

COPYRIGHT PROTECTION OF PALETTE IMAGES BY A ROBUST LOSSLESS VISIBLE WATERMARKING TECHNIQUE*

Pei-Pei Chen (陳佩貝)¹ and Wen-Hsiang Tsai (蔡文祥)^{1, 2}

¹Dept. of Computer Science, National Chiao Tung University, Hsinchu, Taiwan

²Dept. of Computer Sci. & Information Eng., Asia University, Taichung, Taiwan

ABSTRACT

A method for robust lossless visible watermarking of palette images for copyright protection against watermark removal attacks is proposed. A visible opaque watermark is embedded into a palette image according to a color mapping which is reversible. The embedded watermark can be losslessly removed when the original image is needed. And the proposed method is made robust against watermark removal attacks by a scheme of a two-level color randomization in the watermark area using a user-specified key. Experimental results show the effectiveness and robustness of the proposed method.

Keywords: palette image, opaque watermark, lossless visible watermark, robust, removal attack, copyright protection.

1. INTRODUCTION

In order to protect the copyright of images, digital watermarking techniques are proposed for embedding a pre-defined watermark into an image. There are two types of watermarking: invisible watermarking and visible watermarking. Traditional processes of invisible watermark and visible watermark embedding usually result in image distortions. Even though the distortions are tiny, in some applications like medical and military ones, such distortions are unacceptable due to the high precision requirements in these applications. This intensifies the demand for lossless watermarking techniques, which have the capability to recover original images from watermarked ones.

In addition to satisfying specific applications requirements, lossless watermarking techniques can save image owners a lot of storage space. The owner

can preserve only the stego-images instead of both the original images and their stego-versions, because by using lossless watermarking techniques they can obtain distortion-free original images from stego-images. Most of the lossless watermarking techniques focus on invisible watermarking [1]-[4], and few papers are found on lossy visible watermarking. A study is found in Hu *et al.* [5]. We are the first to study on lossless visible watermarking of palette images. To the best of our knowledge, there is no paper on lossless visible watermarking of palette images so far.

Typical visible watermarking techniques were proposed for reducing the distortions of stego-images, so semi-transparent watermarks are embedded traditionally. However, we choose to embed opaque watermarks into cover images in this study. Although an opaque watermark results in more visual distortion than a semi-transparent watermark, it has the advantages of better advertising effects and copyright declaration, and can be removed entirely by the proposed lossless watermarking technique when the image owner desires to get the original image.

In the remainder of this paper, we first describe the principle of the proposed method in Section 2. Then, we describe the watermark embedding technique in Section 3. Some experimental results are shown in Section 4, followed by conclusions in Section 5.

2. PRINCIPLE OF PROPOSED METHOD

Watermarks used in this study are assumed to be binary (black and white). The area in a cover image I where a watermark W is embedded is called the *watermark area*, denoted by I_w , which is assumed to be at the upper left corner of I in this study. The group of the *black* pixels with values 1 in W will be denoted by W_b , and the remaining portion with values 0 denoted by W_w . The pixels in I_w spatially corresponding to W_b in W will be called *black watermark embedded pixels* and the area of them will be denoted by I_w^b , and the remaining pixels in I_w will be called *white watermark embedded pixels* and the area of them denoted by I_w^w . An illustration of the areas of I_w^b and I_w^w is shown in Figure 1.

*This work is supported partially by the NSC Project Advanced Technologies and Applications for Next Generation Information Networks (II) with Project No. NSC93-2752-E-009-006-PAE and partially by the NSC National Digital Archives Program with Project No. NSC93-2422-H-009-001.

The basic idea of the proposed method is to replace the colors of the pixels in I_W^b with distinct colors in such a way that the replacement is revertible with a user-specified key. We try to find the most distinct colors among the palette colors for use in the color replacement. As a result, the embedded watermark looks opaque and visually very different from the adjacent pixels in the watermark area and can be removed losslessly with a right key. In addition, we apply a two-level key protection to ensure the embedded visible watermark remaining visible when an illegal user tries to remove it with a wrong key. More details will be described in the following section.

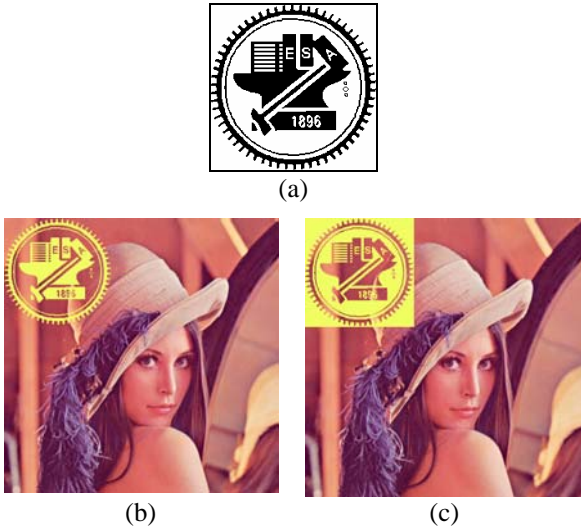


Figure 1 An illustration of pixels in a watermark. (a) A binary watermark. (b) Area of black watermark embedded pixels (yellow pixels). (c) Area of white watermark embedded pixels (yellow pixels).

3. LOSSLESS VISIBLE WATERMARK EMBEDDING

In Section 3.1, the visible watermark embedding process is introduced. And the process of lossless recovery of the original image is described in Section 3.2. A discussion on the robustness of the proposed recovery process against removal attacks is made in Section 3.3.

3.1. Watermark Embedding by A Neighborhood-Dependent Color Replacement Technique

Given a binary watermark W , we first divide the cover image I into a watermark area I_W and a non-watermark area I_{nW} . We are only concerned about the area I_W^b of black watermark embedded pixels in I_W . The color of each pixel in I_W^b will be replaced with another, and that of each pixel in the area I_W^w of the white watermark embedded pixels will be kept unchanged.

Before the color replacement, we count the occurrences of the pixels' colors in I_W^w , and let the occurrence counts of the 256 colors C_0 through C_{255} be denoted as O_0 through O_{255} , respectively. Then, we sort the color palette of I according to these counts in a descending order. We call the sorted result a *sorted color palette* P_s .

On the other hand, we propose the idea of adjusted Euclidean distance between colors which takes the concept of weighting into consideration, and call it *weighted Euclidean distance*. In more detail, the Euclidean distance between two colors $C_1 = (R_1, G_1, B_1)$ and $C_2 = (R_2, G_2, B_2)$ is defined as

$$\mu(C_1, C_2) = [(R_1 - R_2)^2 + (G_1 - G_2)^2 + (B_1 - B_2)^2]^{1/2}.$$

And the weighted Euclidean distance of color C_i in the color palette is defined as

$$\mu(C_i) = \frac{\sum_{k=0}^{255} (\text{Occurrence}(C_k) \times \mu(C_i, C_k))}{\sum_{k=0}^{255} \text{Occurrence}(C_k)}.$$

where the function $\text{Occurrence}(C_k)$ is the occurrence O_k of color C_k counted only in the area I_W^w of the white watermark embedded pixels in I_W . The weighted Euclidean distance $\mu(C_i)$ of a color C_i may be figured out to be a measure of the distinctness of C_i with respect to the other colors in I_W^w ; the larger the value $\mu(C_i)$ is, the more different the color C_i is.

Second, for each color C_i in the sorted color palette P_s , we compute its weighted Euclidean distance $\mu(C_i)$. We then find accordingly the color with the largest weighted Euclidean distance and denote it by C_f . The color C_f is presumably the most different color from those in I_W^w .

After finding C_f , we set up a table, with its entries beginning with the color in the palette P_s which is *closest* to C_f in the sense of Euclidean distance and ending with the color which is *farthest* to C_f . Obviously, the first entry of the table will be the color C_f itself. The resulting table can be thought as a new color palette which has a different order from the original one P_s . And we call it a *rearranged color palette* P_r .

Having a sorted color palette P_s and a rearranged color palette P_r , we make a one-to-one mapping between the two palettes in such a way that if the original color C of a certain pixel ranks the i th in P_s , we map C to the color in the i th entry in P_r . Then we replace accordingly the colors of all the black watermark embedded pixels in I_W^b with the corresponding colors in P_r by this mapping rule, thus obtaining a stego-image with a watermark appearing at the upper left corner of the image I . In the resulting stego-image, the pixels' colors of I_W^b can be seen to come from a group of colors, which look similar to one another but very different from the neighboring colors in I_W^w .

Finally, in order to prevent illegal users from removing the embedded watermark easily, we apply a two-level key protection scheme when doing the above-mentioned color mapping. We add a random offset generated with a secret key to the original color order so that an illegal user cannot recover losslessly the original color easily. A noise-residual watermark will appear on the recovered image if a wrong key is used in the image recovery. In addition, we randomize the positions of the embedded watermark colors by the same key. The owner's copyright of the image can thus be protected further. A detailed algorithm of the above-mentioned method is described in the following.

Algorithm 1: *Lossless visible watermark embedding.*

Input: A cover image I with a color palette P ; a binary watermark W with size smaller than that of I ; and a user-specified key K .

Output: A watermarked image S .

Steps:

1. Divide the watermark area in I into an area I_W^b of black watermark embedded pixels and an area I_W^w of white ones.
2. Count the occurrences of the colors of the white watermark embedded pixels in I_W^w .
3. Sort the colors in the color palette P of I according to the occurrence counts obtained in the last step in a descending order to obtain a sorted color palette P_s .
4. Calculate the weighted Euclidean distance of every color in the color palette P , and choose the color C_f which has the largest weighted Euclidean distance.
5. Calculate the Euclidean distances between C_f and each of the colors in the color palette P , and sort the colors according to the computed distances in an ascending order, resulting in a rearranged color palette P_r with the C_f being the first entry of P_r .
6. Embed each pixel t in the area W_b of the black watermark pixels of W into the original image I at the upper left corner in the following way.
 - 6.1 Find the color C_m of the pixel t' in the original image I at the corresponding position of pixel t .
 - 6.2 Find the rank n of color C_m in the sorted color palette P_s .
 - 6.3 Add an offset generated randomly with the key K to the rank n to get a new rank n' , and find the color C_m' of this new rank n' in P_r .
 - 6.4 Replace the color of the pixel t' in the original image at the corresponding position of pixel t with the color C_m' .
7. Randomly pair the watermarked pixels together using the key K to form $|W_b|/2$ pairs of pixels, and then swap the colors of the two pixels in each pair.

3.2. Lossless Recovery of Original Images by Removal of Visible Watermarks

In this section, we describe how to recover the image losslessly and explain why we can achieve the goal.

In the watermark embedding process, we only replace the colors of the pixels in I_W^b . Therefore, the colors of the pixels in I_W^w are kept unchanged. Moreover, the sorted color palette P_s and the rearranged color palette P_r were set up by taking into account only the colors of the pixels in I_W^w . So in the recovery process, we can set up the two palettes which are respectively identical to the sorted and the rearranged color palettes P_s and P_r set up in the watermark embedding process. We let the corresponding area of I_W^b in the input stego-image be denoted as S_W^b and the corresponding area of I_W^w in the stego-image as S_W^w . Then we find the rank of each color C of S_W^b in P_r , and replace it with the color of the same rank in P_s as the result of color recovery after using the secret key to get the right rank and the right position of color C . The details of the above-mentioned lossless recovery process of the original image colors are described as an algorithm as follows.

Algorithm 2: *Lossless recovery of original image.*

Input: A watermarked image S ; the original binary watermark image W ; and the original user-specified key K .

Output: A recovered image R .

Steps:

1. Divide the watermark area in S into an area I_W^b of black watermark embedded pixels and an area I_W^w of white ones.
2. Count the occurrences of the colors of the white watermark embedded pixels in S_W^w .
3. Sort the colors in the color palette P of S according to the occurrence counts obtained in the last step in a descending order to obtain a sorted color palette P_s .
4. Calculate the weighted Euclidean distance of every color in the color palette P , and choose the color C_f which has the largest weighted Euclidean distance.
5. Calculate the Euclidean distances between C_f and the other colors in the color palette P , and sort the colors according to the computed distances in an ascending order, resulting in a rearranged color palette P_r with the C_f being the first entry of P_r .
6. Pair the watermarked pixels together using the key K to arrive at the same $|W_b|/2$ pairs of pixels as done in watermark embedding, and then swap the colors of the two pixels in each pair.
7. Restore the color of each watermarked pixel t in S_W^b to be its original color by the following way.

- 7.1 Find the color C_t of the pixel t .
 - 7.2 Find the rank n of color C_t in P_r .
 - 7.3 Subtract an offset generated by K from the rank n to get a new rank n' , and find the color C_m with rank n' in P_s .
 - 7.4 Replace the color C_t of the pixel t with the color C_m .
8. Take the final result of modified S as the desired recovered image R .

3.3. Noise-Residual Recovery against Removal Attacks

In order to provide protection of stego-images from illegal removal of the watermarks, we use a user-specified key in the above-described watermark embedding process by adding a random offset to the color rank found by the color mapping from the sorted color palette P_s to the rearranged color palette P_r in Step 5.3 of Algorithm 1. The range of the random rank offset is set to be between 0 and 20 in this study. After embedding the watermark with this way of protection, if an illegal user tries to remove the embedded watermark without a right key, a watermark-shaped noise region will survive in the recovered image. The larger the range of the offset is, the worse the quality of the embedded watermark will be, but the more obvious the noise region will appear in the recovered image.

Moreover, we randomize the positions of the embedded watermark colors by picking every two pixels of the embedded watermark and exchange each other's color, as described in Step 7 of Algorithm 1. In this way, it is even more difficult for an illegal user to recover the original pixels' colors in the watermark area. Although this kind of randomization yields an opaque watermark which visually distorts the original image, it has the advantage of better advertising effects and copyright declaration.

4. EXPERIMENTAL RESULTS

Some experimental results of applying the proposed method are shown in this section. A binary image of size 200×200 as shown in Figure 2 is used as the input watermark. The cover images are all with size 512×512 and the watermarks are positioned at the upper left corner of the cover images. Figure 3(a) is a color image of "Lena" and Figure 3(b) shows the resulting stego-image after embedding the watermark. Figure 3(c) shows the losslessly recovered image and Figure 3(d) shows the lossy recovered image with a wrong key. Figures 4 and 5 show two additional examples with the cover images of "Painting" and "Jet," respectively. The corresponding peak-signal-to-noise-ratio (PSNR) values of (b) and (d) in these figures are shown in Table 1.

We measure the quality of a stego-image S by the PSNR value of the stego-image with respect to its cover image I . The mean square error MSE_S and the $PSNR_S$ for a stego-image S after embedding a watermark W of size $M \times N$ are defined respectively to be:

$$MSE_S = \frac{1}{M \times N} \sum_{x=1}^M \sum_{y=1}^N (S(x, y) - I(x, y))^2;$$

$$PSNR_S = 10 \times \log_{10} \left(\frac{255^2}{MSE_S} \right).$$

The PSNR values of the stego-images listed in the Table 1 are all smaller than 15dB, which show that the embedded watermarks look visually very different from its neighborhood in the original images.

Besides, we measure the quality of a recovered image R by its PSNR value with respect to its original image I . The mean square error MSE_R and the $PSNR_R$ for a recovered image R are defined respectively to be:

$$MSE_R = \frac{1}{M \times N} \sum_{x=1}^M \sum_{y=1}^N (R(x, y) - I(x, y))^2;$$

$$PSNR_R = 10 \times \log_{10} \left(\frac{255^2}{MSE_R} \right).$$

Table 1 PSNR values of images after embedding visible watermarks.

	Lena	Painting	Jet
stego-image	15.0	12.0	10.1



Figure 2 A binary watermark image of size 200×200 .



Figure 3 An example of results of applying proposed method. (a) A color image of "Lena". (b) Stego-image after embedding visible watermark of size 200×200 . (c) Losslessly recovered image with (b). (d) Lossy recovered image without a right key.

In Table 2, the PSNR values of the images recovered with right keys are all -1 , which mean that the MSE_R values are all zero. That is, the recovered images and the original images are exactly the same. And the PSNR values of the images recovered with wrong keys are smaller than 20dB, which show that the recovery results are still very different from the original ones due to the noise surviving in the watermark areas of the recovered images.

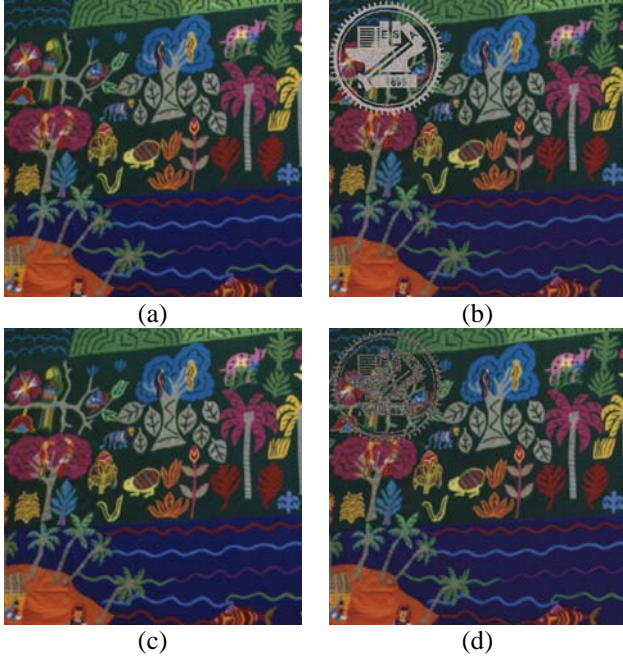


Figure 4 An example of results of applying proposed method. (a) A color image of “Painting”. (b) Stego-image after embedding visible watermark of size 200×200 . (c) Losslessly recovered image with (b). (d) Lossy recovered image without a right key.

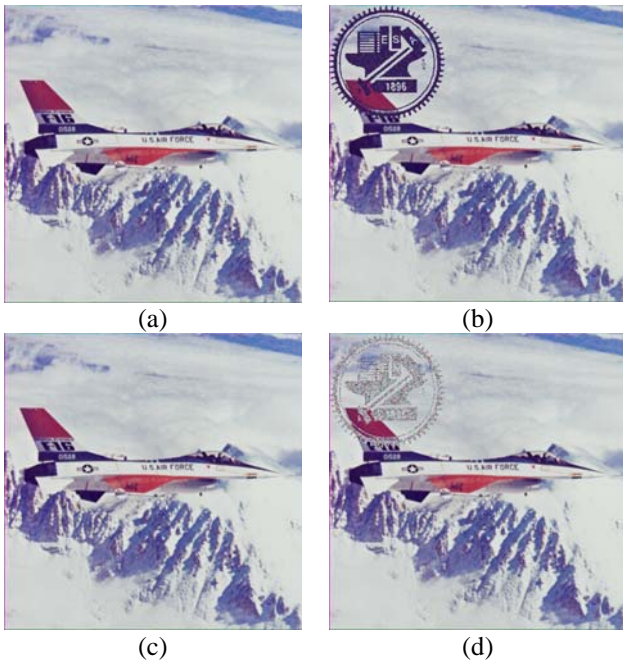


Figure 5 An example of results of applying proposed method. (a) A color image of “Jet”. (b) Stego-image after embedding visible watermark of size 200×200 . (c) Losslessly recovered image with (b). (d) Lossy recovered image without a right key.

Table 2 PSNR values of recovered images.

	Lena	Painting	Jet
Recovered with a right key	-1	-1	-1
Recovered with a wrong key	19.7	17.0	16.0

5. CONCLUSIONS

In this paper, we have presented a novel method to embed a removable visible watermark into palette images to protect image copyright. We embed a given binary watermark by changing the colors of the black watermark embedded pixels in the cover image according to a color mapping. The resulting opaque watermark can be removed losslessly later to recover the original cover image. User-specified keys are used to randomize the mapping rules and the mapped color positions in the embedded watermark, thus increasing the protection of the watermark from being removed by illegal users. Experiment results show that the PSNR values of the stego-images are smaller than 15dB and that the embedded watermarks look very different from its neighborhood of the original images. Noise will appear in the watermark area if incorrect keys are used in the recovery process of the original image. Because the watermark image must be used in the proposed watermark removal process, it will be an interesting topic in the future to study a similar process without the use of the original watermark.

REFERENCES

- [1] C. De Vleeschouwer, J. F. Delaigle, and B. Macq, “Circular Interpretation of Histogram for Reversible Watermarking,” *Proceedings of 4th IEEE Workshop on Multimedia Signal Processing*, Cannes, France, pp. 345-350, Oct. 2001.
- [2] C. De Vleeschouwer, J. F. Delaigle, and B. Macq, “Circular Interpretation of Bijective Transformations in Lossless Watermarking for Media Asset Management,” *IEEE Transactions on Multimedia*, vol. 5, Iss. 1, pp. 97-105, March 2003.
- [3] D. M. Thodi and J. J. Rodriguez, “Reversible Watermarking by Prediction-Error Expansion,” *Proceedings of 6th IEEE Southwest Symposium on Image Analysis and Interpretation*, pp. 21-25, March 2004.
- [4] D. Zou, Y. Q. Shi, and Z. Ni, “A Semi-Fragile Lossless Digital Watermarking Scheme Based on Integer Wavelet Transform,” *Proceedings of 6th*

IEEE Workshop on Multimedia Signal Processing,
vol. 5, pp. 195-198, Sept.-Oct. 2004.

- [5] Y. Hu, S. Kwong, and J. Huang, "An Algorithm for Removable Visible Watermarking," *IEEE Transactions On Circuits And Systems for Video Technology*, Vol. 16, No. 1, January 2006.