Gaussian Pixel Weighting Marks in Amplitude Modulation of Color Image Watermarking with 8 Neighborhood Retrieval

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Abstract: A digital watermarking method based on Gaussian pixel-weighting marks in amplitude modulation and its retrieval method with 8 neighboring pixels are investigated in this research. The basic principle is borrowed from an amplitude modulation technique, which is applied to each channel of RGB color components of image. The proposed method utilizes a technique of weighting marks by averaging the luminance of its own pixel and its neighboring pixels in watermark embedding process. The results showed that the improved performances can be obtained when applying the Gaussian pixel-weighting marks technique, compared to equal gain pixel-weighting and no pixel-weighting marks techniques. The efficiency was further improved by utilizing the average value of 8 neighboring pixels in the retrieval process to determine the embedded watermark bits.

1. INTRODUCTION

Copyright protection for multimedia data is an important issue since rapid evolution of Internet makes digital media easy to be accessed or distributed throughout the network. As a result, replications of digital media are simple and identical to the original one. However, a technique called digital watermarking provides a good way to solve this issue. By embedding a digital signature or an identical watermark signal into the media, which indicates the ownership or intellectual property right of media creator, the

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watermark can later be extracted from an illegally distributed copy and then used to identify the author or the traitor.

The main requirements for digital watermarking are both invisibility to the human eye and robustness to alterations. One of outstanding methods applied the technique of modifying the amplitude of the image's pixels [1]. The method embeds the watermark bits into the blue channel of the pixels, and then uses average value of cross-shaped neighboring pixels to retrieve the embedded watermark bits. The results showed the acceptable outcome concerning the invisibility and robustness. However, the percentage of watermark bit retrieval was not impressive.

In this paper, a novel method for watermarking the color image is proposed to yield a higher level of robustness, and simultaneously suppress the perceptibility of the watermarked image. The embedding process based on Gaussian pixel-weighting marks is applied, while in retrieval process, the average value of eight neighboring pixels are used. The Gaussian pixel-weighting marks technique modifies the original pixel by increasing its amplitude value in blue channel with the factor of neighboring pixels' amplitude values. To retrieve the embedded watermark bit, the amplitude of the watermarked pixel is differentiated with the average amplitude values of the eight neighboring pixels to determine whether the watermark bit is one or zero. We organized the experiments into two parts, the embedding and the retrieval processes. In the experiments, we compare 3 different embedding methods, namely Gaussian pixel-weighting, equal gain weighting and no weighting marks, while in the retrieval process, we compare 2 different extracting methods, namely the average value of cross-shaped neighboring pixels and the eight neighboring pixels'. The performances of the proposed method is evaluated by the improved percentage value of correct retrieved watermark bits, and Peak Signal to Noise Ratio (PSNR) values of the watermarked image.

2. PREVIOUS WORKS

Schyndel *et al.* [2] proposed two methods that modify the Least Significant Bits (LSB) of an image based on assumption that the LSB of data are insignificant. In the first method, the LSB of the image is replaced with a pseudo-noise (PN) sequence, while the second method adds the PN sequence to the LSB of the data. These two methods however are highly sensitive to noises and easy to be destroyed, since the methods modify only the LSB. Another method based on modification of the LSB called Patchwork was proposed by [3]. In this method, n pairs (x_i, y_i) of points in the image are chosen and its brightness of x_i is increased by one unit, while simultaneously

the brightness of y_i is decreased by one. However, this method yielded the similar result to [2] since it was based on the same coefficient modification.

Recently, Tanaka *et al.* [4], [5] suggested the watermarking schemes based on the notion that quantization noise is typically imperceptible to viewers. The first scheme injects a watermark signal into the image by using predetermined data stream to guide level selection in a predictive quantizer. The data stream is chosen in such a way that the resulting image looks like quantization noise. Another one is that the watermark signal, in the form of dithering matrix, is used to dither the image in a certain way. However, the major drawback of these schemes is that they are susceptible to signal processing, especially requantization process and geometric attacks. Moreover, they degrade the image in the same way that predictive coding and dithering do. Kutter *et al.* [1] proposed the method for digitally signing the image using amplitude modulation. In this method, the watermark bits are multiply embedded by modifying pixel values in the blue channel. The robustness tests against the geometrical attacks had been conducted for many types of attack such as blurring, JPEG encoding/decoding, rotation and composition. The results showed that the method was immune to varieties of attacks previously described. One advantage brought by this method is that the watermark can be retrieved regardless of the original image.

3. FUNDAMENTAL CONCEPTS

In this section, a fundamental concepts of RGB color model, details of Gaussian pixel-weighting marks and luminance averaging are described. The RGB color model incorporates the art of human visual systems while the latter two describe in-depth concepts of pixel-weighting marks, RGB-YUV transformation and the luminance averaging.

3.1 RGB color model

Based on the tristimulus theory of vision [6], our eyes perceive color through the stimulation of three visual pigments in the cone of the retina. These visual pigments have a peak sensitivity at wavelength of about 630 nm (red), 530 nm (green), and 450 nm (blue). By comparing intensities in a light source, we perceive the color of the light. This theory of vision is the basis for displaying color output on a video monitor using the three color primaries, red, green and blue, referred to as the RGB color model.

We can represent this model with the unit cube defined on R, G, and B axes. Vertices of the cube on the axes represent the primary colors, and the remaining vertices represent the complementary color for each of the

primary colors. Thus the pixels in spatial domain can be represented by the RGB color model.

3.2 Gaussian pixel-weighting marks

Gaussian pixel-weighting marks, also known as super-sampling algorithm, is often implemented by giving more weight to sub-pixels near the center of pixel area, since we would expect these sub-pixels to be more important in determining the overall luminance of a pixel. The distribution of the weight in the masks can also be implemented with Gaussian distribution having characteristics below:

$$G_{\text{gaussian}}(x, y) = \frac{1}{ps} e^{-\frac{(x+y)^2}{s}} \quad (1)$$

Lumination for each color pixel was found by using the relationship between YUV and RGB models. In YUV color model, luminance information is contained in Y parameter while chromaticity information is incorporated in U and V parameters. The luminance carries the information on lightness and brightness. It measures the amount of energy an observer perceive from a light source and proportional to the amount of light perceived by the eye and luminance component of an image can be processed without affecting its color content [7]. The relationship between YUV and RGB is as follows:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.30 & 0.59 & 0.11 \\ -0.15 & -0.29 & 0.44 \\ 0.62 & -0.52 & -0.10 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

For each image, the variance σ^2 of luminance L can be obtained from

$$\sigma^2 = E(L^2) - [E(L)]^2 \quad (3)$$

where E is expectation value

By applying the variance to Gaussian distribution, the result we expected will be 3 by 3 Gaussian distribution matrix as follows:

$$\begin{bmatrix} & 4 & 1 \\ 4 & 12 & 4 \\ 1 & 4 & 1 \end{bmatrix} \quad (4)$$

The center sub-pixel here is weighted 12 times and 4, 1 times at the nearest remaining sub-pixels. Luminance calculated for each grid of 9 sub-pixels would then be averaged. The center sub-pixel is weighted by a factor of 12/28, while the nearest top, bottom and side sub-pixels are each weighted by a factor of 4/28; and the nearest corner sub-pixels are each weighted by a factor of 1/28. An array of values specifying the relative importance of sub-pixels is sometimes referred to as a '*mask*' of sub-pixel weights. Similar masks can be set up for larger sub-pixel grids. Also these masks are often extended to include contributions from sub-pixels belonging to neighboring pixels, so that the luminance can be averaged over adjacent pixels.

3.3 Luminance averaging by Gaussian marks

Since the luminance portion obtained from the transformation and the Gaussian pixel-weighting marks technique are used, it results in less perceptibility of the watermarked image. The basic approach for determining the average value of luminances by Gaussian pixel-weighting marks is as below:

$$L(x, y) = \sum_{v=y-}^{y+} \sum_{u=x-}^{x+} k L(u, v) \quad (5)$$

$$\text{where } k = \begin{cases} \frac{3}{7} & u = x \text{ and } v = y \\ \frac{1}{7} & \text{either } u = x \text{ or } v = y \\ \frac{1}{28} & \text{otherwise} \end{cases}$$

4. THE PROPOSED METHOD

In this section, a method for watermarking the color image is proposed to yield a higher level of robustness, and at the same time reduce the degradation of the image quality. The watermark embedding, watermark retrieval and all parameters involved are described below

4.1 Watermark embedding process

Our goal is to embed watermark bit (w) into original image ($OriginalPixel [x, y]$) to obtain watermarked image ($EmbeddedPixel [x, y]$). We specify a scaling parameter (c), which determines the extent to which c alters original image. Three natural formulae for computing watermarked image are

$$EmbeddedPixel [x, y] = OriginalPixel [x, y] + wc \quad (6)$$

$$EmbeddedPixel [x, y] = OriginalPixel [x, y] \times (1 + wc) \quad (7)$$

$$EmbeddedPixel [x, y] = OriginalPixel [x, y] \times e^{wc} \quad (8)$$

Equation (6) may not be appropriate when the $OriginalPixel [x, y]$ value vary widely. If $OriginalPixel [x, y]$ equals to 10^6 , then adding 100 may be insufficient for establishing a mark, but if $OriginalPixel [x, y]$ equal to 10 adding 100 will distort this value unacceptably. Inserting based on eq.(7) or eq.(8) are more robust against such differences in scale. We note that both equations give similar results when wc is small. Also when $OriginalPixel [x, y]$ is positive, then eq.(8) is equivalent to $\log(EmbeddedPixel [x, y]) = \log(OriginalPixel [x, y]) + wc$, and may be viewed as an application of eq.(6) to the case where the logarithms of the original values are used. We used eq.(7) in the experiments with the same reason previously described. Therefore, the watermark bit w is embedded by modifying each color channel at position (x, y) by a fraction of luminance as below:

$$EmbeddedPixel [x, y] = PixelColor [x, y] + wc L_G [x, y]$$

where $L_G [x, y]$ is the Gaussian pixel-weighting marks

4.2 Watermark retrieval

Consider a watermarked image as a noisy image $g(x, y)$ formed by the addition of watermark or noise $n(x, y)$ to an original image $f(x, y)$; that is

$$g(x, y) = f(x, y) + n(x, y) \quad (9)$$

where the assumption is that at every pair of coordinates (x, y) the watermark is uncorrelated. The objective of the following procedure is to reduce the watermark effects by adding a set of watermark image. If the watermark satisfies the constraints just stated, it is a simple problem to show that if an image $g'(x, y)$ is formed by averaging M pixel of square original image.

$$\bar{g}(x, y) = \frac{1}{M} \sum_{i=1}^M g_i(x, y) \quad (10) \text{ then it}$$

follows that

$$E\{\bar{g}(x, y)\} = f(x, y) = \text{original image}$$

In this approach, the average value of amplitudes of eight neighboring pixels is determined and subtracted by the amplitude value of center pixel. The result is then assigned to the binary digit of watermarking bit.

$$\begin{aligned} \text{WatermarkPixel}(x, y) = & -\left[\sum_{u=x-}^{x+} \sum_{v=y-}^{y+} \text{EmbedPixel}(u, v) \right] \\ & - \text{EmbeddedPixel}(x, y) \end{aligned} \quad (11)$$

If $\text{WatermarkPixel}[x, y]$ is positive then the watermark bit equal to 1

If $\text{WatermarkPixel}[x, y]$ is negative then the watermark bit equal to 0

5. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this section the performance of each method previously described is compared. The experiments were performed by using a bitmap color image with the size of 256 by 256 pixels. Random binary digits were formed with the size of 256 by 256 bits as a watermark signal. The original image and its corresponding versions after embedding the watermark in each channel, red, green and blue, are illustrated in the figure below.

Figure 1. (a) original image (b) the watermarked image with red channel embedding (c) with green channel embedding (d) with blue channel embedding

The degradation in each watermarked image can be noticed when the signature strength was increased to the value of 0.2, 0.1 and 0.5 in red, green and blue channel respectively. Therefore, the blue channel is the most suitable channel for embedding the watermark signal.

The PSNR at various levels of the signature strength for watermark embedding in each channel are shown in Figure 2 and 3.

Figure 2. The comparison between PSNR at different values of signature strength for watermark embedding processes in red, green and blue channels

Figure 3. The comparison between PSNR at different values of signature strength for Gaussian, Equal gain and No pixel-weighting marks techniques

From the Figure 2, it is obvious that at the same signature strength level the embedding in blue channel gave the best quality of watermarked image, while in the Figure 3, the result showed better performance of Gaussian pixel-weighting marks technique, compared to the equal gain pixel-weighting marks and no weighting pixel-weighting marks techniques.

Figure 4. The comparison between percentages of correct retrieved watermark bits of 2 different retrieval methods

Figure 5. The comparison between percentages of correct retrieved watermark bits of 3 different embedding methods

From Figure 4, it can be seen that the proposed retrieval method is more efficient than the existing one. Also, by using the Gaussian pixel-weighting marks technique, the percentage value of correct retrieved watermark bits was significantly improved.

6. CONCLUSIONS

In this paper, we have introduced a novel watermarking method based on the Gaussian pixel-weighting marks with 8 neighboring pixels retrieval. Our method exploited the advantage of Gaussian pixel-weighting marks to improve the scaling factor used in the watermark embedding process. Moreover, the average value of eight neighboring pixels was used in the retrieval process without requiring the original image. The experimental results have shown the improved performance, compared to the original method.

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