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The Image Watermarking Scheme Using Edge Information in YCbCr Color Space

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Abstract. In this paper, we propose the spatial domain based watermarking scheme for color images. The proposed scheme embeds the watermark into cover image in YCbCr (Luminance, chrominance) components of the color cover image. This scheme uses the Sobel and Canny edge detection methods to determine edge information of the Luminance and chrominance components of the color image. The edge detection methods are used to determine the embedding capacity of each color components. The large capacities of watermark bits are embedded into a component of large edge information. The robustness of the proposed scheme is analyzed considering different types of image processing attacks, like blurring and adding noise.

Keywords: Edge, Watermarking, Color space, robust, Perceptual similar, RGB, YCbCr.

1. Introduction

The color space representation has played a major role in coding, compression, transmission, pattern recognition and digital multimedia applications. Furthermore, color has become more recently a major component in watermarking applications of multimedia contents [1]. As digital technology allows unauthorized reproduction of color digital images, the protection of the copy rights of digital image is a very important issue. The image watermarking schemes are used to protect the copy rights of digital images [2]. The watermarking schemes will use the methods of embedding information transparently into a cover image. In image watermarking the copyright data is embedded imperceptibly inside the cover image such that it is difficult to extract or alter the watermark by various image processing attacks [4]. Several schemes have been proposed to embed the watermark in gray-scale images [14]. But, very few schemes have been designed for color images. In color images the embedding of watermark may be done either in spatial domain or frequency domain [5]. The Spatial domain schemes embed the watermark by directly modifying the color intensity values of the cover image and these schemes are less complex in computation [2]. On the other hand, frequency domain schemes [6], [7] embed the watermark by modulating the frequency coefficients of the transformed image. The most widely used frequency transformed domains used for watermarking are Discrete Cosine Transform (DCT) [8], Discrete Fourier Transform (DFT) and Discrete Wavelet Transformation (DWT) [7], [9], [4], [10], [11].

In color image watermarking schemes, the embedding will be carried by considering different representations of the color space. The most widely used color representations are *RGB, YUV, YCbCr, HSV* and *CIElab* [10]. The YUV representation is used in watermarking of color information in television systems, where as the YCbCr is used in digital watermarking of color information in video and still-image [2]. One of the important issue in color image watermarking is to find the appropriated color space for embedding the watermark. The RGB color space representation has the most correlated components, while the *YCbCr* color components are the least correlated components [4]. The forward and backward transforms between RGB

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and *YCbCr* color spaces are linear. The correlated RGB components are not suitable to embed the watermark. In RGB color space the perceived color quality of an image is dependent on all components. Thus, embedding watermark bits into one component independently of the other RGB components is not the best choice. On the other hand the *YCbCr* permits to extract uncorrelated components and it favor the separation of the achromatic part from the chromatic parts of the color image. To achieve high robustness and large embedding capacity, the proposed scheme uses the least correlated *YCbCr* components of the color image. This scheme embeds the pseudo random sequence of binary watermark bits into color image. The color image is represented by *Y, Cb* and *Cr* components. From these three components, the change in the intensity of chrominance components is the most sensitive to human eyes whereas for luminance components are least sensitive [3]. Thus, the proposed scheme uses the luminance component for embedding the watermark.

The paper is organized as follows: In Section 2 the edge detection methods are explained. The proposed schemes with embedding and extraction algorithm are described in Section 3. The results and discussions are given in Section 4. The effects of the image processing attacks are analyzed in Section 5. The paper is concluded in Section 6.

2. Edge Detection Method

The edge detection is the process of identifying and locating the sharp discontinuities in an image [21]. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in an image. There are many edge detection operators available, each operator is sensitive to certain types of edges. The variable factors which are involved in selection of an edge detection algorithm include:

2.1.1. **Edge orientation:** The geometry of the algorithm determines a characteristic direction in which it is most sensitive to edges. Operators can be optimized to look for horizontal, vertical, or diagonal edges.

2.1.2. **Noise environment:** Edge detection is difficult in noisy images, since both the noise and the edges contain high frequency. This attempts to reduce the noise result in blurred and distorted edges. Operators used on noisy images are typically larger in scope, so they can average enough to eliminate the localized noisy pixels.

2.1.3. **Edge structure**: Not all edges involve a step change in intensity. Effects of refraction or poor focus may results in objects with boundaries defined by a gradual change in intensity. The algorithm needs to be chosen must be responsive to gradual change.

2.2. Edge detection Techniques

2.2.1. Sobel Operator: This operator consists of a pair of 3×3 convolution kernels. The kernels are arranged such that one kernel is other kernel rotated by 90. These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid. The kernels can be applied separately to the input image to produce separate measurements of the gradient component in each orientation. These can be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient.

2.2.2. Canny's Edge Detection: The Canny edge detection algorithm is known to many as the optimal edge detector. The canny's algorithm followed a list of criteria to improve current methods of edge detection. The first and most obvious is low error rate. It is important that edges occurring in images should not be missed and there will be no responses to non-edges. The second criterion is that the edge points be well localized. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be minimal. A third criterion is to have only one response to a single edge. Based on these criteria, the canny edge detector first smooth-en the image to eliminate the noise. Then it finds the image gradient to highlight regions with high spatial derivatives.

3. Proposed Scheme

The proposed scheme uses the color image I of size $m \times n$ as the cover image and the watermark W of size P bits. The color image is transformed into R, G and B components of size $m \times n$ R, G and B component are transformed into Y, Cb and Cr components using following equations:

$$Y = 0.299 \times R + 0.587 \times G + 0.114 \times B \tag{1}$$
$$Cb = 0.596 \times R - 0.275 \times G - 0.321 \times B \tag{2}$$

$$Cr = 0.212 \times R - 0.523 \times G - 0.311 \times B \tag{3}$$

Since, the human eyes are less sensitive to change in the intensity of the Y component, the watermark bits are LSB substituted into the Y component. On Y, Cb and Cr components the Sobel and Canny edge detection methods are applied to determine the high edge components. The pixels of the high edge component are LSB substituted with watermark bits. The embedded Y, C b and C r components are transformed into RGB components using following equations:

$$R^0 = Y^0 + 0.956 \times Cb + 0.620 \times Cr \tag{4}$$
$$G^0 = Y^0 - 0.272 \times Cb + 0.647 \times Cr \tag{5}$$
$$B^0 = Y^0 - 1.108 \times Cb + 1.705 \times Cr \tag{6}$$

From the embedded *R'G'B'* components are combined to achieve watermarked color image. Fig. 1 shows the flow diagram of the embedding algorithm.

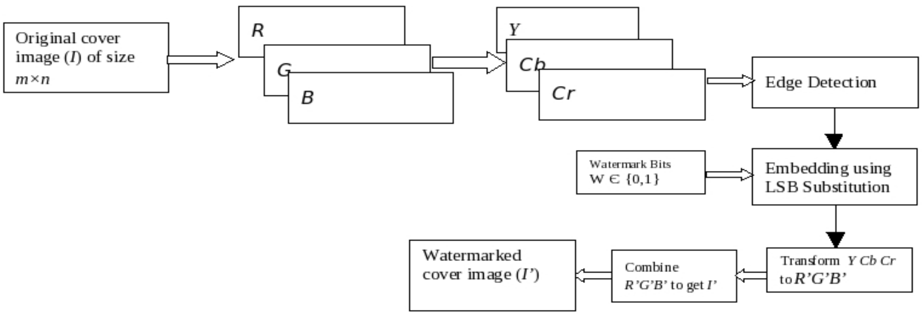

Fig. 1. Flow diagram of embedding algorithm

Algorithm: 1. Embedding

- Input: A Color cover image I of size m × n, watermark W of size P bits, where W ∈ {0, 1}
- Output: Watermarked color image I^0 of size m X n.

1) Separate R, G and B components/components of size m × n from color image I.
2) Transform R, G and B components in to Y, Cb, Cr components using *(1), (2)* and *(3)*
3) Determine Edge information from Y, Cb, Cr components using Sobel/Canny method.
4) Select the component from Y, Cb, Cr which is having large edge information i.e. Y.
5) Embed watermark bit W ∈ {0, 1}
6) Transform Y^0, Cb, Cr into R^0, G^0, B^0 components using *(4), (5)* and *(6)*
7) Combine R^0, G^0, B^0 components to generate watermarked color image I

In extraction algorithm, the scheme uses the watermarked color image I^0 of size m X n. The watermarked image is transformed into R^0, G^0 and B^0 components of size m X n. The R^0, G^0 and B^0 color components are transformed into Y^0, Cb^0 and Cr^0 using (1), (2) and (3). The edge detection methods are applied on these components to determine component which is having large edge information. The component which has large edge is considered in the extraction of the watermark bits. Fig. 2 shows the flow diagram of the extraction algorithm. The embedding and the extraction algorithms are given in Algorithm 1: and Algorithm 2: respectively.

Algorithm: 2. Extraction

- Input: A Color watermarked image I^0 of size m X n.
- Output:: Original image I of size m X n.

1) Separate R^0, G^0 and B^0 components of size $m \times n$ from watermarked color image I^0.
2) Transform R^0, G^0 and B^0 components in to Y^0, Cb^0, Cr^0 components using *(1), (2)* and *(3)*

3) Determine Edge information from each component using Sobel/canny method.
4) Select the component from Y', Cb', Cr' which is having large edge information i.e., Y'.
5) Extract watermark bit W ∈ {0, 1} from the LSB of the pixels.

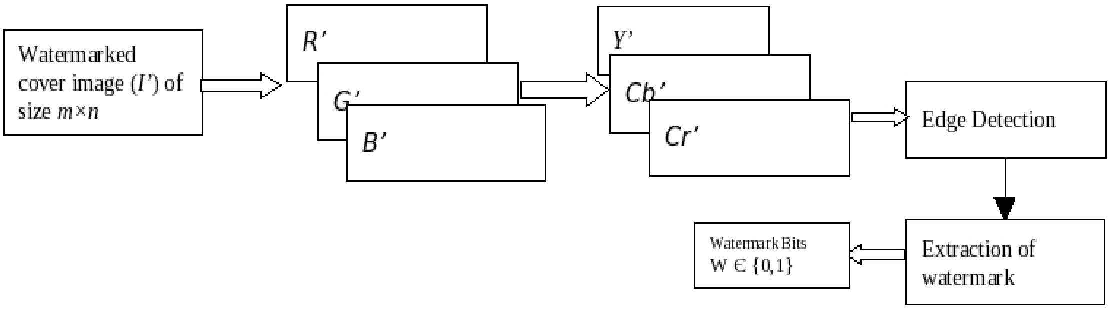

Fig. 2 Flow diagram of extraction algorithm

4. Results and Discussions

The series of experiments are conducted to analyze the effect of embedding and extraction algorithm on the color images. In these experiments, the color images of Lena, Blue hills, Sunset and Water Lilies of different sizes are considered as the cover images. The watermark W ∈ {0, 1}, is generated using pseudo random binary generator. Fig. 3 shows the color cover images considered in our experiments and Fig. 4 shows the watermarked color images. The experiments are conducted to evaluate embedding capacity of the proposed scheme using different edge detection methods. The parameters like Mean Square Error (MSE), Peak Signal to Noise ratio (PSNR), Normalized Correlation (NC) and Standard Correlation (SC) are used to measure the performance of embedding and extraction algorithms. These parameters are defined as follows:

1) **Structured Correlation (SC):** It measures how the pixel values of original image are correlated with the pixel values of modified image. When there is no distortion in modified image, then SC will be 1.

$$SC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I[i,j]-I'\right)\left(J[i,j]-J'\right)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I[i,j]-I'\right)}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(J[i,j]-J'\right)}}$$

(a) Blue Hills (b) Water Lilies (c) Sunset (d) Lena

Fig. 3: Original cover images

(a) Blue Hills (b) Water Lilies (c) Sunset (d)Lena

Fig. 4: Watermarked color images

where, $I(i, j)$ is original image, $J(i, j)$ is modified image, I' is the mean of original image and J' is mean of modified image.

2) **Normalized Correlation (NC):** It measures the similarity representation between the original

image and the modified image.

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I[i,j]\,I'[i,j]\right)}{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I[i,j]\right)^{2}}$$

where, I (i, j) is original image and I^{0}(i, j) is modified image, M is height of image and N is width of image.

3) **Mean Square Error (MSE):** It measures the average of the square of the error. The error is the amount by which the pixel value of original image differs from the pixel value of modified image.

$$MSE = \frac{\sum_{\in\{R,G,B\}}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I[i,j]_{k} - I'[i,j]_{k}\right)^{2}}{3MN}$$

where, M and N are the height and width of image respectively. $f(i, j)$ is the $(i,j)^{th}$ pixel value of the original image and $f^{0}(i,j)$ is the $(i,j)^{th}$ pixel value of modified image.

4) **Peak Signal to Noise Ratio (PSNR):** It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel. PSNR is given by

$$PSNR = \frac{10\log(2^{n}-1)^{2}}{MSE}$$

Table 1. shows the estimated values of MSE and PSNR between the original and watermarked images using Sobel edge detection method. Table 2 shows the estimated values of MSE and PSNR between the original and Watermarked images using Canny edge detection method. From the results analysis of it was observed that the Canny edge detection method will helps to determine the more edge information available in an image. Hence, using Cannyedge detection we can embed large number of watermark bits into cover images.

Table 1. PSNR and MSE between watermarked and original images for Sobel

Image Name	Size of image	MSE	PSNR (dB)
Lena	225 × 225	0.0060	26.0512
Sunset	800 × 600	0.0021	29.7994
Blue Hills	225 × 225	5.3125e − 004	35.8200
Water Lilies	800 × 600	5.3125e − 004	35.8200

Table 3. Shows the NC and SC between extracted and original watermark bits for different cover images. The experimental results show that the NC and SC for all images are equal to 1 which shows that the extracted watermark bits are completely correlated to the original watermark bits.

Table 2. PSNR and MSE between watermarked and original images for Canny

Image Name	Size of image	MSE	PSNR (dB)
Lena	225 × 225	0.0070	25.0512
Sunset	800 × 600	0.0051	27.7994
Blue Hills	225 × 225	0.0031	22.8200
Water Lilies	800 × 600	0.004	32.8200

5. Effect of attacks

In this section, we explain in brief the effect of image processing attacks against the watermarked image. The attacked watermarked image is tested and evaluated in order to validate the proposed scheme. The robustness of the proposed scheme is evaluated by considering attacks like adding Gaussian noise and Gaussian blurring. After extracting the watermark from the attacked watermarked image. The Normalized Correlation (NC) is calculated between the bits of original and extracted watermark. The following section describes the effect of adding Gaussian noise and Gaussian blurring on watermarked images.

5.1. Adding Gaussian Noise

One of the un-intentional attacks that may occur on the cover images is addition of noise. A series of experiments are conducted to analyze the effect of adding Gaussian noise to the watermarked images. The noise density is varied from

5 pixels to 25 pixels and noise is added to the watermarked images. From these watermarked images the watermark is extracted and compared with original watermark in terms of NC. Table IV shows the effect of adding Gaussian noise on the set of cover images, where the PSNR and NC of extracted watermarks with original watermark shows that the watermark are less distorted.

Table 3.: The NC and SC between the extracted and original watermark

Properties	Lena	Sunset	Blue Hills	Water Lilies
NC	1.00	1.00	1.00	1.00
SC	1.00	1.00	1.00	1.00

Table 4. The effect of adding Gaussian noise on watermarked images in terms of NC between the extracted and original watermark

Noise Density	Lena	Sunset	Blue Hills	Water Lilies
5	1	0.99	0.91	0.9
10	0.98	0.9	0.88	0.87
15	0.9	0.88	0.8	0.81
20	0.88	0.8	0.8	0.8
25	0.87	0.8	0.8	0.78

Table 5 The effect of Gaussian blurring on watermarked images in terms of NC between the extracted and original watermark

Blurring width	Lena	Sunset	Blue Hills	Water Lilies
5	1	1.00	0.99	0.90
10	0.90	0.95	0.91	0.90
15	0.90	0.89	0.90	0.80
20	0.85	0.84	0.88	0.81
25	0.82	0.81	0.81	0.81

5.2. Effect of Gaussian Blurring

The Blurring is applied on the watermarked color cover images. In the analysis of attacks we applied Gaussian blurring with radius of varied from 5 to 25 pixels. The rectangle blurring is applied by varying the blurring size from 5 pixels to 25 pixels to the watermarked images. From these watermarked images the watermark is extracted and compared with original watermark in terms of NC. Table V shows the effect of Gaussian blurring on the set of cover images. The NC and PSNR parameter shows that extracted image is perceptual similar to original watermark.

6. Conclusion

We have proposed a spatial domain based blind watermarking scheme. The *YCbCr* components are considered to embed the watermark. Since, the Y component defines large edge information the watermark is embed into the Y component. The watermark is embedded into Y component and it is very difficult to remove or destroy the watermark. The watermarking scheme is analyzed by considering various types of image processing attacks and the scheme was found robust to various types of image processing attacks.

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