Color to Gray and Back transformation for distributing color digital images

V.N. Gorbachev, E.M. Kaynarova,∗ I.K. Metelev, E.S. Yakovleva †

North-Western Institute of Printing
of St-Petersburg State University of Technology and Design,
Russia

Abstract

The Color to Gray and Back transformation watermarking with a secret key is considered. Color is embedded into the bit planes of the luminosity component of the YUV color space with the help of a block algorithm that allows using not only the least significant bits. An application of the problem of distributing color digital images from a database among legitimate users is discussed. The proposed protocol can protect original images from unauthorized copying.

1 Introduction

Digital watermarking is one of the popular techniques of copyrighting digital content. However, this technique has a high potential and allows to solve some other problems particularly the Color to Gray and Back transformation. The main idea of this transformation is to hide the color into a grayscale version of a color image and then, (e.g. after printing) to extract the hidden data to retrieve the original. Indeed, in practice this transformation is irreversible.

Some applications of Color to Gray and Back transformation are discussed in literature. It may be suitable if e.g. a color printer is not available and the document needs to be printed anyway [1]. In this case someone might want to recover the colors later on from a printed black-and-white hardcopy. Next application is a Hardcopy Image Backup System [2] proposed for archival storage of photos or any analog hard copies. While a photo is stored the color can be changed or faded and the System creates documents with hidden information about the initial color. Also a color-shielded image transmission can be achieved if color is embedded in the randomly selected position [3]. The set of positions is a secret key and only a legitimate user which has the key can recover the accurate color from a transmitted gray image.

The considered Color to Gray and Back transformation has the following particular features. Someone can get a grayscale version of a color image from its representation, e.g. in YCbCr color space. The desired grayscale is Y luminosity, as the National Television Standards Committee recommends. The usual representation has 24 bit for color pixel and 8 bit for gray pixel. Thus the transformation from color to gray formally is not reversible because entropy is not preserved. In fact, a reversible transformation can be achieved by watermarking a color into a grayscale image. Formally the retrieved color image can not

∗E-mail: helenkainarova@gmail.com
†E-mail: 2305lena@mail.ru
be equal to its original. However watermarking provides two images that are undistinguishable by human visual system and mapping can be viewed as reversible.

To embed a color into a grayscale image numerous techniques have been proposed, e.g. DWT (Discrete Wavelet Transform) [3], consistent gradient field methods [5], a virtual trit memory model [6] and many others. Also information about a color can be watermarked in a halftone of the printed image using halftoning algorithms. For example, a clustered- dot halftoning may be applied to carry information by shifting of the halftone clusters [7].

In this paper we consider digital color watermarking with a secret key. In accordance with the Kerckhoffs’s principle the security of a system should reside in the chosen key. At the same time the secret key allows to send images to a legitimate user. The key can be chosen as a set of random positions in which color is embedded [3]. In contrast, we consider the key as a random matrix that is used together with our block coding algorithm [8] to hide color information. This algorithm preserves the brightness of the block in which a message bit is encoded. It results in enhancement of the embedded data because not only the least significant bits can be used.

As a practical application of our approach we consider distributing of digital color images from a data base. The problem is that any user could get the interested image before buying. It seems to be an important problem because many applications need the high quality photos or color images (particulary images with MOS that are needed in image processing). A solution can be found with the help of visible removable watermarking [9]. The idea is that a visible watermark is embedded into an image and the interested user can remove it to retrieval unmarked image original by a secret key that is available for an additional fee [10]. This is an analog of a free-trial version, when the interested user can stop running the trial period of time by removing the watermark on [11]. In contrast to the mentioned above idea our approach uses an invisible watermark that is presented as a hidden color. The proposed solution is based on the trade-off and exploits the idea of $\beta$-version. In fact, a grayscale version with a hidden color is available for the interested user instead of the original color image. We present a protocol for retrieving the original from its grayscale $\beta$-version.

The paper is organized as follows: first we introduce the embedding algorithm, then an experiment and the protocol for image distribution are presented.

2 Color Embedding

The Color to Gray and Back transformation is an original example that shows how digital watermarking technique works for image processing applications. We briefly discuss it following Queiroz et al [4].

The solution of Queiroz is based on DWT. A RGB image is transformed into the YCbCr color space, where Y is a luminosity and two chrominance components Cb and Cr keep the color information. One level DWT of luminosity DWT(Y) has four blocks, the size of each block is a quarter of Y. Two blocks are replaced by two quarters of coefficients from Cr and Cb and a new luminosity $Y'$ appears. Then an inverse transform of $Y'$ results in a grayscale version $Y_c=\text{IDWT}(Y')$ with color embedded. To recover the color we need to reverse the mentioned above steps. According to this approach a quater of all color information was exploited. That means that the initial and retrieved color images are not equal however they are visually indistinguishable.

In our model an RGB image is transformed into YUV color space, where Y is a luminosity and $X=U,V$ are two chrominance components. Using a secret key $K$ we create a message

$$M = (K + X) \mod (255),$$

(1)
where $K$ is a random matrix. Then $M$ is embedded into luminance $Y$, that represents a coverwork.

To embed $M$ we use our algorithm [8] that keeps the brightness of an image as far as it is possible. Thus more information can be embedded without introducing noticeable distortions. The algorithm uses the $Y$ bit planes and works as follows. Each bit plane $Y_v$ has weight $2^{v-1}$, $V = 1, \ldots, 8$ and it is divided into a set of non-overlapping blocks $Y_{va} = \{ y[m,n] \}$ of $h \times h$ size. Let us introduce a parity bit of the block side diagonal

$$d_a = \bigoplus_{x \in Y_{va}} y[x, h - x].$$

A bit of the message $m$ is encoded by the block $Y_{va}$ as follows:

$$E : Y_{va} \rightarrow S_{va} = \begin{cases} Y_{va}, & \text{if } d_a \oplus m = 0, \\ ZY_{va}, & \text{if } d_a \oplus m = 1. \end{cases}$$

where the operator $Z$ either modifies a bit of the side diagonal or finds a block $S_{va}$ whose brightness is equal or closest to the brightness of $Y_{va}$. So brightness of luminance $Y$ is preserved as far as it is possible.

The next example illustrates how operator $Z$ works in case of $h = 2$.

$$M = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \rightarrow Y_{va} = \begin{bmatrix} 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}; S_{va} = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}.$$

Here a message $M$ is a $2 \times 2$ matrix. Each bit of $M$ is embedded into one of four blocks of $Y_{va}$. The stegoimage $S_{va}$ consists of four blocks and only one of them, the top right block, has its brightness that is change to 1.

A detection algorithm is blind. A hidden message is extracted from the bit plane of the stegoimage $S_{va}$ by calculating the parity bit $d_a = m$. Then new chrominance components $X' = U', V'$ are retrieved using the secrete key

$$X' = (M - K + 255) \ mod(255).$$

Indeed, a bit plane up to $V = 5, 6$ can be used without introducing any visual changes.

## 3 Experiment

The initial RGB image and its luminosity $Y$ of the YUV color space are presented at Figure 1. Amount of bits $H_Y$ available for embedding depends on the number of the bit planes $T$, the number of total pixels $n$ and the size of the block $h$ as $H_Y = nT/h^2$. It is obvious, that all color information can’t be hidden into $Y$. Then we decimate chrominance components $U, V$ by averaging over the $u \times u$ environment. For $u = 4$ amount of color information $H_C$ is $1/8$ from $Y$ or $H_C = (1/8)nk$, where $k$ is a bit depth of the channel $Y, U, V$ and usually $k = 8$. If $h = 2$ we find $H_Y = (T/4)H_C$. It means that all color information $H_C$ can be embedded if $T = 4$, in another words it needs all $Y$ bit planes be up to $V = 4$. Figure 1-(d) shows the luminosity component with color embedded into four bit planes $V = 1 - 4$.

To retrieve the initial RGB image we need the secret key $K$. If $K$ is unknown, it can’t be found in practice. The reason is that searching of $2^{nk}$ matrix is a hard problem with the non polynomial (NP) computational complexity. Fig. 1-(c) illustrates an example when color is retrieved without the secrete
key so we take a corrupted key, that has some bits changed. A large number of distortions can be found. If the secret key is known the retrieved color image seems to be visually undistinguishable from its original, as shows Figure 2-(a). However there are invisible differences, they are shown at Figure 2-(b) as a blue component.

To illustrate the proposed approach a user interface associated with *Adobe Photoshop* is presented at Figure 3.

4 Protocol of color images distributing

Let us introduce our approach with a secret key to the problem of digital images distributing among legitimate users. It may address to high quality photos or database of unique images distributing. The problem is as follows. *Alice has a digital color image and she wishes to sell it. Bob wishes to buy it but before this he wants to get it to know; however Alice distrusts Bob.* The solution can be found using the following protocol. Instead of transmitting the original color image $A$, Alice sends to Bob its grayscale version $B$ with hidden color. After Bob informs Alice about his decision Alice sends him the secret key and Bob retrieves the desired color image. As a result Alice keeps her copyright because she uses the secret key and Bob can get the interested image to know it, but this will be a grayscale version. Let us consider another solution. Alice has two images, an original color image $A$ and its grayscale version $B'$ for free distributing. In this case both images $A$ and $B'$ have to be transmitted through the channel to Bob. Then any criminal Eve can get color image $A$ attacking the channel. According to our model it is impossible. The color image is not transmitted through the channel. As for sending the secret key to Bob, this is a well known problem of key distribution and Alice can use one of the standard protocols of cryptography.

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5 Conclusions

Steganographic techniques allows us to solve the problems of information protection and many others. During image processing there are numerous transformations of color image into gray. In practice these transformations are irreversible. However reversibility can be examined from the point of view of human vision. So, a transformation can be considered as reversible if original and its retrieval version are undistinguishable by human eyes. And we can find that Color to Gray and Back transformation is reversible. Applications of Color to Gray and Back transformation refer to printing when color is retrieved from a halftone hard copy. Actually printing makes the color detection very hard so we consider an example without printing. Our example refers to the problem of color digital images or photos from a database distribution. The goal is that any user can get the interested photo to know before buying. The proposed solution is based on the idea of $\beta$-version. Instead of the original image, its grayscale version with hidden color is available, then the legitimate user could retrieve the interested color photo using the secret key.

References

[1] K. Braun and R. L. de Queiroz, Color to Gray and Back: Color Embedding Into Textured Gray Images, Proc. IS&T/SID 13th Color Imaging Conference, pp.120-124, (2005).
REFERENCES

[2] E. Hoarau, I. Tastl, N. Moroney. A Hardcopy Backup and Reconstruction System for Digital Images. Proc. of 2009 ICIP, Cairo, Egypt Nov. (2009).

[3] F. Nohara, T. Horiuchi, S. Tominaga. An Accurate Algorithm For Color to Gray and back / ICIP. Ü 2009. Ü pp. 485-488.

[4] R. L. de Queiroz, K. M. Braun. Color to Gray and Black: Color Embedding Into Texture Gray Image. ISEE Translation on Image Processing, V. 15, No. 6, JUNE 2006, p. 1464-1470.

[5] L. Neumann, M. Čadík, A. Nemcsics. An Efficient Perception-based Adaptive Color to Gray Transformation. Computational Aesthetics in Graphics, Visualization, and Imaging (2007), D. W. Cunningham, G. Meyer, L. Neumann (Editors).

[6] M. V. Kharinov. Invariant Representation of Information and Information Quantity in Image-Processing Tasks. ISSN 1054-6618, Pattern Recognition and Image Analysis, 2008, Vol. 18, No. 4, pp. 643-648. Pleiades Publishing, Ltd., (2008).

[7] B. Oztan, G. Sharma. Multiplexed Clustered-dot halftone watermarks using bi-directional phase modulation and detection. Proceedings of 2010 IEEE 17th International Conference on Image Processing, September 26-29, Hong Kong, (2010).

[8] V.N. Gorbachev, E.M. Kaynarova, I.K. Metelev, E.S. Yakovleva. An algorithm of block watermarking using LSB undo conditions of preserving of brightness. Russian Jurnal Izvestia vusov. Problemi poligrafiyi i izdatselskogo dela., Ì: Moscow State University of Printing, No 1, (2010).

[9] C. Mintzer, J. Lotspiech, and N. Morimoto. (1997, Dec.). Safeguarding digital library contents and users: Digital watermarking. D-Lib Magazine [Online]. Available: http://www.dlib.org/dlib/december97/ibm/12lotspiech.html.

[10] Y. Hu, S. K., J. Huang An algorithm for removable Visible Watermarking. IEEE Transactions on circuits and systems video technology, v. 16, No 1, p.129-133, (2006).

[11] Y. Yang, X. Sun, H. Yang, C.-T. Li. Removable visible image watermarking algorithm in the discrete cosine transform domain. Journal of Electronic Imaging 17(3), 033008, (2008).
Figure 1: Color embedding. (a) Color original; (b) coverwork image, luminosity component $Y$ of $YUV$ color space; (d) luminosity $Y$ with hidden color; (c) the retrieved original with slightly corrupted secret key.
Figure 2: (a) Retrieved color image; (b) difference in blue channels between the original and the retrieved images.
Figure 3: Adobe Photoshop Interface.