A new image watermarking using texture component: application color image

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Abstract

This paper presents a new robust watermarking scheme for color image based on Partial Differential Equations (PDE). Specifically, the mark is inserted in to texture component obtained after decomposition of the image by PDE. The watermark used is a binary matrix for the texture component. Experimentation has ensured the mark invisibility, the facility of detection of the mark and the robustness against different kinds of attacks.

Keywords: *Partial differential equations, texture component, watermarking, robustness, watermarking attacks, watermark invisibility.*

1. Introduction

With the increasing use of internet and effortless copying, tempering and distribution of digital data, copyright protection for multimedia data has become an important issue. Digital watermarking emerged as a tool for protecting the multimedia data from copyright infringement.

In digital watermarking an imperceptible signal “mark” is embedded into the host image, which uniquely identifies the ownership. After embedding the watermark, there should be no perceptual degradation. These watermarks should not be removable by unauthorized person and should be robust against intentional and unintentional attacks.

The most important issues in image watermarking are the invisibility of the watermark and the resilience of watermarking to attacks. A variety of watermarking techniques has been proposed recently in the literature [1]-[2]-[3], meanwhile each method proves its efficiency against special attacks and none of them is totally effective against malicious attacks.

The image watermarking algorithms can be classified into two categories: spatial-domain techniques [4]-[5] (spatial watermarks) and frequency-domain techniques [6]-[7]-[8] (spectral watermarks). The spatial-domain techniques directly modify the intensities or color values of some selected pixels while the frequency-domain techniques modify the values of some transformed coefficients.

In the work presented here, we use the spatial domain. So, the watermark embedding is achieved by modifying the pixel values of texture component obtained by decomposing the host image using the PDE.

We propose a realistic improvement which is performed under a convenient decomposition of the textured image. This decomposition is based on the mathematical model in the PDE introduced by Meyer [9] which split an image into a geometrical and texture component. The basis idea of our method is to insert a different mark into the each component after decomposing the image by the PDE. This scheme of insertion has the merit to provide a good performance of detection of the mark against attacks because of the redundancy of the watermark in the watermarked image. The rest of the paper is organized as follows. Section 2 describes the proposed watermarking method and in section3, the experimental results are discussed. Finally, some conclusions are drawn in section 4.

2. Proposed Method

During the past two decades, image processing, has attracted the attention of many mathematicians. then the combination of image processing, vision analysis and mathematical model, has given rise to new discoveries as well as revived various classical subjects. Mathematics has provided the solid ground for solving many challenging imaging and vision problems in a unified and mass-production manner.

In the context of color textured images, this study presents a new approach where we proceed firstly to a decomposition of the original image into two components. Then the insertion of watermark scheme is applied not

directly on the original image but on the texture component obtained by the PDE.
Section II.1 explains the decomposition models of image, section II.2 defines Watermark embedding and section II.3 defines watermark detection.

2.1 Decomposition model

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Let u be the true image and f the distorted image. Then the model of ROF invented by Rudin, Osher and Fatemi to solve is:

$$\min\left\{\alpha J(u) + 1/2\|u-f\|_2^2\right\}$$

Where J is the Total Variation regularization:

$$J(u) = \int_\Omega |\nabla u| dx$$

.

∇ denotes the spatial gradient .α measures the tradeoff between the regularization and the best fit to the noisy data. This model decompose an image f into a component u and a component v= f - u; which is supposed to be the noise. In [9] Meyer out some limitations of the ROF model.

$$\inf_{(u,v)\in BV\times G/\, f=u+v}\left\{J(u) + \alpha\|v\|_G\right\}$$

Where BV is the space of functions of bounded variation [10] and G is the space of oscillating functions (in particular textures and noise).
Inspired by this works, many numerical algorithms have been developed to carry out the decomposition of grayscale images [11], [12] and [13].
For color images, an extension has been recently proposed [14].The version of model, can be expressed as

$$\inf_{(\vec{u},\vec{v})}\left\{F(\vec{u},\vec{v}) = \int|\nabla\vec{u}| + \lambda\|\vec{v}\|_{L^2}^2,\ \vec{f} = \vec{u}+\vec{v}\right\}$$

For u=(u1,u2,u3), this can be approximated by

$$\inf_{\vec{u}\in BV} F(\vec{u}) = \int\sqrt{|\nabla u_1|^2 + |\nabla u_2|^2 + |\nabla u_3|^2} + \lambda\sum_{i=1}^{3}\int|f_i - u_i|^2 dxdy$$

Formally minimizing the above energy with respect to u1,u2 and u3 , we obtain the following system of PDE's:

$$\begin{cases} u_1 = f_1 + \dfrac{1}{2\lambda}div\left(\dfrac{\nabla u_1}{|\nabla\vec{u}|}\right), \\ u_2 = f_2 + \dfrac{1}{2\lambda}div\left(\dfrac{\nabla u_2}{|\nabla\vec{u}|}\right), \\ u_3 = f_3 + \dfrac{1}{2\lambda}div\left(\dfrac{\nabla u_3}{|\nabla\vec{u}|}\right). \end{cases}$$

Then, the function (residual) representing noise or texture in the vector ROF model is $\vec{v} := \vec{f} - \vec{u}$
Given by:

$$\vec{v} = -\frac{1}{2\lambda}\left(div\left(\frac{\nabla u_1}{|\nabla\vec{u}|}\right), div\left(\frac{\nabla u_2}{|\nabla\vec{u}|}\right), div\left(\frac{\nabla u_3}{|\nabla\vec{u}|}\right)\right),$$

u ∈ BV containing the structure of the image, a second one, v ∈ G the texture.
The parameter λ controls the L2– norm of the residual f - u - v. He smaller λ is, the smaller the L2 norm of the residual f - u - v is. The larger μ is, the more v contains information, and therefore the more u is averaged. Figure 1 shows the results of this algorithm with λ = 0,5 and μ = 140.
In Fig 1 we present an example of decomposition of a color image.

fig 1: Color decomposition: (a) initial image f, (b) cartoon component u, (c) texture component v.

2.2 Watermark embedding using decomposition model

As a first application of image watermarking using the Texture Component after decomposition by the model introduced by Meyer [9], we will use the "Patchwork" algorithm; proposed by Bender and Al [15]. We will apply the additive watermarking scheme to texture component obtained by the PDE where the watermark is a binary matrix in {- 1, 1}, and at the end watermarked image is reconstructed by adding the watermarked texture component and carton component (see Figure 2). The watermark insertion scheme is as follow:
Step.1 Decompose the original image to the two components:
f = u + v
u is the Geometrical component ,v is the texture component.
Step.2: for texture component, using a secret private key to select randomly a sequence of n couples of pixels (A ,B) to be modified lightly in such a way to increase (or decrease) by a unit the intensity value of the pixels of the type A and to decrease (or increase) by a unit the intensity value of the pixels of the type B .
Step.3: Embedding in texture component the equivalent mark: $v_w = v + \alpha * R$
with

$$R = \begin{cases} 1 & if \quad pixel\ are\ in\ A \\ -1 & if \quad pixel\ are\ in\ B \\ 0 & others \end{cases}$$

v_w is the watermarked texture component, α is a ponderation and R is the binary watermark matrix .

Step.4: Building the watermarked image by adding the watermarked component of the decomposition of the original image by model introduced by Meyer:

$$f_w = u + v_w$$

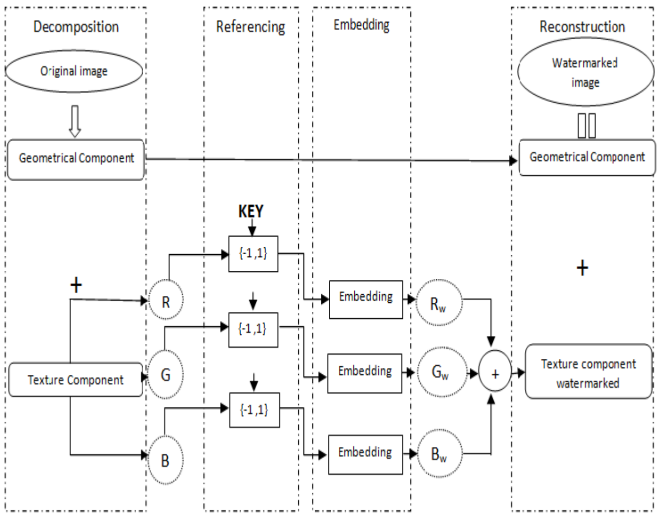

Fig 2: Diagram of the image watermarking method using decomposition model

2.3 Watermark detection using decomposition model

Full the watermark detection is done by operation dual of the one used in image watermarking process (Figure.3).The watermark detection scheme is as follow:

Step.1: Decompose the watermarked image to the Geometrical component, Texture component:

$f_w = u + v_w$

Step.2: For texture component v_w using the secret private key; used in the referencing stage in the watermarking process; select the sequence of n couples pixels (A, B) in the v_w to be modified lightly in such a way to increase (or decrease) by a unit the intensity value of the pixels of the type A and to decrease (or increase) by a unit the intensity value of the pixels of the type B.

Step.3: Extraction of the watermark from texture component:

$v^* = v_w + \alpha * R$ with

$$R = \begin{cases} 1 & if \quad pixel\ are\ in\ A \\ -1 & if \quad pixel\ are\ in\ B \\ 0 & others \end{cases}$$

v_w is the watermarked component, v* is component after extracting the watermark, α is a ponderation and R is the binary watermark matrix.

Step.4: Verifying the existence of the watermark by a threshold on the result of correlation between v* and v, and between the original image and the image after extraction of the watermark.

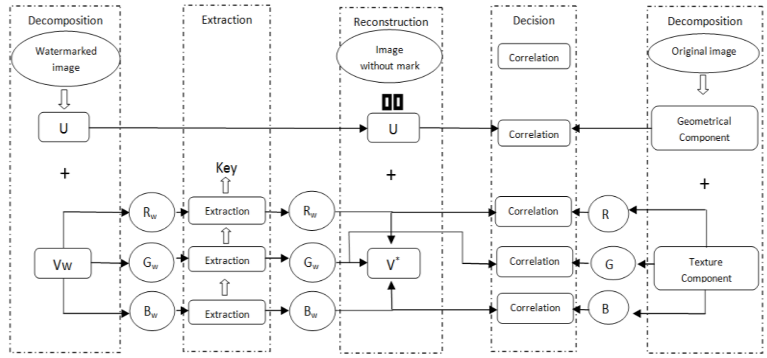

Fig 3: Diagram of watermark detection method using decomposition model

3. Experimental results

3.1 Watermark detection using decomposition model

A first application is to test our method for a color image of 300 x 237 and try to extract the watermark without any attack on the watermarked image.

Embedding :In Figure 4 we presented in (a) the image before insertion of the watermark (original image), in (b) the watermarked image is presented to show the invisibility of the watermark in the watermarked image and at the end in (c) the difference (the watermark) between the original image and the watermarked image is presented.

Fig 4:.Watermark embedding: a) Original image, b) Watermarked image, c) difference between original image and watermarked image.

It is clear that the first characteristic of a watermarking method which is the invisibility of the watermark is respected in our method.

Detection: We presented in Figure 5 the results of the detection of the watermark in the watermarked image. So, to verify the existence of the mark in the watermarked image, a measure of correlation between the watermarked image after extraction of the watermark and the original image is done.

If there are no attacks the detection of the watermark is done without any problem.

Image	1
Geometrical component	1
Texture component	1

(a) (b) (c)

Fig 5: Detection of the existence of the watermark without any attack: a) Watermarked image, b) image after extraction of the watermark, c) correlation between the watermarked image after extraction of the watermark and the original image as well as the correlation between the two component (geometrical and texture).

3.2 Robustness of the method against attacks

Certainly once watermarked images are diffused in the internet can beings victim of attacks and arbitrary transformed. If these attacks do not much degrade the watermarked image, a robust watermarking method should detect the watermark as long as the watermarked image quality is not rendered useless. So, to test the robustness of our method against attacks, we will present some examples of attacks/detection.

3.2.1 Robustness against white noise attack:

the noise in our image is considered to be additive: the image f is decomposed into three components u + v+ w, where u is the geometrical component ,v should contain the textures of the original image, and w the noise [16].

That means that the problem of noise attacks on the watermarked images could be treated at the w component without influencing a lot the other component.

F - w = u + v: image after reducing the noise.

Image	0,99999
Geometrical component	1
Texture component	0,99999

(a) (b) (c)

Fig 6:a) Watermarked Image with white noise, b) Watermarked image after reducing the noise, c) correlation between the watermarked image after extraction of the watermark and the original image as well as the correlation between the two components (u and v only).

3.2.2 Robustness against white noise attack:

Image compression consists in transmitting only the significant components, and since the watermark is invisible in the watermarked image it will be seen in the compression process as non useful information. To remedy this problem Cox and al [17] proposed to insert the watermark in significant places in the image. The idea to make our method robust to the JPEG compression is to modify the DCT coefficients [18] of each components en the JPEG process as follow:

Split each components into non-overlapping 8x8 blocks.

- Take the two-dimensional DCT of each block.
- Scanning the DCT component matrix in zigzag pattern to keep only significant components located in the upper left corner.
- Finally, the modifications are done on the low frequency coefficient quantified triplet. In this way we are sure that the watermark will be not removed from the image and also it will be invisible

The existence of the watermark is checked by comparing the original image and the decompressed image watermarked image after extracting the watermark.

Image	0,99615
Geometrical component	0,9989
Texture component	0,9932

(a) (b) (c)

Fig 7:a) watermarked image JPEG compressed using quality 50%, b) Image after watermark extraction, c) Correlation between the two images

In Figure.7, we presented the watermarked image with quality factor equal to 50%, the image after extracting the watermark and the correlation between the two images and each component. The correlation results show that the watermark exists in the watermarked image after Jpeg compression and decompression.

4. Conclusions

In this paper we presented a new and robust watermarking technique for texture color image based on Partial Differential Equations. It consists to insert the mark into texture components. So we can ensure the redundancy of the watermark into the watermarked image. In this way, we can say that we proposed a new way that gives more robustness with respect to methods aiming to extract the watermark.

Although, we did not present the robustness of the method with respect to all the attacks but seen the results presented here, our method presents an excellent behavior against noise and JPEG compressions attacks which lets us say that it is very promising images watermarking method.

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