Watermarking Based on the Density Coefficients of Faber-Schauder Wavelets

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Abstract. The field of watermarking is of great development in recent years. There is still relevance to find high-performance methods that link robustness and discretion. In this paper, we will present a method of watermarking based on a mixed scale wavelet transformations of Faber-Schauder and the selection of high-density regions of the dominant coefficients. Simulation results demonstrate the robustness of our image watermarking procedure under various attacks and could serve for the image watermarking of identity and access cards.

Keywords: Digital watermarking, Faber-Schauder wavelet transformation, dominant coefficients.

1 Introduction

The digital watermarking tends to exploit the imperfections of the human visual system to embed invisible identification information into a digital content (video, audio or image), in order to protect it [10]. In the original document, we insert a signature (Watermark), which is formed by a sequence of bits. The insertion must respect the imperceptibility compared to the human visual system and the robustness (i.e. difficult to extract or to delete).

The wavelet transformation (DWT) is now widely used in image processing [12]. They are distinguished by a multi-scales decomposition of the image to separate the structures of different sizes. Most of the watermarking methods in the wavelet domain are working with scales separated [15]. For each scale, pixels are decorrelated by this transform and information is only present in a small number of wavelet coefficients: the dominant coefficients [6,7]. These coefficients are located mainly around the edge of the image and characterize all the information of the image. This is especially true for identities images which are the topic of our interest (the images scanned from sensitive documents: passports, identity cards, access cards....). The originality of our method is the use of mixed-scale visualization [6], that permit to distinguish very particular regions around the edges of the image, where we have a high density of dominant wavelet coefficients. These regions are characterized by the fact that they are highly textured regions, therefore ideal to hide information. It is also the regions with a high density of the dominant coefficients, therefore unavoidable in the characterization of the image and a priori stable for any transformation of the image. Another originality of our method is the use of the density of dominant coefficients as a criterion at the insertion and the extraction.

In this paper, we present a method based on the density of wavelet coefficients. The Faber-Schauder wavelets are chosen since they are particularly well adapted for the watermarking [7].

After describing the mixed-scale visualization, we will propose a strategy for watermarking and test its robustness following various attacks.

2 Faber-Schauder Wavelet Transform

The algorithm of Faber-Schauder wavelet transform (FSWT) is simple to express by a lifting scheme [6, 16]. We can consider a image as a sequence $f^0 = \left(f_{m,n}^0 \right)_{m,n \in \mathbb{Z}}$ of $L^2(\mathbb{Z}^2)$, Transform FSWT is done in three steps as shown in the following figure:

Fig. 1. The transformation by lifting scheme

The Scheme lifting of the FSWT [6] is given by the following algorithm:

$$\text{TOFS : } \begin{cases} f_{ij}^0 = f_{ij}; & \text{pour } i, j \in \mathbb{Z} \\ \text{pour } 1 \leq k \leq N & \text{et } i, j \in \mathbb{Z} \\ f_{ij}^k = f_{2i,2j}^{k-1} \\ g_{ij}^{k1} = (g_{ij}^{k1}, g_{ij}^{k2}, g_{ij}^{k3}) \\ g_{ij}^{k1} = f_{2i-1,2j}^{k-1} - \frac{1}{2} (f_{2i,2j}^{k-1} + f_{2i+2,2j}^{k-1}) \\ g_{ij}^{k2} = f_{2i,2j+1}^{k-1} - \frac{1}{2} (f_{2i,2j}^{k-1} + f_{2i+2,2j+2}^{k-1}) \\ g_{ij}^{k3} = f_{2i+1,2j+1}^{k-1} - \frac{1}{4} (f_{2i,2j}^{k-1} + f_{2i,2j+2}^{k-1} + f_{2i+2,2j}^{k-1} + f_{2i+2,2j+2}^{k-1}) \end{cases} \quad (1)$$

3 The Watermarking by the Density of the Coefficients of Faber-Schauder Wavelet

3.1 Watermark Embedding

The basic idea consists in inserting a mark on the edges detected by the density by block of coefficients of FSWT, while taking into account two important aspects: the robustness and invisibility.

The algorithm for watermark embedding can be presented as following:

- Firstly we calculate FSWT of original image **I**, to get a transformed image **F** in mixed scales representation [6].
- The second step consists of selecting the high density blocks of wavelet coefficients followed by a classification of these blocks in ascending order, and so to insert the mark in the important blocks (in the sense of density). The embedding can also be effected on all blocks selected. this way, the mark to embed may be redundant if it has a length less than the total number of blocks extracted.
- The third step consists of applying a spread spectrum method into the watermark **W** by using a random sequence broadband **U** [8], so, the gotten message reinforces the resistance of the signature to perturbations provoked on the image. Each block is going to carry information in related with a given bit of message obtained in the form of an additive term. The watermark embedding follows the following equation:

$$C_f^*(i, j) = C_f(i, j)(1 + \alpha W_k(i, j)) \quad (2)$$

Here the constant α gives the watermark strength.

$C_f^*(i, j)$: The marked coefficient (with $i, j=1..$ the block size).

$C_f(i, j)$: Initial coefficient of the selected block.

$W_k(i, j)$: the sequence obtained by the spread spectrum method.

After the marking of a block, we replace it at the corresponding block in the image **F**.

- Finally, we reconstruct the changed image by using the inverse wavelet transform.

The selected blocks are those containing large densities of dominant wavelet coefficients as shown in Fig. 2.

Fig. 2. The selection of blocks of high-density of the dominant coefficients (For Lena image: 8x8 blocks, SC = 10, SD = 20%)

The selection of blocks is based on the following selection criterion:

- A threshold SC is fixed to select the dominant coefficients: A coefficient is considered dominant if its absolute value is superior to SC .
- A threshold SD of density is fixed to select insertion blocks: All block whose density passes this threshold will be selected as a dominant block.

3.2 Watermark Detection

The insertion of the watermark is made by a spread spectrum in the dominant blocks. At the reception of a marked image, we calculate the correlation with the random sequence $\mathbf{U}$ used for the modulation [8].

More precisely we proceed as follows:

- Calculate Faber-Schauder wavelet transformation of the supposed marked image.
- Select the dominant blocks: blocks with high density of wavelet dominant coefficients.
- Calculate the correlation between the selected blocks and the random sequence $\mathbf{U}$:

$$r(\mathbf{B}, \mathbf{U}) = \frac{\sum_m \sum_n (B_{mn} - \bar{B})(U_{mn} - \bar{U})}{\sqrt{\left(\sum_m \sum_n (B_{mn} - \bar{B})^2\right) \left(\sum_m \sum_n (U_{mn} - \bar{U})^2\right)}} \quad (3)$$

With $\mathbf{B}$ the constructed vector from a given block.

- Choose the maximum of the calculated correlations, noted $\mathbf{r}_{\max}$.
- If $\mathbf{r}_{\max}$ superior to a threshold T then the image is considered marked.

4 Results and Conclusion

4.1 Visual's Deterioration

The first tests done to measure the image deterioration (by the watermark) are the calculation of the PSNR (table1). We can notice that the deteriorations are very little visible for the marked image (lena 512) (Fig. 7). As long as the threshold is lower than 10, PSNR remains well above 30 dB.

The performances of a marking algorithm are measured by the degree of resistance to classic attacks and to filtering, We will use for the proposed method the bench attacks CheckMark[13], The test bench is generated from one or several marked images, Then we will apply the algorithm of detection on each attacked image, one tried to detect the mark and we look if the detection succeeded or no,

This decision is made while defining a threshold of detection; the threshold is equal to **0.40**. It is an empirically chosen from several tests.

Table 1. PSNR for marked images

The watermark strength.	PNSR (db)	correlation
2	37.4035	0.437552
7	32.8847	0.633063
10	30.2074	0.743258
15	27.3072	0.805537
20	25.0252	0.809627
30	21.7905	0.929487

4.2 Robust Against Compression

Fig. 3. The correlation for different qualities of compression by JPEG DCT: The resistance to the JPEG compression (DCT) is relatively efficient

Fig. 4. The correlation for different qualities of JPEG 2000 compression algorithm: it's always important (more far from the predefined threshold)

4.3 Filtering

Fig. 5. The correlation obtained after an attack with the Gaussian filtering: the correlation still high than the threshold

Fig. 6. The correlation obtained after an attack by the Wiener filtering: the correlation still very important

threshold =20, PNSR= 25.02 db

The difference image between the marked image and the original imag

Fig. 7. If the threshold of marking is too important, the distortions of the marked image are very important

Fig. 8. Example of geometric attack

Fig. 9. Example of Stirmark attack: correlation= 0.42

4.4 Geometric Distortions

The geometric attacks such as cropping, resizing and rotation attacks knock down the correlation scores significantly (cf. Fig 8 and 9). It is therefore necessary to improve the performances of this method, particularly by finding a solution to the problem of synchronization: Indeed the geometric distortion introduced a spatial desynchronization

changing the density of blocks dominant of wavelet coefficients. So when we turn the image by 10° the detection of the signature by the proposed method become ineffective. But for relatively small distortions (for example rotations lower to 4°) the detection of the signature still possible with our proposed method. The application that we aim has the particularity to provoke geometric distortions of very low amplitude [12] which shows that our approach could be successful.

5 Conclusion

In this papers we have presented a method of images watermarking based on mixed-scales visualization by Faber-schauder wavelet. The experimental results have confirmed that this method is robust against various attacks: JPEG compression and geometric of small angle or displacement. It could therefore be used for images watermarking in this case. This method will be tested on images of access systems with magnetic badge where we have a geometric attack with small amplitude.

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