COLOR IMAGE WATERMARKING WITH ADAPTIVE STRENGTH OF INSERTION

A. Parisis[1,2], P. Carré[1], C. Fernandez-Maloigne[1]   *N. Laurent[2]*

[1]IRCOM-SIC laboratory, university of Poitiers
SP2MI – Blvd Marie et Pierre Curie – BP 30179
86962 FUTUROSCOPE CHASSENEUIL
{parisis,carre,maloigne}@sic.sp2mi.univ-poitiers.fr

[2]FRANCE TELECOM, DIH/HDM
4 rue du Clos Courtel
35510 CESSON SEVIGNE
nathalie.laurent@rd.francetelecom.com

ABSTRACT

This paper presents a watermarking technique, specific to color images. The insertion and the detection are based on the 2D discrete wavelet transform, applied on each color components. Three color vectors are extracted from the wavelets coefficients. The insertion consists in modifying one vector for each location, with regards to the bit value and the vectors triplet. The mark is extracted without the original image, by observing the scheme of each vectors triplet. This new method has shown to be resistant to JPEG compression, median filtering and noise adding. Moreover, each insertion is weighted by an adaptive strength, obtained with a retroactive process between the original and the watermarked images. This process allows optimizing the compromise between invisibility and robustness, considering the local image color content.

1. INTRODUCTION

The intellectual property has to be more developed considering the today facility of numerical data transferring. It concerns audio, video, photography objects. Moreover, watermarking techniques has to be extended to other applications, as authentication or indexation [1]. The special interest for color in watermarking scheme has brought new problems about the quality. On the one hand, there is no adapted metric for color image assessment. For example, the PSNR (Peak Signal To Noise Ratio) which has demonstrated its efficiency for gray-level images, gives inconsistent results when using color images [2]. On the other hand, the local image content (texture and color) has to be considered when inserting the watermark.

In this paper, we propose a watermarking technique, applied in the multiresolution domain, and specifically adapted to color images. This approach, using wavelets coefficients, improve the robustness to JPEG compression and high frequencies processing. Moreover, the most important watermarking problem is to optimize the compromise between the mark invisibility and its robustness. In order to achieve this optimization, we propose a retroactive algorithm. It

weighted each bit of the inserted mark and considers its effects on the color watermarked image.

The remainder of this paper is organized as follow. In the second section, we propose a quick overview of color image watermarking techniques. Then, chosen insertion and detection techniques are exposed in section three. Section four is dedicated to the retroactive technique mentioned above. We present results of this study (watermarked images and robustness tests) in the fifth section. Finally, we make some conclusion about the presented approach and talk about future work.

2. COLOR WATERMARKING, AN OVERVIEW

First color watermarking techniques were built around the idea of using gray-level methodologies on one or set of components. In this way, Kutter and al. [3] propose an additive watermark on the blue component. Fleet and Hegger [4] present the insertion of sinusoidal signals on the a component in the $L^*a^*b^*$ color space, which is a perceptually uniform space, where a corresponds to the yellow and blue opposition. Those algorithms take into account Human Visual System (HVS) properties (i.e. its less sensitivity to variation in the blue range).

Another concept of color watermarking starts from a color quantification that allows to obtain a one-dimensional color image representation, where the mark is added. One example of this technique was applied by Chou and al. in [5] where the quantification is done in the $L^*a^*b^*$ color space.

More recent strategies are very specific to color images, using the intrinsic properties of color and HVS characteristics. A method of integrity protection based on this kind of strategy is proposed by Kostopoulos and al. in [6]. Thus, the mark represents an approximation of the luminance component extracted from YC_rC_b color space. This information is then inserted in the three color components. An another method is presented by Chae and al. in [7]. This non-blind technique uses multidimensional lattice structures. Vectors are defined by wavelets coefficients from each YUV components. A Wavelet Transform is also applied on the mark (that could be an image). For each coordinates, this mark is
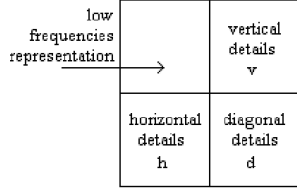
Fig. 1. wavelet decomposition in the first level

Fig. 2. example of name vector affectation , function of their position from each others

Fig. 3. convention example

weighted and added to the vectors extracted from the original image.

In the next section, we explain the insertion and the detection schemes of our color watermarking technique, used for secure documents.

3. WATERMARKING TECHNIQUE

This algorithm described below could be used with different color spaces in the family of spaces of primary (such as RGB, XYZ, CMY, etc.). Nevertheless, all the illustrations of this paper are based on the RGB color space.

3.1. Watermarking insertion

In the first step of the insertion algorithm, we apply a wavelet transform on the host image I, for each component, to the Nth level. To define the signature S, we use a pseudo-random code, controlled by a key K. The mark M is generated by the signature repetition, to improve its robustness. At this N^{th} level, for each component R, G and B, we define vectors as:

$$\vec{V}_a(x,y) = \{v_{Na}(x,y), h_{Na}(x,y), d_{Na}(x,y)\}$$

with $a = \{R, G, B\}$, (x, y) represents the coordinates, and h, v and d, parts of the wavelets decomposition as shown in figure 1.

The watermarking principle consists in moving one of those three color vectors, according to the corresponding local value of the mark. For each coordinate, we have to define one vector $\vec{V}_M$ which will be modified during the watermarking stage, and two reference vectors $\vec{V}_{ref1}$ and $\vec{V}_{ref2}$. We also note P_β the extremity of the vector $\vec{V}_\beta$. $\vec{V}_M$, $\vec{V}_{ref1}$ and $\vec{V}_{ref2}$ are described with respect of the following equations (figure 2):

$$\|P_{ref1} - P_{ref2}\|^2 = \max_{\substack{(a,b)\in\{R,G,B\}\\i\neq j}} \|P_a - P_b\|^2$$
$$P_M = P_c$$

with $c \in \{R, G, B\}$ and $c \neq a$ and $c \neq b$.

Now, let's define a watermarking convention, as presented on figure 3. We note $\vec{V}_{M,W}$, the watermarked vector. After watermarking, if $\vec{V}_M$ correspond to $\vec{V}_R$, then:

- if $M(x,y) = 0$ then $\vec{V}_{R,W}(x,y)$ will be nearer to $\vec{V}_G(x,y)$ than $\vec{V}_B(x,y)$ (see figure 2);
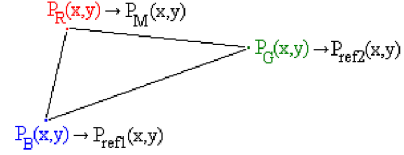- else $\vec{V}_{R,W}(x,y)$ will be nearer to $\vec{V}_B(x,y)$ than $\vec{V}_G(x,y)$.
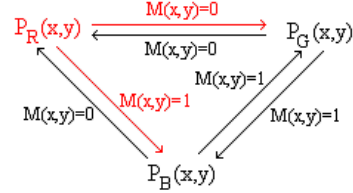
One of the most important possibilities lies on the ability of tuning the $P_{M,W}$ moves in order to limit the visual degradations on the image. The figure 4 shows the possible moves of $\vec{V}_{M,W}$. Two moving cases are envisaged, knowing $P_{M,W}$ initial position. Considering the case 2, in figure 4, $P_{M,W}$ is first positioned at P_{int}. Thus, the watermarked point is set nearer P_{ref2} than P_{ref1}.

For the case 1, where P_M is the initial point of $P_{M,W}$, and for the case 2, where P_{int} is the initial point of $P_{M,W}$, the watermark is defined by:

$$\vec{V}_{M,W}(x,y) = \vec{V}_{refi}(x,y) - (1 - F_a(x,y)).(\vec{V}_{refi}(x,y) - \vec{V}_S(x,y))$$

with $i = \{1, 2\}$, $a = \{R, G, B\}$ and $0 \leq F_a(x,y) \leq 1$. Moreover, S equal to M (resp. equal to int) for the case 1 (resp. case 2). F_a represents the strength matrix. On a simple way, F_a can be constant on each pixel (x, y).

- If $F_a = 0$, then the strength is minimum.
- If $F_a = 1$, then the strength is maximum and $P_{M,W}$ is superpose on P_{refi}.

In the case of maximum strength, a conflict problem is highlighting. On figure 3, the bit condition between P_R and P_B can be different: $M(x,y)$ can receive 0 or 1. It means that, in the detection step, the vector identification ($\vec{V}_R$, $\vec{V}_G$ and $\vec{V}_B$ to $\vec{V}_M$, $\vec{V}_{ref1}$ and $\vec{V}_{ref2}$) could be false. So, in this case, $F_a(x,y)$ is set to *0.9*. This value has been defined empirically.

Those operations are applied on the whole host image. The last insertion step consists in reconstruction of the image in the spatial domain.

3.2. Watermark Detection and Decision

The first step of the detection consists also in a decomposition of the image with the same wavelet basis used in the insertion step. For each coordinates (x, y), $\vec{V}_M$, $\vec{V}_{ref1}$ and $\vec{V}_{ref2}$ are determined. The detected mark M_D is detected
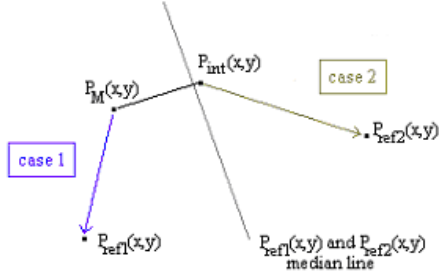
Fig. 4. possible positions of $P_{M,W}$

by measuring the largest distance between $\|\vec{V}_{ref1}(x,y) - \vec{V}_M(x,y)\|$ and $\|\vec{V}_{ref2}(x,y) - \vec{V}_M(x,y)\|$. Following the convention used in insertion (see figure 3), the mark is thus reconstructed, bit by bit. The signature S_D is obtained by making an average that corresponds to the redundancy method used for the mark M creation. In order to decide if S_D corresponds to S, a correlation measure cc is applied:

$$cc(S, S_D) = \frac{\sum S(x,y) * S_D(x,y)}{\sqrt{\sum S^2(x,y) * S_D^2(x,y)}}$$

If $cc(S, S_D) \geq T$, then S_D corresponds to S, else the original signature S is not detected in this process.

4. LOCAL STRENGTH ADAPTATION BY RETROACTIVE ALGORITHM

4.1. Retroactive Technique

To take into account the local context in the watermarking process, we propose to adapt the strength matrix F_a by using a local measure of visual degradation on watermarked image.

The aim of this algorithm is to adapt the watermarking strength in order to limit the visual degradations. For this, at each location, we verify after reconstruction in the spatial domain that the difference between the original and the watermarked image is not visible by human observer [4]. The main idea is to use the common evaluation method of difference between two colors (C_1 and C_2), defined in $L^*a^*b^*$ by:

$$\Delta E(C_1, C_2) = \sqrt{(L_{C_1} - L_{C_2})^2 + (a_{C_1} - a_{C_2})^2 + (b_{C_1} - b_{C_2})^2}$$

If $\Delta E \leq 3$, then, commonly admitted, C_1 and C_2 are visually identical. Notice that one mark bit affects a square of 2^{2N} pixels, with N wavelet decomposition level, because of the application on the wavelet coefficients. So, for one mark bit, we propose two solutions:

- Case A: computation of $\Delta E_A(x,y)$ average of all ΔE measures in squares of 2^{2N} pixels, corresponding to the position of one inserted bit.
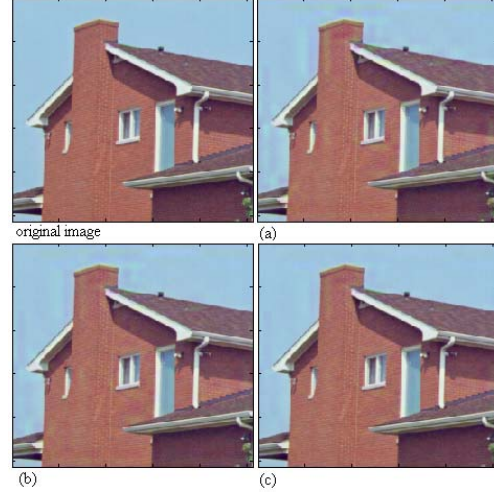

Fig. 5. (a) watermarked image I_{w1} with constants F_a ; (b) watermarked image I_{w2} with F_a determined with retroactive algorithm, in case A (average) ; (c) watermarked image I_{w3} with F_a determined with retroactive algorithm, in case B (maximum)

- Case B: computation of $\Delta E_M(x,y)$ is the maximum of all ΔE measures in squares of 2^{2N} pixels, corresponding to the position of one inserted bit.

Let F_a be strength matrix, the retroactive algorithm is defined by :
All $F_a(x,y)$ elements are set to 0.9
Repeat :
- Computation of the watermarked image
- Computation of the color difference ΔE
- If $\Delta E(x,y) > 3$, then $F_a(x,y) \leftarrow (F_a(x,y) - 0.1)$
until $\min_{x,y} \Delta E(x,y) \leq 3$.

4.2. Evolution

Concerning the choice of using $\Delta E_A(x,y)$ or $\Delta E_M(x,y)$ in the retroactive algorithm, we propose to test the combination of those techniques with a texture segmentation algorithm. Indeed, it has been observed that the HSV is not very sensitive to variation of color in texture areas. Thus, in the most textured areas, the case A can be applied. Therefore, in the homogenous area, the degradation is controlled by the case B of the retroactive algorithm.

5. RESULTS

5.1. Parameters

In our tests, we have chosen the 'Daubechies' filter, with a 4 level ($N = 4$) decomposition in order to have good compromise between ratio and robustness face to JPEG compression. In the case of using constant values for F_a, we set $F_R = 0.7$, $F_G = 0.5$ and $F_B = 0.9$. Those values allows a good balance concerning robustness and invisibility compromise for the set of tested images. We propose $T = 0.7$
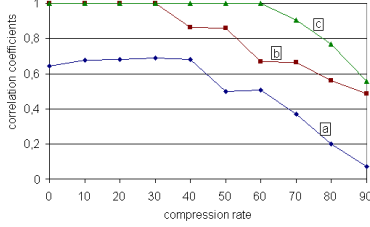
Fig. 6. JPEG compression attack on watermarked images. (a), (b) and (c) respectively correspond to Iw1, Iw2 and Iw3 from figure 5
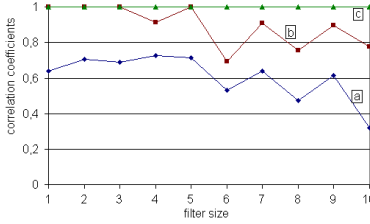

Fig. 7. Median filtering attack on watermarked images. (a), (b) and (c) respectively correspond to Iw1, Iw2 and Iw3 from figure 5

to eliminate false detection possibilities. This value, chosen by the user, depends on the targeted application.

5.2. Images and tests results

The presented results concern robustness to JPEG compression, median filtering and noise adding, for "house" color image. Measures represent average of correlation for watermarking based on different keys.

On figure 5, we present different watermarking results on a well-known color image. Degradation are located around transition situated nearby on homogenous areas (on figure 5, artefacts are situated around the chimney, on the sky). As shown on figures 6, 7 and 8, we logically observe that using the retroactive algorithm improves the compromise between mark invisibility and robustness. This is a consequence of the low constant F_a values proposed in section 5.1. The choice between evaluating the local degradation with $\Delta E_A(x,y)$ (case A) or $\Delta E_M(x,y)$ (case B) depends on the compromise needed by the user. Indeed, robustness in case A is better than in case B, but with more visible degradations introduced in the image. Equivalent results have been obtained on a large image database, with different color and texture contents.

6. CONCLUSION

In this paper, we have proposed a watermarking technique, specific to color images. Our method has shown a robustness to JPEG compression, noise adding and median filtering. The retroactive technique for controlling the local degradation is efficient. It improves the visual quality of color watermarked image and the mark robustness as we have tested on numerous different images.
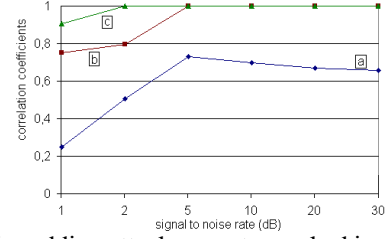

Fig. 8. Noise adding attack on watermarked images. (a), (b) and (c) respectively correspond to Iw1, Iw2 and Iw3 from figure 5

Future works concern test of the combination of the texture segmentation with the retroactive algorithm, in order to refine the local strength values and to improve the robustness and invisibility compromise. We will also propose to combine a second generation of watermarking scheme [3] to this one, to improve this technique robustness in front of geometric attacks.

7. REFERENCES

[1] I. J. Cox, M. L. Miller, and J. A. Bloom. *Digital Watermarking*, chapter 2, pages 11–40. Morgan Kaufmann, 2002.

[2] C. Fernandez-Maloigne. Image quality assessment: metrics and psychosensorial experiments applied to colour image compression and watermarking. In *Summer research Institute, EPFL, Lausanne, Suisse*, July 2003.

[3] M. Kutter, S.K. Bhattacharjee, and T. Ebrahimi. Towards second generation watermarking schemes. In *6th International Conference on Image Processing ICIP'99, Kobe, Japon*, volume 1, pages 320–323, october 1999.

[4] D. J. Fleet and D. J. Hegger. Embedding invisible information in color image. In *IEEE International Conference on Image Processing, Santa Barbara*, volume 1, pages 532–535, october 1997.

[5] C.H. Chou and T.L. Wu. Embedding color watermarks in color images. In *EURASIP Journal on Applied Signal Processing*, volume 3, pages 32–40, 2003.

[6] I. Kostopoulos, S.A.M. Gilani, and A.N. Skodras. Color image authentification based on a self-embedding technique. In *14th Int. Conf. on Digital Signal Processing, Santorini, Greece*, volume 2, pages 733–736, july 2002.

[7] J.J. Chae, D. Mukherjee, and B.S. Manjunath. Color image embedding using multidimensionnal lattice structures. In *Proc. IEEE Int. Conf. on Image Processing, Chacago, Illinois*, volume 1, pages 460–464, october 1998.