

Colour Watermarking: Study of Different Representation Spaces

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Abstract

Watermarking is a subject of research that increases during the last ten years, particularly because of evolves of Internet. Now, a lot of algorithms and methods have been developed for greyscale images. But the particularities of color spaces have to be studied. On the other hand, the wavelet transform allows different possibilities of integrate a mark because of the uses of different parameters: the scale of decomposition, size, shape and localisation of the mark, and the used color space, etc. The aim of this paper is to study different watermarking combinations for different color spaces, to determine the capacities, possibilities and limits of watermarking in each wavelet color representation.

Introduction

Because of evolves of multimedia technologies, it becomes necessary to develop high quality copyrights techniques. A lot of techniques are defined for grey-scaled image, using time, frequency or multi-scale domain. The study of color image is growing recently. Some problems are met: manage the robustness and the invisibility of a mark for each color component, measured the degradation of a color marked image, etc. The aim of this work is to determine and evaluate a technique of a robust and invisible strategy of watermarking.

This paper consists of three parts. In the first part, one method of watermarking and an overview of colour techniques are proposed. In the second part, experimental results of our method applied on different images and for different color spaces are presented. In the last part, some propositions are done to discuss those results. Some modifications are proposed to improve the presented watermarking.

Method

We have chosen to work with wavelet decomposition. First, wavelet decomposition allows working simultaneity in time and frequencies domain. Moreover, this representation space is interesting because it is used in recent compression standard (JPEG2000, MPEG4). On an other hand, it allows an easily use of a psycho-visual model, because of the subband image decomposition, close to perceptive channels decomposition.

The used algorithm is an extension of the Kundur and Hatzinakos's techniques.² It allows watermarking mono-

chrome image by using wavelet decomposition. The principle of this algorithm follows this scheme:

- Wavelet decomposition: we obtain three sub-images corresponding to the band-pass frequencies. This decomposition is performed until the level l ;
- Sort: for each localisation of those three sub-images, we sort the three coefficients

$$\{c_l^H, c_l^V, c_l^D\},$$

where H, V and D represent respectively the horizontal, the vertical and the diagonal subband. With the sort, we obtain:

$$c_l^{n_1} \leq c_l^{n_2} \leq c_l^{n_3}$$

- We define also the quantification step Δ by:

$$\Delta = \frac{c_l^{n_3} - c_l^{n_1}}{2K - 1} \quad (1)$$

where the constant K allows to control the force (the degree of robustness and invisibility) of the mark.

- Integration of the mark: figure 1.



Figure 1. Quantification scale of wavelets coefficients

$$\min \rightarrow c_l^{n_1}; \max \rightarrow c_l^{n_3}$$

- if the bit to introduce is '1', $c_l^{n_3}$ is set to the more close value defined by a bold line.
 - if the bit to introduce is '0', $c_l^{n_1}$ is set to the more close value defined by a dotted line.
- Reconstruction of the image by inverse wavelet transform is computed with the new coefficient

The detection process is based on the inverse principle.²

To apply this algorithm on color image, we work independently on the three components:

- We transform our image from RGB to the space color that we want to evaluate,
- We apply the algorithm of watermarking on the three components. We can use different forces of watermarking for each component.

3. We recompose our image from the studied space to RGB.

The stage of detection of the mark is done as the stage of watermarking:

1. We decompose our image from RGB to the space color that we want to evaluate,
2. We apply the algorithm of detection on the three components, with taking care of the different forces used for each component.

The base used for the decomposition corresponds to the 'Daubechies D8' wavelet.¹ We apply the watermarking algorithm at the fourth scale of wavelet decomposition. Also can choose to work in particular band-pass frequencies. Indeed, watermarking of the high frequencies is not robust to common attacks (for example filtering), and watermarking of the low frequencies degrades images.

In this study, we only test JPEG compression on the watermarked images as attack. In a more general study, we will test others attacks.

We define two stages of evaluation after a watermarking:

- In a first time, the robustness is evaluated by a correlation coefficient, noted CC ($-1 \leq CC \leq 1$). This coefficient is the correlation between the initial mark and the detected mark. A watermark will be qualified of robustness when $CC > 0.35$ (this value is defined experimentally).
- In a second time, the problem is to determine the image degradation caused by the watermarking. Indeed, it is possible to measure the PSNR (ratio signal/noise) by comparing the original image and the watermarked image, for grey-scaled image. But for color image, we can not apply the PSNR on each component: each one does not have the same impact on human visual system. So the user evaluates the image quality himself.

Some Spaces

The first representation space studied is naturally RGB . We have also tested XYZ space, which is an equivalent of RGB , to complete our first results. As RGB , it's a chromatic space, define as:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0,490 & 0,310 & 0,200 \\ 0,117 & 0,813 & 0,011 \\ 0 & 0,010 & 0,990 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

We can observe that Z is highly correlated with Blue, and Y with Green.

We also work on system with a luminance component. The most uses of them are YIQ and YUV . Indeed, YIQ correspond to the NTSC standard:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0,299 & 0,587 & 0,114 \\ 0,596 & -0,273 & -0,322 \\ 0,212 & -0,522 & 0,315 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3)$$

and YUV correspond to the PAL standard:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0,299 & 0,587 & 0,114 \\ -0,147 & -0,289 & 0,436 \\ 0,615 & -0,515 & -0,1 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (4)$$

For both, Y represents the luminance component.

Some works have been done on watermarking for colored images. Kutter proposes a method using a binary mark, where modifications are either additive or subtractive, and proportional to the luminance. This method is based on amplitude modulation. He defines that⁴ for tri-chromatic representation, the blue channel is the best support for the mark. Indeed, in a psycho-visual view, this canal is the less sensitive to disturbance.

To resolve the problem of degradation on an image, Fleet and Heeger⁶ propose a scheme based on a psycho-visual model. They use the $CIELAB$ space and present the $S-CIELAB$. The mark is introduced to the b component (yellow/blue) in the frequencies domain. The force of integration of the mark is enslaving by the psycho-visual model $CIE Lab$, and $S-CIELAB$ allows measuring the psycho-visual impact of the image modification. This method is particularly robust against analogic attacks (printing and scanning).

Mussa and al⁵ proposed a watermark where the robustness of the mark is depending of its size, its nature and the host image. It's using wavelet decomposition algorithm and the place of embedding is depending of the channel.

Experimental Results

Chromatic Spaces

About chromatic spaces (RGB and XYZ), our results confirm Kutter results⁴: embedding the blue channel does not visually degrade the image. The problem encountered is the non-robustness of the mark in blue component. However, the inverse problem is showed for green component: integrated mark in that component is robust but can degrade image. There is no intermediate solution for those spaces.

For example, we mark with a force $K = 4$ (experimentally define as the best compromise between invisibility and robustness) the three components of an image, define first in RGB , then in XYZ .

In the general case (for different images), we have concluded that only the second component G of RGB is robust; we are sure to obtain $CC_G > 0,5$. For the same quality of image, the components X and Y of RGB are robust; we are sure to obtain $CC_X > 0,6$ and $CC_Y > 0,7$. For the robust view, it will be more interesting to work with the XYZ space than the RGB . Results in those spaces well robustness and invisibility compromise: watermarking degrade lightly the image and the correlation coefficient is not efficient.

About the third channel (based on red), watermarking can be just a supplemental secure, because it is not very robust for a non-degraded result image.

The observed degradation is localised in the uniform area (the sky for example). At the end of this section, we will propose some methods to eliminate this kind of problem, and to improve this watermarking technique.


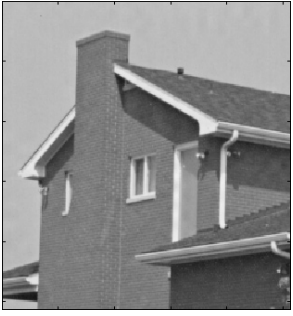

	← Original Image	
		
$CC_R = 0,2969$ $CC_G = 0,7109$ $CC_B = 0,4219$	$CC_X = 0,7188$ $CC_Y = 0,8047$ $CC_Z = 0,3438$	

Figure 2. Degradation and robustness for RGB and XYZ spaces.






Image result	Force	Robustness
	$K_Y=5$	$CC_Y=0.7188$
	$K_Q=1$	$CC_Q=0.4219$
	$K_Y=4$	$CC_Y=0.2969$
	$K_V=4$	$CC_V=0.7109$
	$K_W=4$	$CC_W=0.4219$

Figure 3. Degradation and robustness for YIQ and YUV spaces

▪ *Achromatic Spaces*

About spaces defined by one luminance component and two chromatic components, we work the same as previously. First, we know that we can not mark with high force the luminance component, because of its high impact on human visual system. We will see that we can choose to mark *Y* component with a force $K = 4$, which define the best compromise between invisibility and robustness.

For every luminance component of an achromatic space, it is not possible to apply a force superior to $K = 4$ (i.e. it must be $K \geq 4$). For $K < 4$, it provokes degradations, and for a force which does not degrade the image, the correlation coefficient is low ($CC < 0.35$). For the chromatic component, see figure 3 for example. (We show the best obtained results.)

For *YIQ* space, we obtain interesting result: we can mark with an important force ($K=1$) the *Q* component, without degraded image, with giving $CC_Q > 0,35$. However, embedding *I* component (even if $K > 4$), highly degrades image and the mark is absolutely not robust.

For *YUV* space, the equal marking of the three component, with a force $K=4$, is a possible method which gives a good ratio between degradation and robustness.

We also remark that degradations are localised in uniform area of images.

For this kind of spaces, the luminance is the most important component for human visual system. So the force of the embedded mark can not be important. In a general case, watermarking the two chromatic components is affected by the passage from the RGB space to the space studied and inversely.

Discussion

The color representation (chromaticity diagram), cf. fig 4 and 5, shows the different distances between colors.

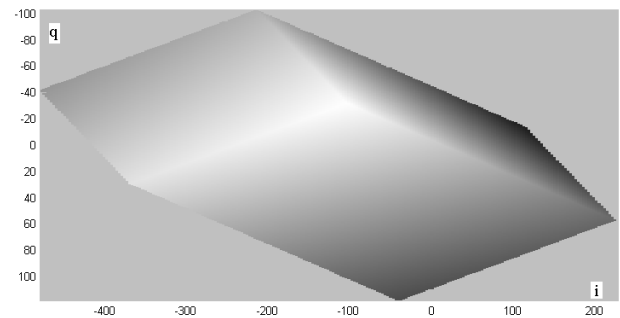


Figure 4. Chromaticity diagram *iq* of *YIQ* space

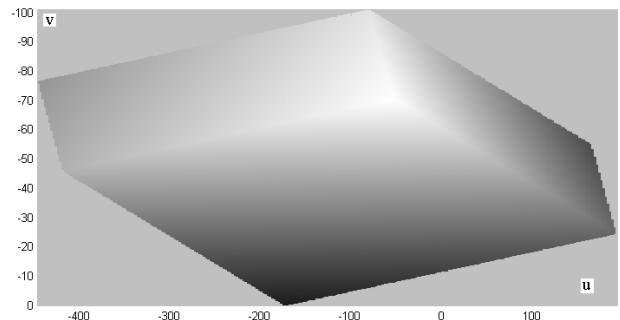


Figure 5. Chromaticity diagram *uv* of *YUV* space

During the reconstruction stage of the marked image into the RGB space, distortions, introduced by the watermarking into the studied space, are more or less reduced. For a distance of difference between original color and watermarked color, define for example in YUV for blue area, the equivalent distance in RGB will be smaller. Those modifications can or not introduce degradation in the image for the human visual system.

To resolve problem of degradation, we can apply a pre-segmentation of the image before watermarking. The aim of this operation is to localise the area with the maximum of coefficients energy, i.e. the more textured area. It's call the second generation watermarking scheme and is defined in Ref. 3.

To grow the robustness of a mark, we propose to work with an error code corrector. The principle of this method is to determine the binary code of the signature (name, invoice number, etc.), and to define an error code corrector. According to the use of the bit, it will be, for example, repeat in the sequence.

Conclusion

To watermark color image, we must take care of the use space. Each component of each space has different quality of robustness and different impact on the visual human system. About chromatic space, we have observed that watermarked blue channel does not degraded image but the mark is not robust. Inversely, the green channel offers good robustness of the mark, but can easily degrade the image. This problem is good representation of the compromise between robustness and invisibility.

About achromatic spaces, watermarking the luminance component is possible if the force is not too important. Indeed, this component is the more important

regard to the human visual system. This watermarking is just a supplementary secure because it is not very robust for a non-degraded result image.

The idea we can proposed that is some watermark provoke a color modification visible or not to the human visual system, for the same force of watermarking.

In the general case, the use of a second generation watermarking scheme and of a 'intelligent' mark will be the next stage to improve the technique.

In this next stage, we will have to develop this structure versus different types of attacks (the only one treated is the JPEG compression), and a scheme to mathematically evaluated the psycho-visual degradation.

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