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A multi-watermarking method based on wavelets combined with the EZW coder

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Abstract

In this paper, we present a new semi-blind watermarking method with secret key by embedding several watermarks in the same image. This embedding is done when the originale image is being coded by the Embedded Zerotree Wavelet (EZW) coder, a compression method based on the wavelets transform, proposed by Shapiro in 1993 [1]. Therefore, the detection processus is performed at the time of decoding the compressed watermarked image. Our algorithm, tested on several greyscale images of size 256 x 256 and for several compression rates, staies robust to intentional or unintentional image processing operation as long as the compressed watermarked image is stilling exploitable.
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1. Introduction

There has been an explosion in the growth of multimedia distribution and communications in the past few years, creating a demand for content protection techniques [7] Cryptographic systems provide security by scrambling the multimedia contents, but nothing prevents the user from manipulating or copying the decrypted data for illegal uses. In order to solve these issues, watermark algorithms have been proposed as a way to complement the encryption processes and provide some tools to track the retransmission and manipulation of multimedia contents [2,3,8].

We present in this paper a new watermarking method combined with the EZW (Embedded Zerotree Wavelet) based wavelets coder proposed by Shapiro [1] in 1993. Insertion process intervenes after multi-level decomposition step of the host image when detection process intervenes and this before the watermarked compressed image reconstruction step. The principle in our watermarking algorithm is to replace significant wavelet coefficients which belong to the host image by other significant wavelet coefficients too belong to a certain watermark that is also a greyscale image but much more small in size than the host one. The significance of both wavelet coefficients sets is determined in proportion as the EZW coder is changing its threshold. We ensure, like this, the watermark imperceptibility at first and, in addition, the robustness in front of EZW compression.

Combination of a watermarking process and a compression one must be considered because one of the most hard attaks that affect a watermarked image is the compression one. In addition, this combination is one of the JPEG2000 objectives where a watermarking module has been integrated in the product but it doesn't accomplish yet its objectives. The principle is to benefit of the compressor operating, construct a certain prevention against its quantization that induces loss of data and embed watermark so that it will remain even after performing quantization step in this compressor. So, robustness against this first attak, very frequent, that is compression is implicit in our watermarking scheme that we will propose in this paper.

Our paper prensents brief outlines on watermarking and wavelets based compression [4,5]. Particularly, we

will accentuate our study on EZW coder operating that acts as platform for our watermarking algorithm.

2. Watermarking for protection author rights

A watermarking system is based on an imperceptible insertion of a watermark (a signal) in an image (an other signal). Within the context of protection author rights, the embedded watermark correspondes to copyright code. This type of watermarking algorithms must answer to both constraints that are robustness and imperceptibility. Indeed, watermark must remain as long as data is exploitable even if this last was licitly or illicitly attaked. In addition, this watermark must not be detected except by authorized persons who possess the detection key. Therefore, , the multi-watermarking notion correspondes to embedding several watermarks in the same host image, each one is a different copyright code. Many algorithms have been recently presented but no one of theme fully satifsfies the ideal conditions of the contract.

The wavelets domaine is one of the privileged domaines for watermark insertion [2,3]. One of the most advantage of the wavelets transform is its obedience to the human visual system (HVS) characteristics compared to other transforms (FFT, DCT, .. etc). This characteristic permits to us to use height energy watermarks in regions where the HVS is less sensitive like detail subbands. Watermarks insertion in these regions increases the robustness without affecting image quality.

3. The wavelets transform

The wavelets transform is a dyadic decomposition of the image [5], achieved by a pair of quadratic miror filters (QMF filters). To perform this transformation, Mallat [6] proposed an algorithm colled the *2-D DWT* (D for discret) that decomposes an image into space-frequency subbands by applying lowpass (L) and corresponding highpass (H) filters to the original image at each dimension and subsequently downsampling the result by a factor of 2. In this way, the so-called *detail* images are produced: HH, HL and LH following diagonal, horizontal and vertical spatial orientations respectively, as well as a smoothed image (LL). This can be repeatedly performed up to the desired resolution level constructing so a multiresolution representation of the original image (cf. Figure 1).

4. Embedded Zerotree Wavelet

The idea of the EZW algorithm developped by Shapiro [1] is to find the best transmission order of the wavelet coefficients, that is their absolute value decreasing order. Therefore, the transmission is done by progressive embedding of the most significant coefficients's bits starting with significant bits. This process permits the stoppage of the decoder at any time in the bit stream and so providing the best possible reconstructed image [4].
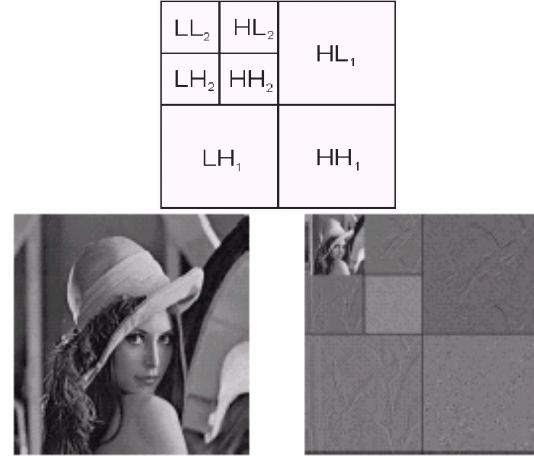

**Figure 1 – Tow resolutions level decomposition of Lena.**

After performing the 2-D DWT [6] on the image, the resulting wavelet coefficients are coded by using a decreasing sequence of thresholds $T_0,...,T_{N-1}$ with

$$T_i = \frac{T_{i-1}}{2} \text{ and } T_0 = \frac{|c_{max}|}{2}$$ where $|c_{max}|$ is the bigest coefficient's amplitude. The algorithm executes recursively tow sussessive passes by considering in each time significant coefficients in relation to the current threshold only, i. e. absolute value is upper than current threshold.

In the first pass called the dominant pass, we look through significant coefficients in relation to the current threshold according to the scan order given in figure 2(a). using the hierarchy given in figure 2(b), the algorithm then provides positions and signs of significant coefficients in a map that associates, at each coefficient and according to its absolute value and their children one, one of the following symbols: *Zerotree root* (ZT) for a non significant tree, *Isolated zero* (IZ) for a non significant coefficient having significant children, *Positive significant* (P) and *Negative significant* (N) for a significant coefficient according to its sign. Each significant coefficient is then set at

zero in the DWT matrix in order that no encoding its position again and its absolute value is put in a list for encoding by successive approximations (subordinate pass).

Indeed, each map is so followed by a sequence of symbols « 0 » and « 1 » that permits to the decoder to fix a reconstruction approximative value to significant coefficients. This value refines in order to draw nearer of the real value of coefficients in proportion as symbol sequences are encoded.
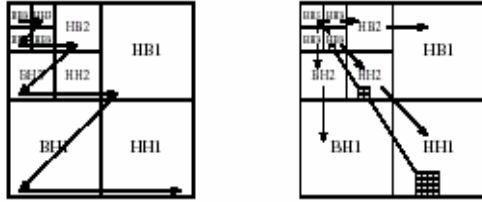
Figure 2 - (a) Scan order of wavelets coefficients,
(b) hierarchical organisation of coefficients.

If T_i is the current threshold so, coefficients marqued in the precedent pass have their absolute value in $[T_i, 2T_i[$. This interval is then divided in tow parts : $[T_i, 3\frac{T_i}{2}[$ and $[3\frac{T_i}{2}, 2T_i[$. At coefficients that absolute value is within the 1st interval, we associate the « 0 » symbol when the others that absolute value is within the 2nd interval, we asociate the"1" symbol. When completing the 2nd pass, the process takes back generating therefore the next map, the new threshold is now T_{i+1} and a new intervall generated in the 2nd pass is added to the precedents one: $[T_i, T_{i+1}[$. These three intervals are then refined as in the pass of precedent cycle to transmit a sequence of symbols « 0 » or « 1 », each one is associated to a significant coefficient. This recursive process stops when T_{N-1} is attained or that the number of desired bits has been transmitted.

To finish and before transmission, an adaptatif arithmetic coder is performed to the provided symbol sequences. The decoding process follows inverse operations, i.e. arithmetic decoding, dominant pass then subordinate pass and at least the IDWT [6] (Inverse Discret Wavelet Transform) to construct the compressed image.

5. Proposed watermarking algorithm

The multi-watermarking with secret key algorithm developed in this paper is semi-blind because, when performing the EZW decoding, the initial watermark is used to detect the embdded one. The watermarks embedded are greyscale images as the host one but more small in size. Tow processes are being added to the EZW coder: *insertion* process in the compressor after the wavelets decomposition step (DWT) and *detection* process in the decompressor before the reconstruction step (IDWT).

Algorithms will being presented in sections 5.2 and 5.3 are developed for a unique watermark. Therefore, to insert (or to extract) several watermarks in the same image, we need to perform algorithms as much as that watermarks exist. Therefore, the notations that will be sed are:

$[T_0, T_{N-1}]$: Thresholds interval.

T_i : Current threshold.

$|c_{i,j}|$: Significant coefficient in the original image.

$|\hat{c}_{i,j}|$: Significant coefficient in the watermarked image.

$|m_{k,p}|$: Significant coefficient in the watermark.

$|\hat{m}_{k,p}|$: Significant coefficient in the detected watermark.

Key : detection key.

5.1. Watermark insertion process

After performing a multi-level decomposition (2-D DWT) on the host image by using a QMF filter, a wavelets coefficients matrix is provided. Then, we decompose the watermark using the same or an other QMF filter until a desired level then, we perform the following algorithm which tries to insert the wavelets coefficients matrix of the watermark:

> *Initialisation* : empty Key.
> *For* each threshold $T_i \in [T_0, T_{N-1}]$
>> *For* each $|c_{i,j}| \in [T_i, \frac{3T_i}{2}]$ and $(i, j) \notin$ Key,
>>> *Search* a $|m_{k,p}| \in [T_i, \frac{3T_i}{2}]$,
>>> $|\hat{c}_{i,j}| := |m_{k,p}|$,
>>> *Add* i, j, k and p to Key,
>>> $|m_{k,p}| := 0$,
>> *End For*
>> *For* each $|c_{i,j}| \in [\frac{3T_i}{2}, 2T_i]$ and $(i, j) \notin$ Key,
>>> *Search* a $|m_{k,p}| \in [\frac{3T_i}{2}, 2T_i]$,
>>> $|\hat{c}_{i,j}| := |m_{k,p}|$,
>>> *Add* i, j, k and p to Key,
>>> $|m_{k,p}| := 0$,
>> *End For*
> *End For*

5.2. Watermark detection process

After the arithmetic decoding step performing by the EZW decoder, the wavelets coefficients matrix of the compressed watermarked image is constructed and before runing the reconstruction step of the image, the watermark detection process intervenes. In this step, we need the wavelet coefficients matrix of both the original watermark and the watermarked compressed image to construct the detected wavelets coefficients matrix.

Initialisation : put at 0 the wavelet detected coefficients matrix.

For each threshold $T_i \in [\, T_0, T_{N-1} \,]$,

    For each $\left| m_{k,p} \right| \in [\, T_i, \frac{3T_i}{2} \,]$ and $(k,p) \in$ Key,

        Search a $\left| \hat{c}_{i,j} \right| \in [\, T_i, \frac{3T_i}{2} \,]$,

        $\left| \hat{m}_{k,p} \right| := \left| \hat{c}_{i,j} \right|$,

        subtract (k,p) of Key

    End For

    For each $\left| m_{k,p} \right| \in [\, \frac{3T_i}{2}, 2T_i \,]$ and $(k,p) \in$ Key,

        Search a $\left| \hat{c}_{i,j} \right| \in [\, \frac{3T_i}{2}, 2T_i \,]$,

        $\left| \hat{m}_{k,p} \right| := \left| \hat{c}_{i,j} \right|$,

        subtract (k,p) of Key

    End For

End For

Finally, we apply the 2-D IDWT to $\hat{m}$ and to the wavelets coefficients matrix in order to reconstruct the detected watermark and the compressed watermarked image respectively.

6. Experimental results

Several tested greyscale images of size 256 x 256 pixels have been watermarked by embedding three different watermarks of size 32 x 32 pixels shown in Figure 3 (a, b and c). Images have undergone several transformations (translation, rotation, resizing, cropping, adding noise, affine and projective transformations and filtering). Figures 5, 6 and 7 recapitulate the detection response of each one of the three watermarks after some attaks (expressed in PSNRs) for the watermarked compressed image *Puppers* with a compression ratio of 6.5. This rate has been chosen after several experiments to have an exploitable image. Also, we have used several QMF filters of different lengths (QMF9, QMF5, QMF8, QMF13, …etc). In this paper, the QMF5 is used.

The PSNR calculated between the original image and the compressed one is 27.60 dB. After integrating the watermarking system, the PSNR calculated between the original image and the watermarked one is 27.51 dB, so this proves the imperceptibility of the embedded watermarks.
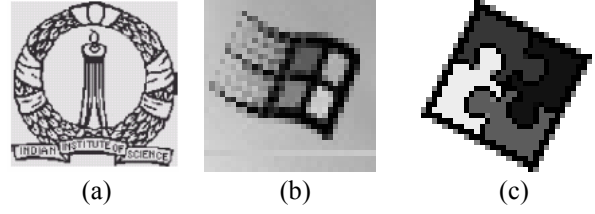

(a)   (b)   (c)
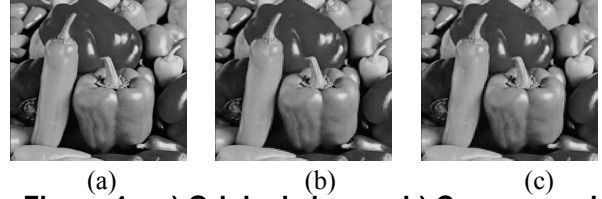
Figure 3 – watermarks used (a, b, c.)

(a)   (b)   (c)

Figure 4 – a) Originale image, b) Compressed image, c) Watermarked compressed image.
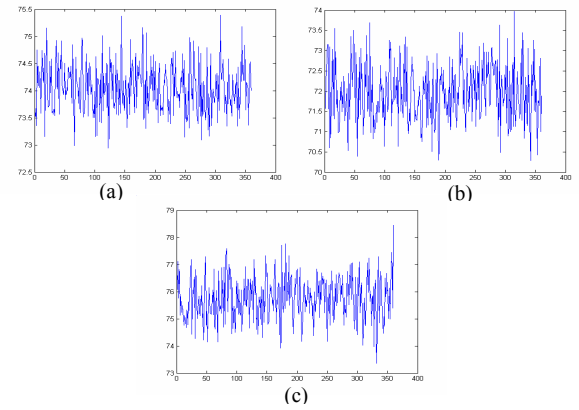

(a)   (b)

(c)

Figure 5 – Rotation : PSNR calcuated between the 1st (a), the 2nd (b) and the 3rd watermark and the detected one according to the rotation angle in degree.
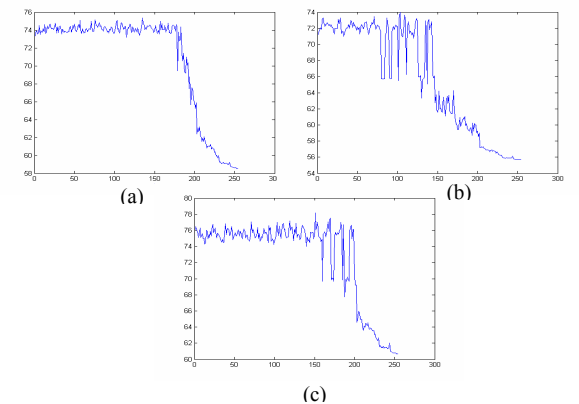

(a)   (b)

(c)

Figure 6 – Translation : PSNR calcuated between the 1st (a), the 2nd (b) and the 3rd watermark and the detected one according to the number of vertical translation of pixels.
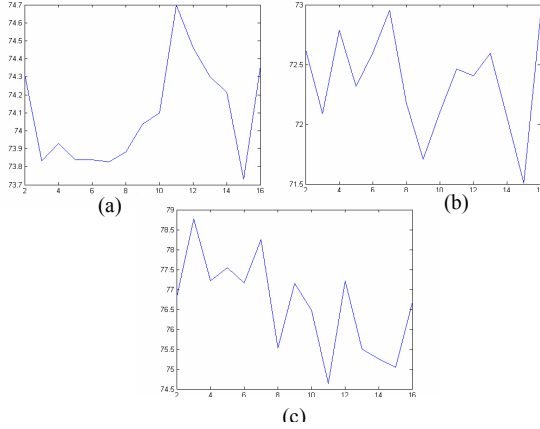
Figure 7 – median filter: PSNR calcuated between the 1st (a), the 2nd (b) and the 3rd watermark and the detected one according to median filter size (X x X).

The proposed method of selecting the insertion sites ensures both watermarking constraints: imperceptibility since the watermark coefficients are almost identical or even equal at those that they replace, and robustness since the substituted coefficients are significant, so will be not lost in the quantization step, and also if the watermark detection process doesn't find the considered coefficient in the watemarked image matrix at the location indicated in the key, it searches an equivalent value elsewhere. Our watermarking method ensures that there is always equivalents for a coefficient because the watermark size is more smaller than the watermarked compressed image, so, the research area is large much more.

If we compare our watermarking algorithm with other methods, we establish that:

Firstly, we can't consider compression attack because the EZW coder used as platform in our method has always given the most weak compression rates when concerning an exploitable compressed image. So, we specify that our watermarking algorithm is considered robust against EZW compression if this last one provides an exploitable image.

In rotation attack, when we refer to Figure 5, we notie immediately that our algorithm proves its robustness against all rotation degrees when the method based on wavelets packets proposed by A. Manouri [9] is being robust unless for small rotations (±5°).

Figure 6 illustrates the detection responses of the watermarks after translating the watermarked image. We note that our watermarking method resists untill 60% of 1D translation and 30% of 2D translation but the Manouri's method [9] fails at this attack.

Figure 7 reveals also the robustness of our method against the median filter, considered here, and several other filters of different sizes for (2x2) to (16x16) like: Weiner filter, average filter, Prewitt filter, Sobel filter, Laplacian filter, … etc. At the same time, the wavelets packets method of Manouri [9] is also robust at some filters like: Gaussian filter and average filter of size 2x2 or 3x3.

On the other hand, if we talk about other attacks not illustrated here, we cetify that our watermarking scheme is much more better than the Xie's algorithm [10], the Cox's method [11] or the Manouri's one [9] against the cropping attack. This third method resists to the cropping for 1 to 10% of the image size when our method resists to attach for 75% of the image size cropped with the proviso that the remaining part is not uniforme.

When talking about geometric transformations, our algorithm extracts totally the watermarks embedded when methods proposed by Xie [10], Cox [11] extract their watermrks partially but Manouri's method [9] is not able to detect the signal embedded.

According to Manouri's thesis [9], the proposed watermarking algorithm is not robust at the resizing attack but in our case, the method remains robust until the image size attains 64x64 pixels when enlargement doesn't affect the detection process.

Adding noise is the last attack that we mention here, it lets the detection process perfect for our algorithm and the Xie's one [10] for a large variance (eg. Gaussian noise, Poisson noise, … etc) but in the Cox's method, the process fails if the variance of the additive noise is too large.

Finally, experimental results that we will present prove the robustness and imperceptibility of our watermarking method for the majority of attaks and for all embdded watermarks. The majority of embedded coefficients is detected as long as the number of watermarked image coefficients is sufficiently grand because the probability to find a coefficient in an area increases with the size of this one.

7. Conclusion

In this paper, we have presented a new multi-watermarking images method that we have integrated in the EZW coder based on the wavelets transform [1]. Our watermarking algorithm is semi-blind because of the initial watermark and also the detection key are needed in the detection process. We have included tow processes in the EZW coder, the first one uses to embed one or several watermarks in the host image after the decomposition step providing separately

therefore one or several detection keys. Also, the second process intervenes before the reconstruction step of the watermarked compressed image to detect watermarks embedded imperceptibly. Our algorithm has proved its imperceptibility since the imbedding process means here a substitution of original coefficients by those equivalents (in the sense of EZW significance) from the watermark. Likewise, the algorithm robustness, in front of different attaks that watermarked image can undergoes, has being remarkably proved except if a big quantity of the watermarked image has been lost, so this last will become unexploitable.

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