subband DCT, and Chirp-Z. Image watermarking techniques are also classified according to the way the watermark is revealed from the watermarked image, which can possibly be distorted. One way is by comparing the watermarked image to the original one, while the other doesn't resort to such a comparison.

There are some desirable characteristics that a watermark should possess. In most applications, it should be imperceptible, and its casting should not degrade the image. Additionally, it should be very difficult to be extracted or removed by anyone, except for the owner of the image. It means that watermarks should be robust to various image attacks like filtering, compression, histogram modification [1, 3].

Slantlet Transform (ST):

Slantlet transform (ST) is based on an improved version of the usual discrete wavelet transform (DWT) where the support of the discrete-time basis functions is reduced [4]. The DWT is usually implemented in form of an iterated filterbank, where a tree structure is utilized. ST owes its inspiration from an equivalent form of the DWT implementation, where filterbank is devised in form of a parallel structure, with some of the parallel branches employing product form of basic filters.

''Slantlet" filterbank employs a similar parallel structure. However, the component filter branches do not rely on any product form of implementation and hence ST possesses extra degrees of freedom. (Figure 1) shows an equivalent form of two-scale orthogonal DWT iterated filterbank with two zero moments, called D2 (proposed by Daubechies) and the corresponding filterbank realized using ST, which maintains desirable properties of orthogonality and two vanishing moments [4]. Here, different filters are conceived for each scale. For the case in (Figure 1), iterated D2 filters are of lengths 10 and 4, while the corresponding Slantlet filters are of lengths 8 and 4, respectively. As we keep on increasing the number of scales (and subsequently number of parallel branches), the difference in the number of supports keeps growing. While iterated D2 filters require (3·(2^i)-2) supports at the *ith* scale, Slantlet filters require *(2^(i+1))* supports. Hence, Slantlet filters can be implemented.

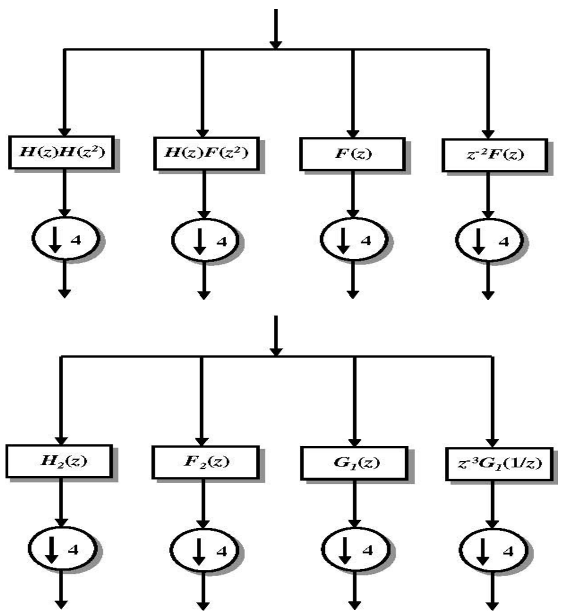


Figure 1: (a) Two-scale iterated D2 filterbank and (b) corresponding twoscale Slantlet filterbank.

with shorter and shorter supports and they can yet maintain all desirable, characteristic features of iterated DWT filterbanks. Each type of filterbank is orthogonal, has an octave-band characteristic, has same number of zero moments and provides a multiresolution decomposition.

In fact, while iterated DWT filters can approximately provide a scale dilation factor of 2, Slantlet filters can exactly provide a scale-dilation factor of 2. Slantlet filters are essentially piecewise linear filters and are particularly suitable for analyzing piecewise linear functions with discontinuities. However, due to the shorter supports of component filters, ST provides a filterbank which is less frequency selective than DWT, although ST provides better time - localization compared to DWT [5, 6].

To provide a mathematical perspective of Slantlet transform, let us fall back on a generalized representation of (Figure 1), for *l* scales. Let *gi(n), fit i(n) and hi(n)* be the filters employed in scale *i* to analyze the signal, where each of these filters has an exact support of 2^(i+1). For *l* scales, ST filterbank employs *l* number of channel pairs, i.e. a total of *2l* channels. Hence, the low pass filter *hl(n)* is paired with its adjacent filter *fl(n),* where each filter is followed by a downsampling by *2^l*. Each of the other (*l* _ 1) channel pairs constitutes of a *gi(n)* filter and its shifted time-reversed version *(i* = 1,2,. . . , *l* _ 1), followed by a downsampling by *2i+1*. The filters *gi(n), fi(n)* and *hi(n)* are implemented in piecewise linear forms and they can be represented as:

$$g_i(n) = \begin{cases} a_{0,0} + a_{0,1}n, & \text{for } n = 0,\ldots,2^i - 1 \\ a_{1,0} + a_{1,1}n, & \text{for } n = 2^i,\ldots,2^{i+1} - 1 \end{cases} \quad (1)$$

$$h_i(n) = \begin{cases} b_{0,0} + b_{0,1}n, & \text{for } n = 0,\ldots,2^i - 1 \\ b_{1,0} + b_{1,1}n, & \text{for } n = 2^i,\ldots,2^{i+1} - 1 \end{cases} \quad (2)$$

$$f_i(n) = \begin{cases} c_{0,0} + c_{0,1}n, & \text{for } n = 0,\ldots,2^i - 1 \\ c_{1,0} + c_{1,1}n, & \text{for } n = 2^i,\ldots,2^{i+1} - 1 \end{cases} \quad (3)$$

Our objective is to determine the parameters as, bs and cs, to perform the filter design procedure for each *ith* scale. These filters must satisfy the following constraints, which, in turn, satisfy orthogonality and two vanishing moments:

(a) each of $g_i(n)$, $f_i(n)$ and $h_i(n)$ is of unit norm i.e.

$$\sum_{n=0}^{2^{i+1}-1} g_i^2(n) = 1 \quad (4a)$$

$$\sum_{n=0}^{2^{i+1}-1} f_i^2(n) = 1 \quad (4b)$$

$$\sum_{n=0}^{2^{i+1}-1} h_i^2(n) = 1 \quad (4c)$$

(b) $g_i(n)$ is orthogonal to its shifted time reverse i.e.

$$\sum_{n=0}^{2^{i+1}-1} g_i(n) g_i(2^{i+1} - 1 - n) = 0 \quad (5)$$

(c) each of $g_i(n)$ and $f_i(n)$ annihilates linear discrete time polynomials i.e.

$$\sum_{n=0}^{2^{i+1}-1} g_i(n) = 0 \quad (6a)$$

$$\sum_{n=0}^{2^{i+1}-1} n g_i(n) = 0 \quad (6b)$$

$$\sum_{n=0}^{2^{i+1}-1} f_i(n) = 0 \quad (6c)$$

$$\sum_{n=0}^{2^{i+1}-1} n f_i(n) = 0 \quad (6d)$$

(d) $f_i(n)$ and $h_i(n)$ are orthogonal to their shifted versions i.e.

$$\sum_{n=0}^{2^{i}-1} f_i(n) f_i(n + 2^i) = 0 \quad (7a)$$

$$\sum_{n=0}^{2^{i}-1} h_i(n) h_i(n + 2^i) = 0 \quad (7b)$$

$$\sum_{n=0}^{2^{i+1}-1} h_i(n) f_i(n) = 0 \quad (7c)$$

$$\sum_{n=0}^{2^{i}-1} h_i(n) f_i(n + 2^i) = 0 \quad (7d)$$

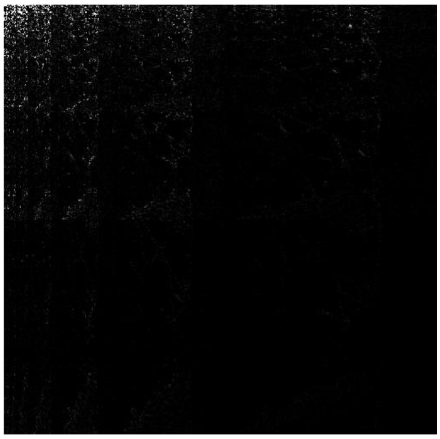
Hence, ST will produce a filterbank, where each filter has its length in power of 2. In case of a finite length signal (with length in power of 2), this results in a periodic output for the analysis filterbank and an orthogonal transformation can be constructed. The ST filterbank gives a reduction of (2^ i _ 2) samples or supports for scale i, compared to iterated D2 DWT filterbank, and the reduction in support approaches one thirds as *i* increases (for coarser scales) [5, 7].

3. Embedding Watermarking Method based on Slantlet Transform

Watermarking in the discrete slantlet transform domain can be split into the two procedures: embedding of the watermark and extraction of the watermark. For embedding a bit stream is transformed into a sequence *w(1)...w(L)* by replacing the 0 by –1, where L is the length of the bit stream and $w(k) \in \{-1,1\}$ (k =1,…,L).This sequence is used as the watermark.

The original image is first decomposed using the discrete slantlet transformation with the pyramidal structure .(Figure 2) shows a gray scale image (512*512 house image) and its slantlet transform.

Figure 2: (a) 512*512 House image



(b) Slantlet transform of the image.

The upper first left corner block, holds the most important part of information of the image, we don't change this block in order to avoid the visual distortion of the image, hence the watermark is added to the largest coefficients in all bands of details which represent the middle frequencies of the image. (Figure 3) shows the blocks used in embedding process.

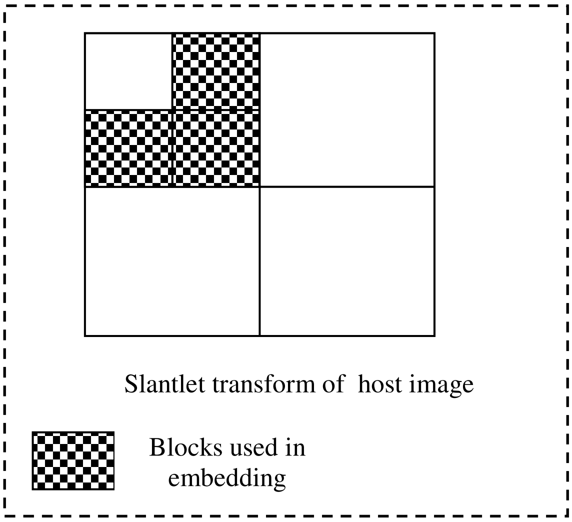


Figure 3: Blocks used in embedding process.

Let $f(m,n)$ denote the DST coefficients which are not located at the low frequency band of the image. The embedding procedure is performed according to the following formula:

$f'(m,n) = f(m,n) + \alpha f(m,n)w(k)$,

where α is the strength of the watermark controlling the level of the watermark $w(1)...w(L)$. By this, DST coefficients at the lowest resolution which are located in the upper left corner block are not modified. The watermarked image is obtained by applying the Inverse Discrete Slantlet Transform (IDST).

In the watermark extraction procedure both the received image and the original image are decomposed into the slantlet transform. It is assumed that the original image is known for extraction. The extraction procedure is described by the formula

$wr(k)=(fr'(m,n)-f(m,n))/(\alpha f(m,n))$,

where $fr'(m,n)$ are the DST coefficients of the received image. Due to noise added to the image by attacks or transmission over the communication channel the extracted sequence $wr(1)...wr(L)$ consists of positive and negative values. Hence, it is better to take the extracted watermark as:

$we(k)=sgn(wr(k))$.

After extraction of the watermark the bit stream is reconstructed according to the replacement rule at the beginning.

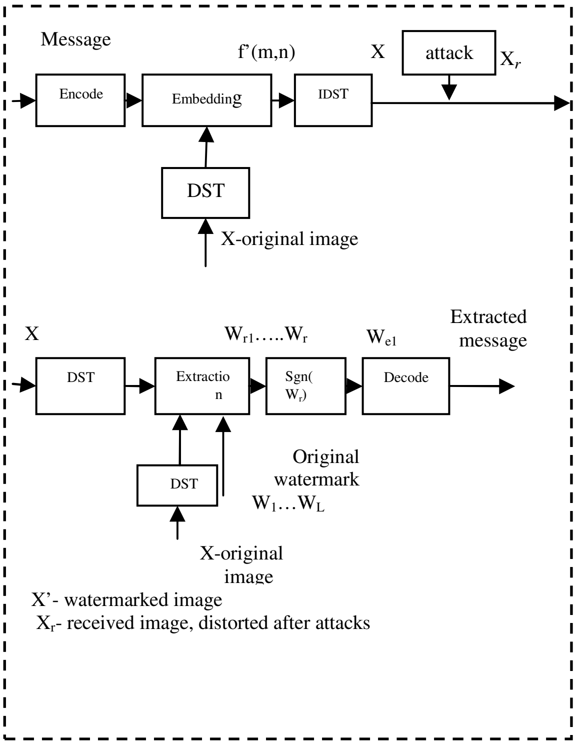


Figure 4: shows the block diagram of the embedding method.

4. Experimental Results and Analysis

The experiments are conducted on the gray-level image House and Bird with size of 512*512. The results obtained from the proposed method are compared with wavelet-based image watermarking system (using Daubechies wavelet transform (DB4) instead of slantlet transform).

4.1. Invisibility test results

To test the invisibility of the proposed watermarking scheme, we first embed the watermark into the original images, the PSNR is used to compare the image quality between the original and watermarked images. (Figure 5) shows the original and watermarked version of House image with PSNR 66.58 dB. (Figure 6) shows the original and watermarked version of Bird image with PSNR 64.01 dB. It can be seen that the watermarked image is not distinguishable from the original one.

(a)

(b)

Figure 5: The comparison of image quality between the original and watermarked images. (a) The original House image and (b) the watermarked image with PSNR 66.58 dB.

(a)

(b)

Figure 6: The comparison of image quality between the original and watermarked images. (a) The original Bird image and (b) the watermarked image with PSNR 64.01dB.

4.2. Watermark embedding capacity

The watermark embedding capacity is one of the standards to evaluate the performance of the watermarking algorithm. The more number of watermark bits can be embedded into the original image, the better performs the method has. Table(1) and Table(2) show the PSNR of House and Bird images versus number of bits watermarked in the image for both proposed slantlet and wavelet systems. The results illustrate that the proposed system gives better performance where the increasing in PSNR is approximately 20 dB.

Table 1: PSNR versus no. of watermarked bits for House test image

Bit	PSNR (slantlet)	PSNR (wavelet)
240	66.58	44.77
304	66.26	44.76
472	64.77	44.73

Table 2: PSNR versus no. of watermarked bits for Bird test image

Bit	PSNR (slantlet)	PSNR (wavelet)
240	64.01	43.39
304	63.92	43.29
472	63.79	43.15

6. Conclusions

In this work the Slantlet transform for watermarking applications has been studied.
In this paper, a novel method for image watermarking has been presented. The method embeds the watermarking data on selected slantlet coefficients of the input image. The selected coefficients reside on the detail subbands and describe the edges of the image. Thus, exploiting the HVS which is less sensitive to alterations on high frequencies, the embedded information becomes invisible. The evaluation of the proposed method shows very good performance as far as invisibility.

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