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Watermarking Application Using Bit Plane Allocation

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Abstract

This paper studies about bit plane watermarking. The watermarking has been studied to protect digital image against illegal copyright action. Generally speaking, adding watermarking symbol in least significant bit (LSB) is desirable. However, sometimes watermarking information in LSB can be lost during the compression and transmission. Therefore, well designed watermarking technique is necessary. In this paper, we show how to design watermarking application, and compare watermarking performance on different bit plane. Two datasets were used; they are Kodak and McM datasets.

Keywords: *Watermark, bit plane slicing, color image*

1. Introduction

Watermarking stands for ensuring data integrity which unites aspects of data hashing and digital watermarking [1-4]. The watermark is an identifiable pattern which seems as various shades of brightness when observed by transmitted light. Traditionally, the watermarks have been employed on postage stamps, currency, and some official documents to protect counterfeiting. As in other industry, watermarking is important in computer science field. The watermarking is a crucial protection approach to where message is concealed in the multimedia information [5-15]. In this work, we study about image watermarking on image processing.

The watermarking has been developed to defense digital image again against illegal copyright violation [16-24]. The best method is to guarantee to provide images with maximal fidelity and robust against different attacks [25-28]. In this paper we study watermarking with bit plane slicing. The bit plane of a digital image is a set of bits fit to a determined bit level in each of the binary numbers representing the signal. Therefore, there are many scenarios to generated watermarked images. There are some pros and cons of watermarking approach. Normally it is good to add watermarking symbol in the least significant bit (LSB), however the symbol may be removed or changed during the transmission because LSB can be ignored hardly or blurred during the compression. However, we cannot add watermarking symbol in the most significant bit (MSB) because it may degrade image quality. Therefore, this relation is trade-off.

This paper is arranged as followed. In Section 2, we present color image bit plane slicing process. Section 3 shows some metrics used for simulation comparison. Section 4 provides assessed performance results. Finally, Section 5 presents conclusions.

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2. Color Image Bit Plane Slicing

A bit plane slicing method is employed for separation of the raw information from black and white or color images into each bit plane. Figure 1 shows the process of proposed watermarking in bit plane slicing.

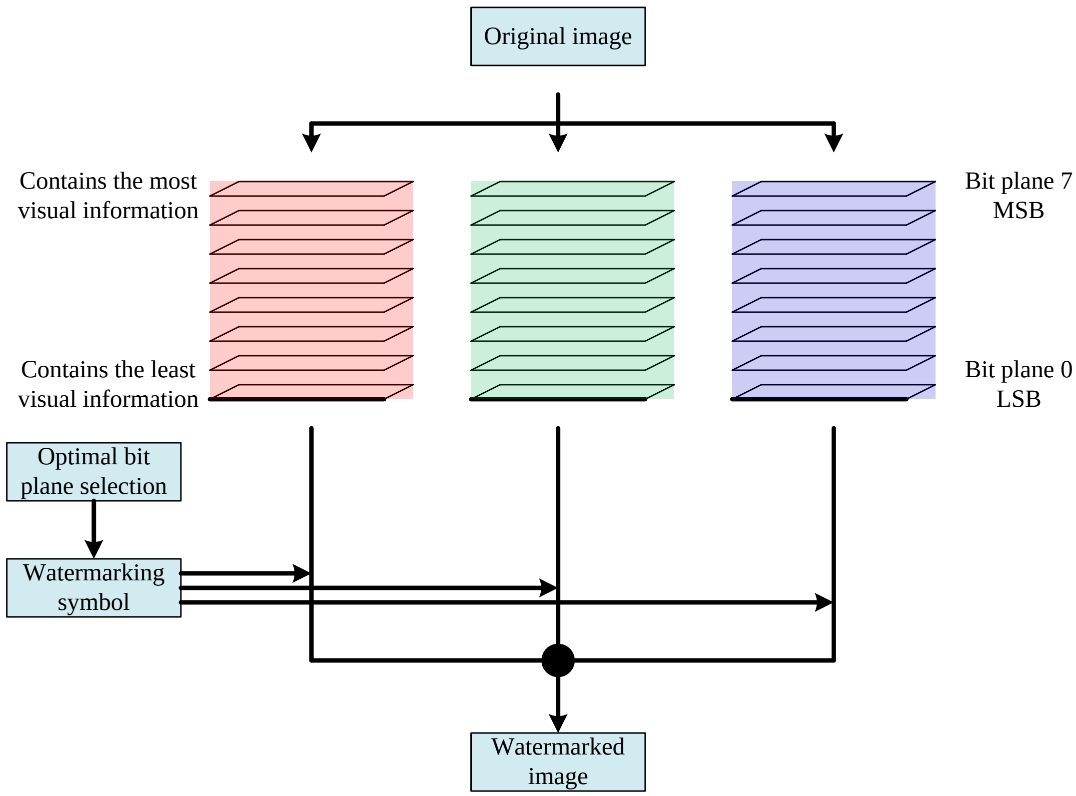


Figure 1. Bit Plane Slicing on Color Image

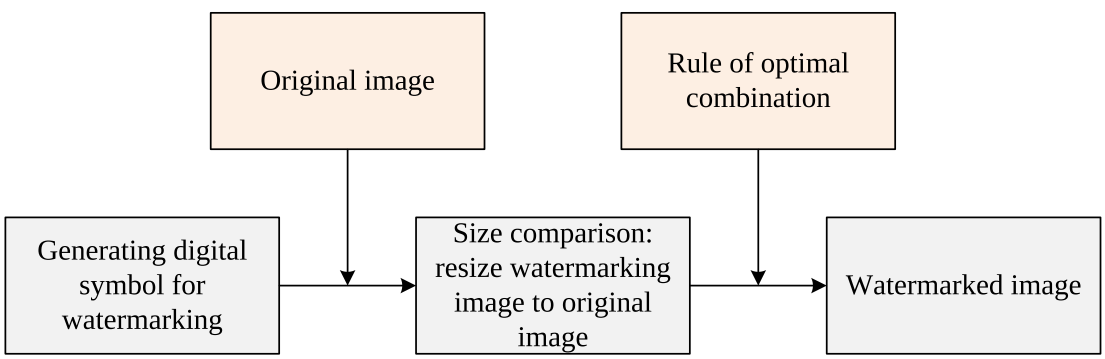
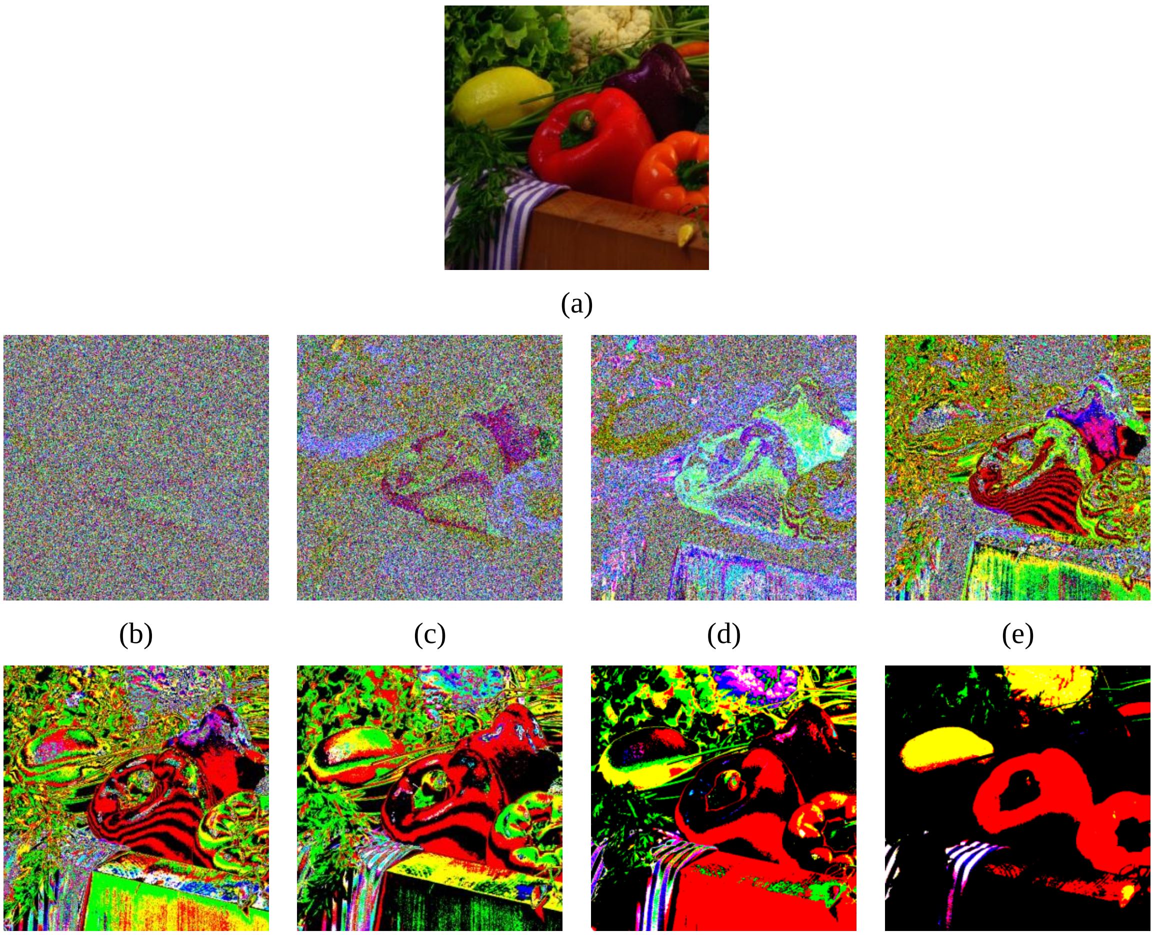


Figure 2. Watermarked Image Generation

We first select optimal bit plane out of eight candidates in each color channel, and add generated watermarking symbol in each channel. As information in LSB may be removed easily, it is requested to avoid using LSB information. The watermarking symbol is generated as shown in Figure 2. The generated watermarking symbol is added in the original image. As both images are not always with the same size, size comparison process is requested. After resizing watermarking symbol with the original image, symbol is merged with original image by the rule of optimal combination. Finally, watermarked images are obtained. Figure 3 shows the different bit plane images acquired using bit plane slice techniques on #11 McM image.



(a)

(b) (c) (d) (e)

(f) (g) (h) (i)

Figure 3. Bit Plane Slicing Example on #11 McM Image: (a) Original Color Image, (b) 0^{th} Bit Plane LSB Image, (c) 1^{st} Bit Plane, (d) 2^{nd} Bit Plane, (e) 3^{rd} Bit Plane, (f) 4^{th} Bit Plane, (g) 5^{th} Bit Plane, (h) 6^{th} Bit Plane, and (i) 7^{th} Bit Plane MSB Image

It can be found from Figure 3 that, each image can be separated into eight images (0^{th} to 7^{th}). Each bit takes different level of values, which affects the characteristics of each sliced image. From Figure 3, it is obvious that the most significant bit (7^{th}) includes the clear manner to describe the image, and it can be utilized to descript the image. The other images (0^{th} to 6^{th}) are not as clear as 7^{th} image, and sometimes those images seem to be noise.

3. Metrics for Evaluating Performance

In this paper, we use three metrics for 10 objective perofmrance comaprison. First of all, peak signal-to-noise ratio (PSNR) is used which is for the ratio between the original maximum possible energy of a image and the energy of corrupting noise that reflect the fidelity of its state. In general, PSNR is used to evaluate the excellency of restored image. Normally the term, noise, stands for erorrs, the differnce between origianl and the reconstructed images. For N bit images, the maximum value is 2^N-1, therefore for N=8 bit image, the maximum value is 256-1=255. The PSNR equeation is shown below:

$$PSNR = 20\log_{10}(MAX) - 10\log_{10}(MSE), \quad (1)$$

where MAX is 255.

We separated color image into three channels, therfore we can evaluate four different PSNR values: PSNR for red channel (M_1), PSNR for green channel (M_2), PSNR for blue channel (M_3), and color PSNR (M_4).

By the way, before obtaining PSNR, it is required to know MSE (mean squared error). The MSE is a metric to evaluate the average of the squares of the errors. Again, errors means the differnce between original and restored images. Given a noise-free $k \times l$ size monochrome image, MSE is obtained as,

$$MSE = \frac{1}{k \times l}\sum_{x=0}^{k-1}\sum_{y=0}^{l-1}\left(ori(x,y) - res(x,y)\right)^2, \quad (2)$$

where $ori(x,y)$ and $res(x,y)$ stand for original and restored pixels at the location of (x,y).

We also use FSIM (Feature SIMilarity) for performance comparison. The FSIM index is defined as

$$FSIM = \frac{\sum_{x \in \Omega} S_L(x) \cdot PC_m(x)}{\sum_{x \in \Omega} PC_m(x)}, \quad (3)$$

where Ω stands for the whole image, PC is phase congruency, $S_L(x)$ is,

$$S_L(x) = [S_{PC}(x)][S_G(x)]. \quad (4)$$

The $FSIM_C$ index is defined as

$$FSIM_C = \frac{\sum_{x \in \Omega} S_{PC}(x) S_G(x)\left[S_I(x) S_Q(x)\right]^{\lambda} \cdot PC_m(x)}{\sum_{x \in \Omega} PC_m(x)}. \quad (5)$$

4. Performance Evaluation

The proposed method is tested in many different types of color iamges. The provided method was conducted using the MATLAB 2010. The used image for simulatio are shown in below Figures. Two testsets were employed: 24 Kodak imageset and 18 McM imageset. They are shown in Figures 4 and 5.

Figure 4. 24 Kodak Image Set

Figure 5. 18 McM Image Set

To conduct simulation we generated a symbol for watermarking. In this paper, the term '`Val is pretty!`' is used for watermarking test, which is shown in Figure 6.

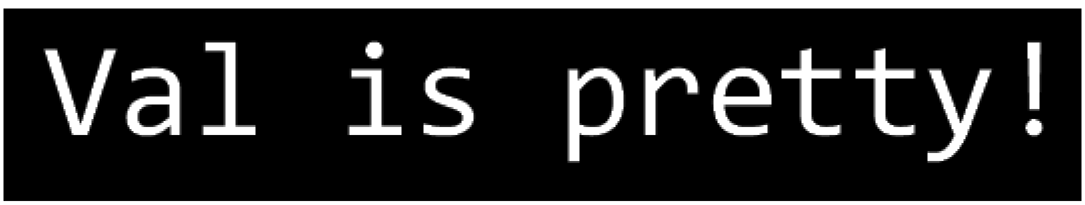
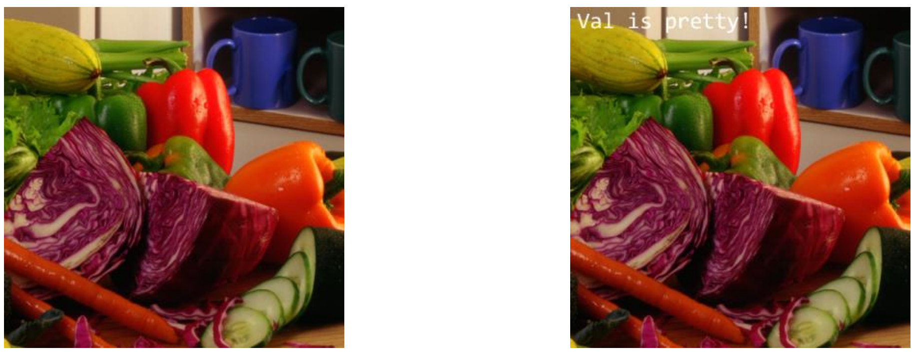


Figure 6. Test Text for Watermarking

The proposed method when applied to different Kodak and McM images provides the results which are shown Figure 7. All image in leftside are origianl images, and all image in rightside are watermarking added images. Figures 7(a), 7(b), 7(c), and 7(d) are watermarked images on #5 Kodak, #6 Kodak, #10 McM, and #11 McM, respectively.

(a)

(b)



(c)

(d)

Figure 7. (Left Images) Original, (Right Images) Watermarked: (a) Kodak #5, (b) Kodak #6, (c) McM #10, and (d) McM #11

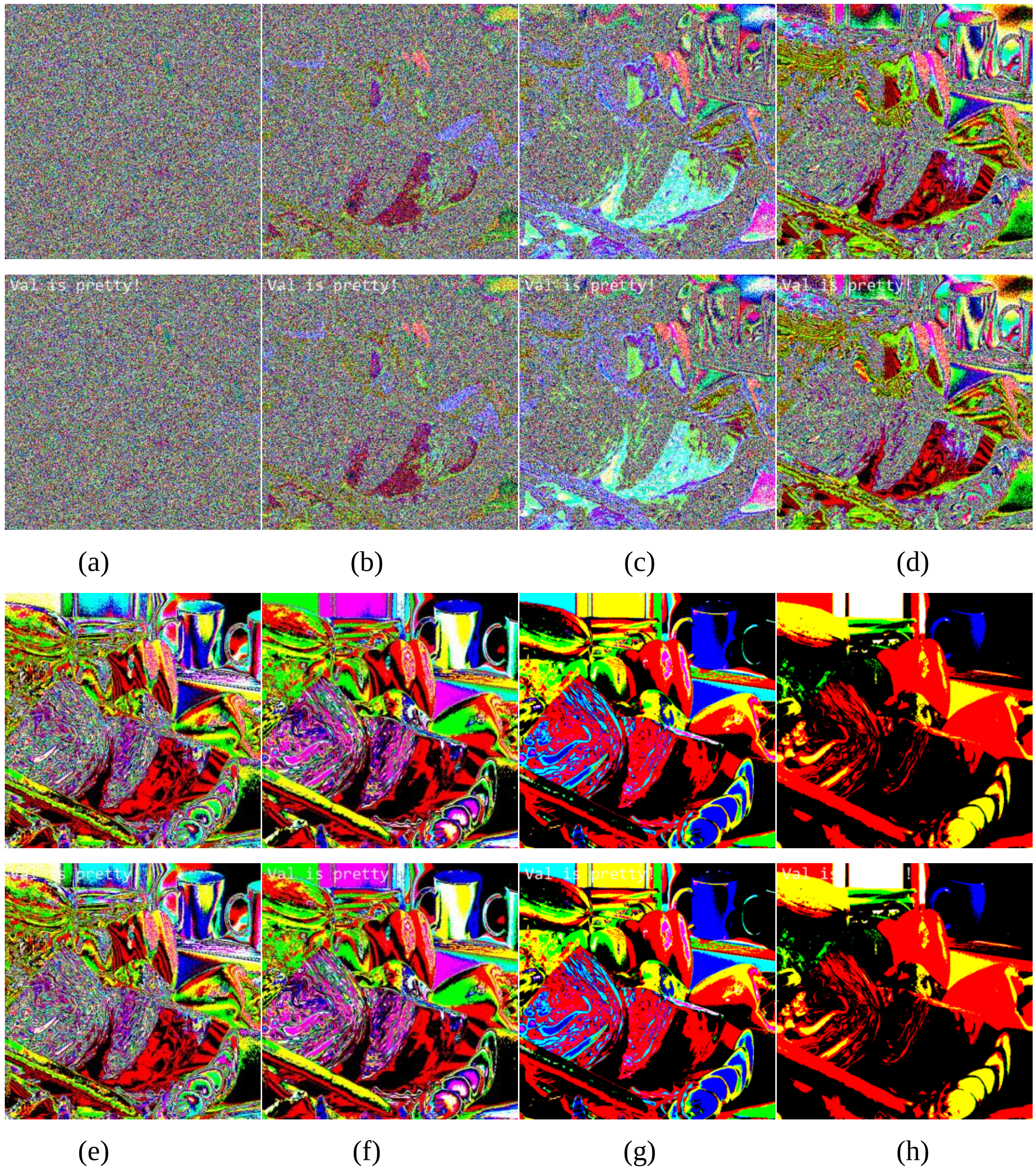


Figure 8. Watermarking Results on 0th to 7th Bit-planes

Figure 8 shows eight-level result images before and after the watermarking is applied. Each example consists of two images where upper-side images are without watermarking process and the images located lower-side are with watermarking process. As bit plane close to LSB looks like noise, it is more efficient to add watermarking symbol on lower planes.

As described in previous section, we use three metrics in this paper. They are MSE, PSNR and FSIM. Metrics M_1 to M_4 are from MSE, metrics M_5 to M_8 are from PSNR, and metrics M_9 and M_{10} are FSIM results. Some descriptions are shown below:

M_1: MSE_R

M_2: MSE_G

M_3: MSE_B

M_4: CMSE_RGB

M_5: PSNR_R

M_6: PSNR_G

M_7: PSNR_B

M_8: CPSNR_RGB

M_9: FSIM

M_{10}: FSIMc

There are eight rows in each Table, which are arranged as,

1st row: watermarking on 0th plane

2nd row: watermarking on 1st plane

3rd row: watermarking on 2nd plane

4th row: watermarking on 3rd plane

5th row: watermarking on 4th plane

6th row: watermarking on 5th plane

7th row: watermarking on 6th plane

8th row: watermarking on 7th plane

Tables 1-4 show the performance comparison on #5 Kodak, #6 Kodak, #10 McM, and #11 McM images.

Table 1. Performance Comparison on #5 Kodak Image

M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
91.9	93.6	98.8	94.8	28.50	28.42	28.18	28.36	0.9852	0.9842
99.7	92.1	95.4	95.7	28.14	28.49	28.34	28.32	0.9842	0.9831
94.1	91.4	100.1	95.2	28.39	28.52	28.13	28.34	0.9869	0.9858
90.1	87.5	102.1	93.2	28.58	28.71	28.04	28.44	0.9911	0.9902
102.8	66.6	100.9	90.1	28.01	29.90	28.09	28.58	0.9957	0.9953
72.1	123.5	141.9	112.5	29.55	27.22	26.61	27.62	0.9958	0.9955
66.0	55.5	90.5	70.7	29.94	30.69	28.56	29.64	0.9966	0.9965
138.6	155.3	160.7	151.5	26.71	26.22	26.07	26.33	0.9881	0.9880

Table 2. Performance Comparison on #6 Kodak image

M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
0.8	3.4	96.5	33.6	48.97	42.76	28.29	32.87	0.9987	0.9985
0.6	3.3	95.2	33.0	50.65	42.91	28.34	32.94	0.9987	0.9985
1.2	2.3	88.9	30.8	47.52	44.59	28.64	33.25	0.9993	0.9991
0.2	1.7	72.8	24.9	55.63	45.92	29.51	34.17	0.9995	0.9994
0.0	0.0	121.2	40.4	Inf	Inf	27.29	32.07	0.9999	0.9999
0.0	0.0	158.2	52.7	Inf	Inf	26.14	30.91	0.9999	0.9999
0.0	0.0	21.4	7.1	Inf	Inf	34.83	39.60	1.0000	1.0000
0.0	0.0	0.0	0.0	Inf	Inf	Inf	Inf	1.0000	1.0000

Table 3. Performance Comparison on #10 McM Image

M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
156.3	149.4	146.8	150.9	26.19	26.39	26.46	26.35	0.9715	0.9692
156.5	149.9	148.8	151.7	26.19	26.37	26.40	26.32	0.9764	0.9747
152.3	159.1	160.9	157.4	26.30	26.11	26.07	26.16	0.9874	0.9864
189.5	197.7	194.7	194.0	25.35	25.17	25.24	25.25	0.9870	0.9863
180.8	99.4	77.9	119.4	25.56	28.16	29.21	27.36	0.9936	0.9930
115.8	184.3	113.4	137.8	27.49	25.48	27.59	26.74	0.9877	0.9874
96.2	78.7	234.2	136.4	28.30	29.17	24.43	26.78	0.9829	0.9823
12.4	71.7	126.6	70.3	37.19	29.57	27.11	29.66	0.9928	0.9926

Table 4. Performance Comparison on #11 McM Image

M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
153.9	154.9	154.3	154.4	26.26	26.23	26.25	26.24	0.9692	0.9670
156.2	146.0	156.4	152.9	26.19	26.49	26.19	26.29	0.9746	0.9728
141.2	153.6	131.0	141.9	26.63	26.27	26.96	26.61	0.9834	0.9821
158.5	159.5	245.3	187.8	26.13	26.10	24.23	25.39	0.9904	0.9896
175.4	151.2	265.3	197.3	25.69	26.33	23.89	25.18	0.9925	0.9918
183.6	157.8	272.6	204.7	25.49	26.15	23.78	25.02	0.9924	0.9919
224.6	183.7	260.4	222.9	24.62	25.49	23.97	24.65	0.9881	0.9877
253.8	242.2	301.1	265.7	24.09	24.29	23.34	23.89	0.9749	0.9748

Note that `inf` represents infinity.

4. Conclusions

In this paper, we studied on bit plane watermarking. Watermarking applications have been studied to protect digital image against illegal copyright violation. Generally speaking, adding watermarking symbol in least significant bit (LSB) is desirable. We showed how to design watermarking application, and compared watermarking assessment on different bit plane. Two datasets were used: Kodak and McM datasets.

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