Digital Watermarking using Color Space Conversion

Hee-Soo Kim, Jin-Woo Park, Eui-Yoon Chung and Yeong-Ho Ha

School of Electronic and Electrical Eng., Kyungpook National University
1370 Sankyuk-Dong, Buk-Gu, Taegu 702-701, Korea
Phone: +82-53-950-5535, Fax: +82-53-957-1194,
E-mail address: yha@ee.knu.ac.kr

Abstract Digital watermarking is a technical solution to the copyright problem and is a necessary technique to protect copyright of multimedia content. Recently, there are many digital watermarking methods that deal in grey scale still images. However, only a few researchers are interested in digital watermarking fro video and color images. In this paper, we focus on digital watermarking for color images. At first, in order to embed the watermark signal in color image, we converted RGB color space to YCbCr color space which is a world-wide digital component video standard[1]. In addition, we adopted the acceptable degree of color difference in order to keep the invisibility.

1. Introduction

The use of digital media for images and video sequences has some serious implications for copyright protection issues. In the early days, without access to negatives, it was relatively difficult to pirate images as it was necessary to use expensive scanners that were not widely available. However, scanners are virtually omnipresent recently and, once the image is in the digital environment, very low cost but high quality processing software can be used to manipulate the image in ways that would have been impossible only a few years ago. Video is still slightly more difficult as a capture card and large amounts of disk space are required – but even this is not onerous nowadays.

Copyright of digital contents such as digital images has been invaded since they can be easily copied without degradation of quality. So it is urgently required to protect copyright from unjust usage. One of the techniques to protect copyright of digital contents is a method of embedding watermarks into digital contents and several watermarking methods have been proposed. A watermarking method not only checks unjust usage but also protects unjust usage in advance by existence of itself and raises consciousness of protecting copyright.

The techniques of protecting copyright of digital contents have not been applied enough for the sake of technical problems of embedding watermark into digital contents and of authenticating copyright information extracted from the digital contents. The requirements of a watermarking scheme for copyright protection purposes as follows:

(1) The image must not be visibly degraded by the presence of the mark while at the same time a unique identifier with high information content is produced.
(2) The mark must be readily recoverable by some form of comparison with the original image.
(3) The mark must be strongly resistant to detection and decoding without access to the original. It must be strongly resistant to attack and it should cause a significant loss of image quality for it to be destroyed. In addition, the mark must be tolerant to reasonable quality lossy compression of the image.

Some recent papers have considered data hiding in color images. Kutter[2] proposes an amplitude modulation scheme where in signature bits are multiply embedded by modifying pixel values in the blue channel. The blue channel is chosen as the human visual system is less sensitive to blue than other primary colors. Also, changes in regions of high frequencies and high luminance are less perceptible, and thus are favorable locations for data embedding. Robustness is achieved by embedding the signature several times at many different locations in the image. Fleet *et al.*[3] propose an embedding scheme using the S-CIELAB, a well-known standard for measuring color reproduction errors. They embed amplitude-modulated sinusoidal signals into the yellow-blue color band of an opponent-color representation scheme.

At first, we consider the characteristics of the human visual system in order to embedding watermark signal in this paper. In general, achromatic component – luminance that in low frequency region is more sensitive than chromatic components – colors that in middle one. Thus we focus on the relatively insensitive components of a color image.

In the next section, we present the basic conception of color spaces. In section 3, we introduce the proposed digital watermarking that contains embedding and extracting procedure. Then experimental results and some remarks are shown in section 4. Conclusions are provided in section 5.

2. Color Spaces

A color space is a mathematical representation of a set of colors. Three fundamental color models are RGB (used in color computer graphics and color television), YIQ, YUV, or YCrCb (used in broadcast and television systems), and CMYK (used in color printing). However, none of these color spaces are directly related to the intuitive notions of hue, saturation, and brightness. This has resulted in the development of other models, such as HIS and HSV, to simplify programming, processing, and end-user manipulation.

All of the color spaces in common use can be derived from the RGB information supplied by devices like cameras and scanners.

2.1. RGB Color Space

The red, green, and blue (RGB) color space is widely used throughout computer graphics and imaging. Red, green, and blue are three primary additive colors (individual components are added together to form a desired color) and are represented by a three-dimensional, Cartesian coordinate system in Fig.1.

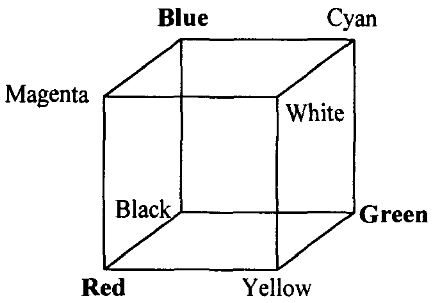


Fig.1. RGB color cube.

However, RGB is not very efficient when dealing with "real-world" images. All three RGB components need to be of equal bandwidth to generate any color within the RGB color cube. The result of this is a frame buffer that has the same pixel depth and display resolution for each RGB component. Also processing an image in the RGB color space is not the most efficient method. To modify color of a given pixel, we need the calculation of converting from RGB to a color space that contains the intensity and color components such as hue and saturation. For these reasons, many video, and image standards use achromatic and chromatic signals.

2.2. YCrCb Color Space

In this paper, we consider YCrCb color space which was developed as part of Recommendation CCIR601 and are scaled and offset versions of the YUV color space.

If the gamma-corrected RGB data has a range of 0 to 255, as is commonly found in computer systems, the following equations may be more convenient to use:

RGB to YCrCb Conversion

$$\begin{aligned} Y &= 0.257R'+0.504G'+0.098B'+16 \\ Cr &= 0.439R'-0.368G'-0.071B'+128 \\ Cb &= -0.148R'-0.291G'+0.439B'+128 \end{aligned} \quad (1)$$

YCrCb to RGB Conversion

$$\begin{aligned} R' &= 1.164(Y-16)+1.596(Cr-128) \\ G' &= 1.164(Y-16)-0.813(Cr-128)-0.391(Cb-128) \\ B' &= 1.164(Y-16)+2.018(Cb-128) \end{aligned} \quad (2)$$

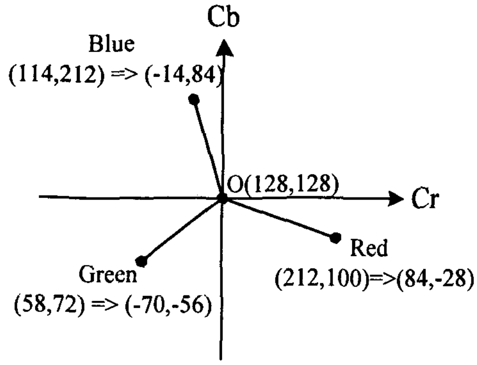


Fig.2. Cr-Cb chrominance plane

Fig. 2 shows the location of RGB primary color components in Cr-Cb chrominance plane of YCrCb color space. The value of Y is defined to have a nominal range of 16 to 235; the values of Cr and Cb are defined to have a range of 16 to 240, with 128 equal to zero.

3. Proposed Digital Watermarking Method

Based on chromatic components (Cr, Cb) are less sensitive than achromatic one (Y), we insert the watermark signal into chromatic region. At the Cr-Cb chrominance plane, an angle of a pixel represents the hue component of a color that refers to its average spectral wavelength and differentiates different colors and a magnitude of a pixel determines the amount of purity of the color. Because the variation of saturation is less sensitive than that of hue between chromatic components - hue and saturation, we manipulate the saturation value to embed the watermark signal according to acceptable degree of color difference.

3.1. Embedding Watermark

To modify the less sensitive color components, we separate both luminance and colors of YCrCb color space from the RGB color space. A schematic of the embedding procedure is shown in Fig. 3.

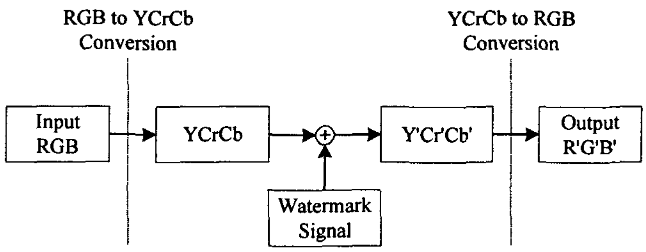


Fig. 3. Embedding Procedure.

In YCrCb color space, Y is achromatic component, luminance that summed up each different rates red, green, and blue of a pixel and Cr and Cb are chromatic components, color. Then we use the Cr-Cb chrominance plane to embed watermark signal. The *phase* of a point in the Cr-Cb plane from the Cr axis differentiates different colors, representing the *hue* property. On the other hand, the *magnitude* of the point from origin of the

Cr-Cb plane has the *saturation* property. So, as the *magnitude* from the origin increases, we will have purer colors.

$$Phase = tan^{-1}\frac{Cb}{Cr} \qquad (3)$$

$$Magnitude = \sqrt{Cr^2 + Cb^2} \qquad (4)$$

Then watermark signal is embedded into the original Cr-Cb chrominance components.

$$\Delta E^{*}_{CrCb} = \left[(\Delta Y^{*})^2 + (\Delta Cr^{*})^2 + (\Delta Cb^{*})^2\right]^{1/2} \qquad (5)$$

We can measure the Cr-Cb color difference level using Eq.(5) in YCrCb color space and Table 1 shows the acceptable degree of color difference.

Table 1. Acceptable degree of color difference

ΔE_{CrCb}	Visual Effect
$\Delta E_{CrCb} < 3$	Not perceptible
$3 \le \Delta E_{CrCb} < 6$	Perceptible but acceptable
$\Delta E_{CrCb} \ge 6$	Not acceptable

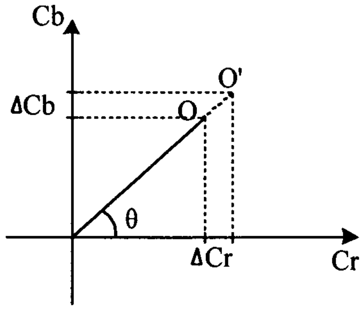


Fig. 4. Embedding method in Cr-Cb plane.

On changing the chrominance data, the phase of a point has to be fixed and only the magnitude of the point that represents the saturation is changed based on the acceptable degree of color difference[4].

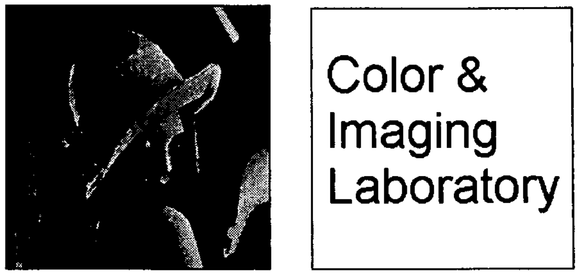
3.2. Extracting Watermark

In watermark signal recovery, at first the watermarked image and original image are converted to the same YCrCb color space and then comparison procedure between two magnitudes is executed. In further studies, the extracting procedure without the original image is considered.

4. Experimental Results

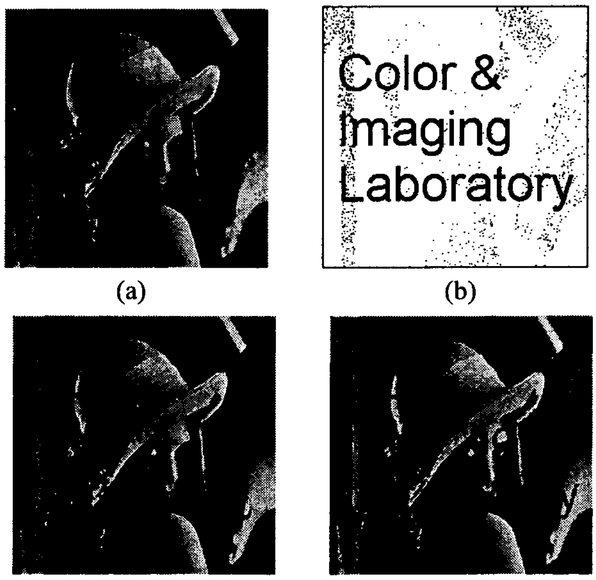
Before the experiment of digital watermarking, we examine whether the color space conversion RGB to YCrCb, and YCrCb to RGB effects in image quality or not. Its results show that the color space conversion doesn't make the degradation of image quality.

In experiment, we used the 256 x 256 'LENA' image and the same size of watermark signal.



(a) (b)

Fig. 5. Experimental images
(a) original image, (b) watermark signal.



(a) (b)

(c) (d)

Fig.6. Experimental Results related on the acceptable degree of color difference
(a) Watermarked image within 3% color difference, (b) extracted watermark image from (a), (c) watermarked image with 30%, and (d) watermarked image with 50%

The simulation results indicate that the proposed watermarking method has good properties in field of invisibility in Fig. 6. The extracted watermark in Fig. 6(b) has several defects in the bright region of the test image. To solve this defect, we must consider the characteristics of HVS in luminance. Amount of the embedded the watermark is decided directly proportional to the brightness of an image.

Table 2. PSNR comparison related on the acceptable degree of color difference [dB]

Channel	3%	10%	30%	50%
Red	10.42	10.47	10.85	11.25
Green	59.25	50.05	40.58	35.89
Blue	17.87	16.16	16.01	16.07

After embedding the watermark signal, the quality of an image is indirectly proportional to quantity of the watermark signal in Table 2.

5. Conclusions

In this paper we have addressed the digital watermarking using color space conversion based on acceptable degree of color difference.

It can be shown that the core problem with the attack described above lies with the compression operation of the watermark detection scheme. It follows that any digital watermarking scheme suitable for video applications does not need strongly original images, or video.

References

[1] Keith Jack, Video demystified: a handbook for the digital engineer, HighText Publications, Inc., 1993.

[2] M. Kutter, "Digital Signature of Color Images using Amplitude Modulation," *SPIE*, vol.3022, pp.518-525, San Jose, Feb. 1997.

[3] D. J. Fleet and D. J. Heeger, "Embedding Invisible Information in Color Images," *IEEE International Conference on Image Processing,* vol.1, pp.532-535, Santa Barbara, 1997.

[4] Jon Yngve Hardeberg, Transformations and colour consistency for the colour facsimile, diploma thesis, The Norwegian Institute of Technology (NTH), Trondheim, Norway, April 1995.

[5] Ken-ichi Hashida, and Akira Shiozaki, "A Method of Embedding Robust Watermarks into Digital Color Images," *IEICE Trans. Fundamentals*, vol.E81-A, no.10, October 1998.

[6] Akira Shiozaki, "Improvement to a Method of Embedding Robust Watermarks into Digital Color Images," *IEICE Trans. Fundamentals*, vol.E82-A, no.5, May 1999.

[7] M. D. Swanson, M. Kobayashi, and A. H. Tewfik, "Multimedia data-embedding and watermarking technologies," *Proc. IEEE*, vol.86, no.6, June 1998

[8] F. Hartung and B. Girod, "Digital watermarking of raw and compressed video," *in Proc. SPIE Digital Compression Technologies and Systems for Video Communication*, vol.2945, October 1996.

[9] Chee Sun Won, Dong Kwon Park, In Yup Na, and Seong Joon Yoo, "Efficient color feature extraction in compressed video," *in Proc. SPIE Storage and Retrieval for Image and Video Databases VII*, vol.3656, Jan. 1999.