Watermarking of color images based on segmentation of the xyz color space

Gaël Chareyron[1], Benoit Macq[2] and Alain Tremeau[1]

[1] Laboratoire LIGIV EA 3070 – Université Jean Monnet Saint Etienne - FRANCE

[2] Laboratoire TELE – Université Catholique de Louvain Louvain-la-Neuve – BELGIUM

Abstract

We have followed a new strategy of watermarking based on histogram specification. Our objective was first to extend the histogram specification method proposed by Coltuc to chromatic (2D) histogram and next to color (3D) histogram.

This paper proposes a method to embed a watermark signal into a color image from the xy chromatic plane. The aims of this scheme are to resist to space deformation (e.g. rotation and scale change) and to cropping. We will explain firstly how the pattern used to modify the chromatic distribution of the image is defined and generated by a secret key, next how chromatic values belonging to the pattern are changed to insert watermark.

To improve imperceptibility of watermark color distances corresponding to color changes are computed in the L*a*b* color space, so that we can evaluate the degradation of the image.

Watermark detection is fast and blind, i.e. only the watermarked image and keys are needed, and not the original image. One part of this paper is devoted to 2D watermark patterns meanwhile the following part is devoted to 3D watermark patterns. Experiment done showed that our new watermark strategy is resistant against scale change or cropping and that 3D pattern improves the process.

Introduction

In this paper we present a new method of watermarking designed for color images. Watermarking techniques generally sign images by introducing changes that are imperceptible to the human visual system but are easily recoverable by a computer program. Consequently, the locations of the signature, which is embedded in the image, are determined by a secret key in order to prevent possible attacks by pirates. Meanwhile lot of methods had been proposed to watermark grey level images, only few methods have been devoted to color images. Kutter [2], next Tao and Orchard [4], proposed to carefully select a color channel (e.g. the blue channel) in order to minimize perceptual changes in the watermarked image. Van Schyndel [3] proposed to introduce watermarking in the hue angle of the HVS coded color image.

We have followed a new strategy of watermarking based on histogram specification. Our objective was first to extend the histogram specification method proposed by Coltuc [1] to chromatic (2D) histogram and next to extend it to color (3D) histogram.

In the first part of this paper we explain how we embed a watermark signal into a color image from the xy chromatic plane. The proposed method aims to introduce a watermark that can resist to space deformation (e.g. rotation and scale change) and to cropping. In the second part, we present firstly how the pattern, used to modify the chromatic distribution of the image, is defined and generated by a secret key, next we explain how chromatic values belonging to the pattern are changed to insert watermark.

In order to minimize visual effects due to the watermark process, we have computed color distances (ΔE) in the L*a*b* color space. Indeed, if color changes are enough small in the L*a*b* color space they are imperceptible to the Human Visual System.

In the last part of this paper, we explain how to extract the watermark signal without using the original image.

Insertion of the watermark

To insert the watermark the following method is used.

Firstly we generate a 2D pattern with a secret key. The pattern is a 2D mask digitized with squared cells. Each cell is either black or white (see examples given by Figure 2). We have used a 1024x1024 mask in order to digitize the xy chromatic plane with 10 bits by component. With 10 bits per component the digitalization of xy plane is imperceptible to the human visual system. The size of cells can be changed from 1x1 to 6x6[1].

In the first stage of the process RGB color data computed from the image are converted in a xyY color image. Thus:

[1] This corresponds to digitize the xy chromatic plane from 10 bits to 5 bits.

1. a matrix transformation is used to convert RGB to XYZ,
2. XYZ coordinates are converted to xyz.

The XYZ system used corresponds to the CIE 1931 XYZ color space [5]. Let us recall that the XYZ color space is based on the principle of the “standard observer” whose spectral response corresponds more or less to the average response of the human visual system. It is also useful to recall that this 3D color space is linear.

It is common to project this space to the X+Y+Z=1 plane. The result is a 2D space known as the CIE xy chromaticity diagram. As example, in the Figure 1, we can see the representation of images “Lenna” and “Parrots” in xyY space and in xy chromatic plane .

The watermark will be next applied in this color space.

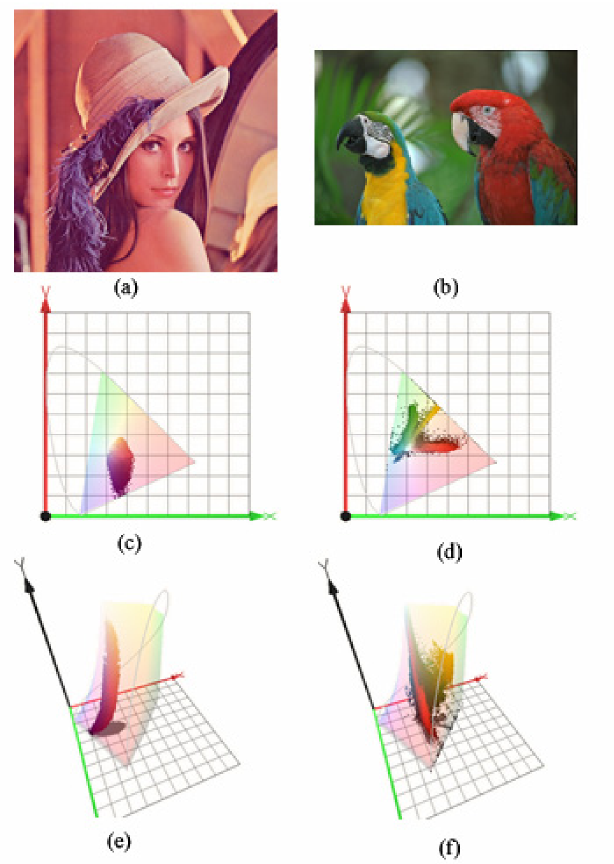


Figure 1: Representation of Image “Lenna” (a) and “Parrots” (b) in xyY color space (e and f) and in xy chromatic plane (c and d).

In the second stage of the process a look up table is computed; at each color of the image is associated an index value computed from its xyz coordinates.

2D watermark process

In a first time, we have developed a 2D watermark strategy. A pattern was then used to select points to keep in the xy plane.

Meanwhile points belonging to a black cell conserve their color; points belonging to a white cell are changed. So, we define two categories of points: « the good ones and the bad ones ». Bad points are then substituted by good points according to the following process:

- at each bad point of the chromatic plane is associated the color of the nearest point among the group of good points neighboring it.

In order to prevent the addition of false colors during the specification of the signature into the chromatic plane, i.e. into the color image, this process uses only colors of the original image.

The process used to select the nearest good point neighboring a bad point, i.e. the closest color belonging to the original distribution corresponding to the color to change, is based on the minimization of color distances in the L*a*b* color space. This space is used because it is considered as uniform for the Human Visual System [5], that is to say computed distances between colors are closed to perceptive distances.

Next after having changed the color of bad points, a new image is generated with watermark embedded. The process of insertion is summarized in Figure 3. In this example we have used a regular binary pattern; in other cases we have use other patterns such as a signature. As example, see Figure 2.

a b

Figure 2: Two examples of patterns

Reading the watermark

To decode the watermark, the user needs to know the secret key used to generate the pattern. It is important to note that the process does not require knowing the original image. To decode the watermark the following process is then applied:

- in a first stage, a look up table of the watermarked image is computed; at each color of the image is associated an index value computed from its xyz coordinates.
- in a second stage, the process search for each point if its xy coordinates belong to a black cell or a white cell of the pattern.

Considering that if the image has been signed with the key considered then there is no point in the white zone, the process counts the number of good and bad points and next decides if the image has been watermarked or not.

Experimentations

We have tested the proposed method on different types of images and with different sizes of cells to see the resistance of the watermark in regards to different patterns. AS example, in Figure 4, we have used a 1024x1024 pattern and we have tested different sizes of cell.

Let us note that the higher the size of cells is the lower the perceptive quality of the image studied is.

Another important thing to note is that: if we use only one pattern to watermark the image the signature is easily perceptible. To prevent this problem, we propose to use two complementary signatures on two complementary portions of the image and to use the following process:

1. Firstly, a partitioning in two classes of the image is done. The partitioning process that we have used is also defined by a secret key.
2. The portion of image corresponding to the first class is then watermarked with the first pattern previously defined (i.e. the “bad points” are changed from “good points”).
3. Next, the second portion of image corresponding to the second class is watermarked with the inverse pattern corresponding to the previous one (i.e. the “good points” are changed from “bad points”).

This method protects the signature and a pirate will not be able to estimate the signature.

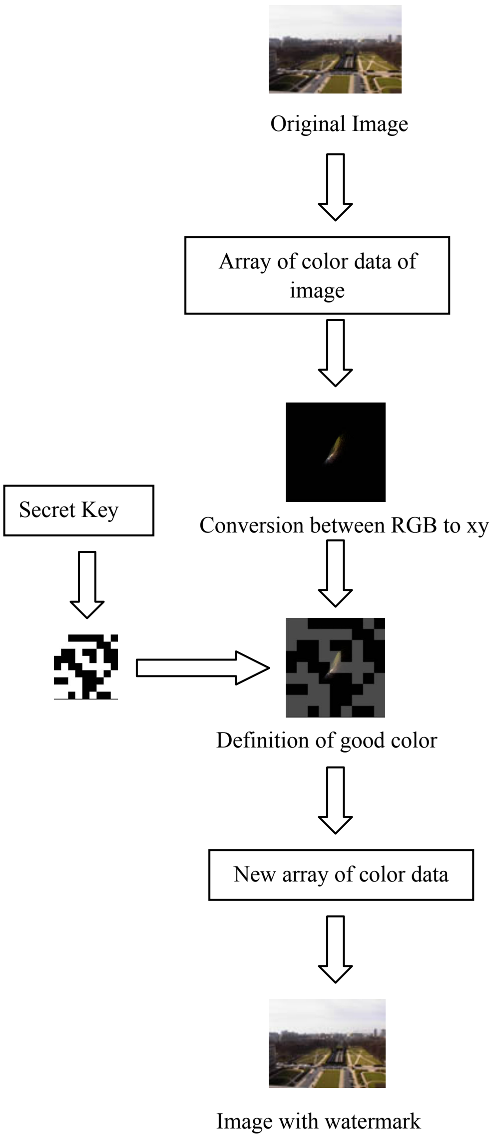


Figure 3: Strategy of watermark insertion

3D watermark process

Another way to protect the embedded signature is to use a 3D pattern to sign the picture. In that way the signature is not easily perceptible due to the fact that when we analyze a 2D or 3D map of the image in xyz space color we can’t estimate the pattern.

In order to generate a 3D pattern:

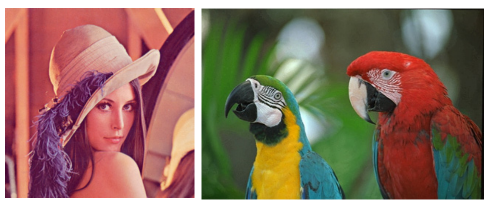
1. several 2D pattern are generated by a key,
2. all 2D patterns are piled.

Nevertheless we use 2D pattern or his inverse in the pile. This pile sequence is generated by the same key as the 2D pattern. It is also possible to use a 3D pattern generated completely by a pseudo-random sequence without repetition.

We can see in Figure 5 how the watermark is more or less perceptible with a watermark strategy based on xy (a), z (b) or xyz (c). When we use watermark strategy based on xy or z, the signature is visible whereas with watermark strategy based on xyz the signature is imperceptible.

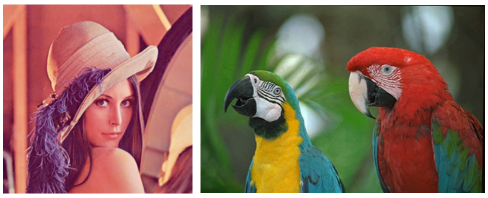
We have tried different attacks on our “simple”, “double”, or 3D watermarking. These attacks modify the geometry of the picture but not the color of image. Our watermark resists to the majority of geometrical attacks if you don’t use interpolation or filter.

Actually the signature resists only to deformation on image. In figure 7, we give some examples the ratio of good and bad pixels versus several attacks.

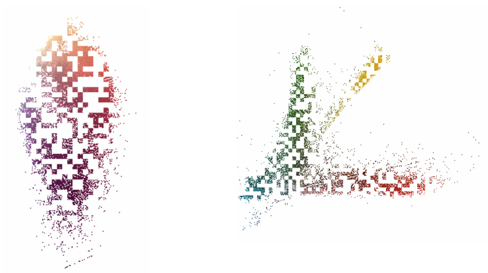


Size of cells : 2x2 points

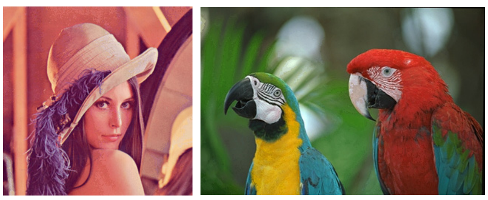
Detail of chromatic plane



Size of cells : 6x6 points



Detail of chromatic plane



Size of cells : 12x12 points

Detail of chromatic plane

Figure 4: Impact of size of cells in regards to perceptive quality of image

If we don't use any filter the ratio of bad pixel remains 0. We have tried also different patterns, such as pattern given in Figure 2b. We can see in Figure 6 the chromatic representation in xy space of an image signed with a signature as pattern.

Watermarked Image	Representation in xy space

Figure 6: Example of watermark with pattern given in Figure 1b

Conclusion and perspectives

In this study we have introduced a new method to watermark color images. This method resists to geometrical deformation but not to major color histograms changes. With a 3D pattern strategy we have improved integration of watermark in the image to prevent extraction of mark by a pirate. The next step will consist to improve the resistance of this method to a higher number of attacks. Even if many improvements have been realized in regards to other methods, other improvements are under study. The first one consists to up for 3D (xyY) to 4D (Video).

In this study we have developed a method in xyY color space. The next step will consist to implement, to extend it to other color spaces such as L*a*b* or YCrCb (color space used in JPEG and MPEG standards). Another study will be also done to optimize the signature from new patterns. Indeed, as the central region in xyY color space is achromatic we consider that it's not necessary to mark in.

Currently we work on 3D color space patterns to increase the resistance of the watermark process and to reduce the perceptive degradations on images.

Bibliography

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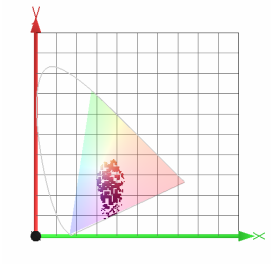
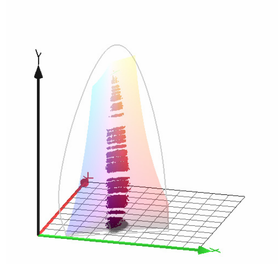
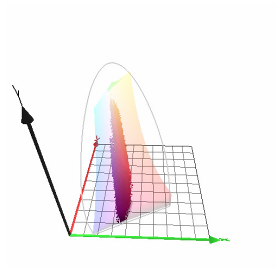


(a)



(b)



(c)

Figure 5 : Representation of image "Lenna" watermarked by a 2D (a), 1D(b), 3D (c) pattern.

Biography

G. Chareyron receives his master degree in Color Science from Université Jean Monnet of Saint-Etienne in 2001 and is preparing a PhD thesis in color image analysis. He works in the laboratory LIGIV at the Université de Saint-Etienne, under direction of Professor Alain Tremeau. His doctoral work is based on the development of a watermarking system devoted to color images.

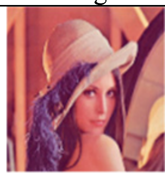
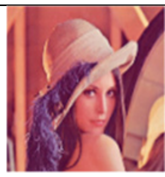
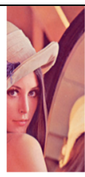
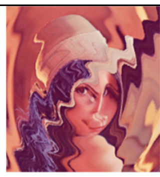
Image	Deformation	Result
	Scale 50 %	Number of pixel detected as good: 16384 Number of pixel detected as bad: 0
	Scale 200 %	Number of pixel detected as good: 262144 Number of pixel detected as bad: 0
	Cropping	Number of pixel detected as good: 33280 Number of pixel detected as bad: 0
	Free rotation	Number of pixel detected as good: 45353 Number of pixel detected as bad: 0
	90° rotation	Number of pixel detected as good: 37627 Number of pixel detected as bad: 0
	Wavelet	Number of pixel detected as good: 65536 Number of pixel detected as bad: 0
	Original watermarked	Number of pixel detected as good: 65536 Number of pixel detected as bad: 0
	Original	Number of pixel detected as good: 29546 Number of pixel detected as bad: 35990

Figure 7: Several attacks on image "Lenna" and ratio of "bad" pixels detected.