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Watermarking on Bit Plane Arranged Images

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Abstract

In this paper we propose a new bit plane-based watermarking approach. In the proposed technique, an image is embedded in the least significant bit (LSB) plane of the original image. The selection of bit planes is a crucial issue because the performance and file size is determined by the selected bit plane. We used ten LC dataset for the experiments. From the simulation results, it is obvious that the presented method is reliable for watermarking.

Keywords: *bit plane decomposition, digital color image, watermarking, image size*

1. Introduction

A watermarking is a hidden but identifiable pattern in an image. A bit plane of a digital discrete image is a set of bits point to a presented bit plane in each of the binary numbers describing the images [1]. Images can be represented in a sequence of binary images by decomposing them into their eight bit planes. The 0^{th} bit plane contains the end bit of each image, and the last bit gives the least impact in the sense of the significance of the value, it is known the least significant bit (LSB). On the other hand, the plane with the $(n\text{-}1)^{th}$ bit of each image is called most significant bit (MSB). However, if an image is with gray level or a particular channel of color images, eight differently assigned binary images can be obtained. Thus when an image is colored one, eight different binary images can be obtained in each color channel. For n-bit image case, there are n bit planes to represent the image. Here the 0^{th} bit plane tells the set of the LSB, and the $(n\text{-}1)^{th}$ contains the MSB. We can say the 0^{th} bit plane yields the least contribution to the image. And the $(n\text{-}1)^{th}$ bit plane shows the coarsest information. If a bit on a p^{th} bit plane on an q-bit image is set to 1, it gives a value of $2^{(q\text{-}p)}$. Thus, bit plane can give half of the contribution of the earlier bit plane.

Few researches have been developed [2-5]. Especially the authors in [2] inserted the watermark in the LSB bit plane and [3] presented bit plane handling of the LSB approach and utilized quasi m-arrays in place of pseudorandom noise as a watermarking. In [4], the authors conversed pseudo-random LSB watermarking, and emphasized the previous works [5] where in LSB adjustments are adopted. They commented that LSB adjustments approach is less reliable nor robust and not much transparent [6-27].

In this paper, we present a watermarking process and analysis the impact between performance and image size, and find the best tradeoff relationship. The paper is divided as follows. In Section 2, concept of bit plane representation is described. In Section 3, the proposed watermarking process is presented. The simulation results are presented in Section 4. Finally, in Section 5, we present our conclusions.

2. Concept of bit plane representation

A bit plane is an important toll in image processing to manipulate images. Particularly image watermarking can be conducted through bit plane [2-5]. In bit plane, there are only two levels, either 0 or 1, thus each bit plane can be represented by only 1 bit. In 8 bit image system, each image can be separated into 8 binary planes, and we assume the 0^{th} plane as the least significant bit and the 7^{th} plane as the most significant bit. Figure 1 shows an example of this concept. As we can see the 7^{th} bit plane is the most important and 0^{th} bit plane is the least important. In other words, images are still natural without 0^{th} bit plane. We denote i^{th} plane as β_i, where i=[0,1,2,…,7]. Each β_i is either 1 or 0. Figure 2 shows eight bit plane images β_i, from β_0 to β_7. The bit plane, β_i, levels are determined as Eq. (1),

$$\beta_i = \Theta\left(\Phi\left(\frac{im}{2^i} \right) \Big/ 2 \right), \tag{1}$$

where im is original image to be watermarked, input signal, Θ is *remainder process*, β_i is bit plane information at i^{th} plane, and Φ is *round process* which returns the results which are closer to either upper or lower integer number. For example, $\Theta(20/3)=2$ and $\Phi(15/7)=2$.

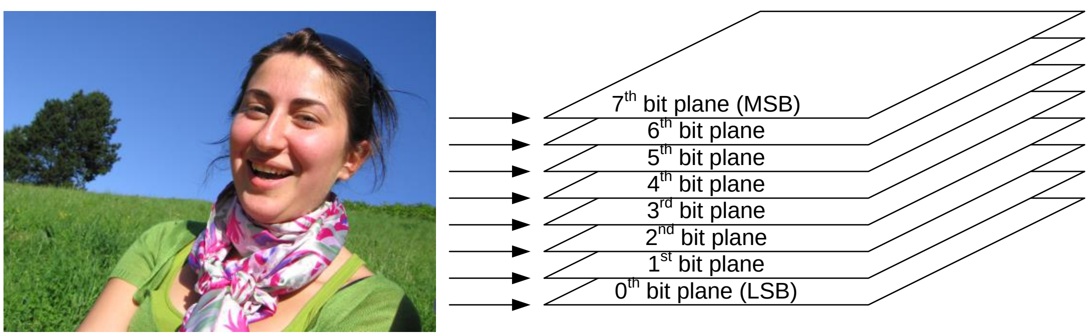


Figure 1. An example of bit plane representation of a tested image. Left: original 13^{th} LC image, (b) decomposed eight bit plane

3. Watermarking procedure

Watermarking is a crucial step and verification process where a hidden watermark in the image or video contains. The watermarking has been researched to guard digital copyright against unlawful attempt, and protect legal ownership. The best method for watermarking should consider human visual system where human eye is able to discern the watermarked image from the original image.

$$im = \beta_0 \cdot 2^0 + \beta_1 \cdot 2^1 + \beta_2 \cdot 2^2 + ... + \beta_7 \cdot 2^7 \tag{2}$$

Here, β_i is replaced by watermarked image. Figure 2 shows the results after replacing β_i with watermarked image.

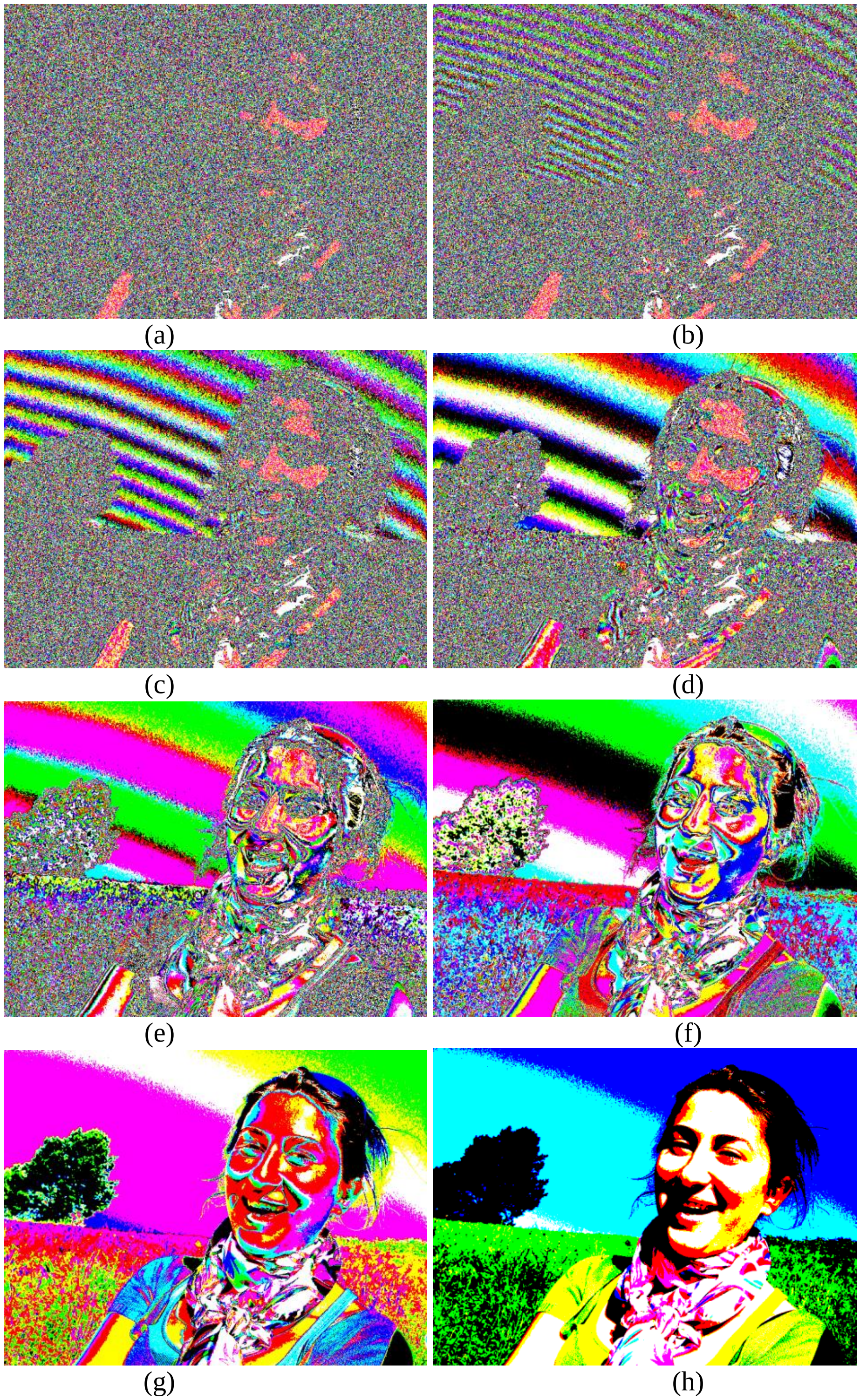


Figure 2. An example of bit plane decomposition using 13th LC image. (a) 0th bit plane (LSB), (b) 1st bit plane, (c) 2nd bit plane, (d) 3rd bit plane, (e) 4th bit plane, (f) 5th bit plane, (g) 6th bit plane, (h) 7th bit plane (MSB)

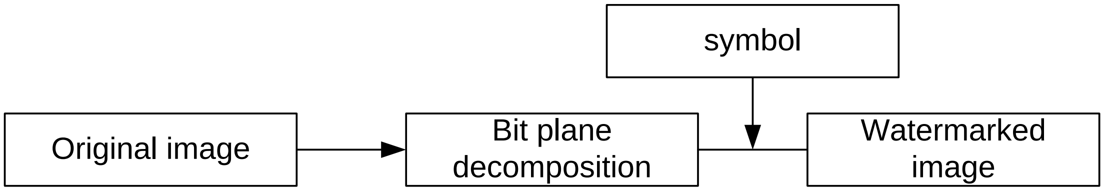


Figure 3. The procedure of proposed watermarking process

4. Performance analysis on different β_i

Figure 4. Example Watermark Image

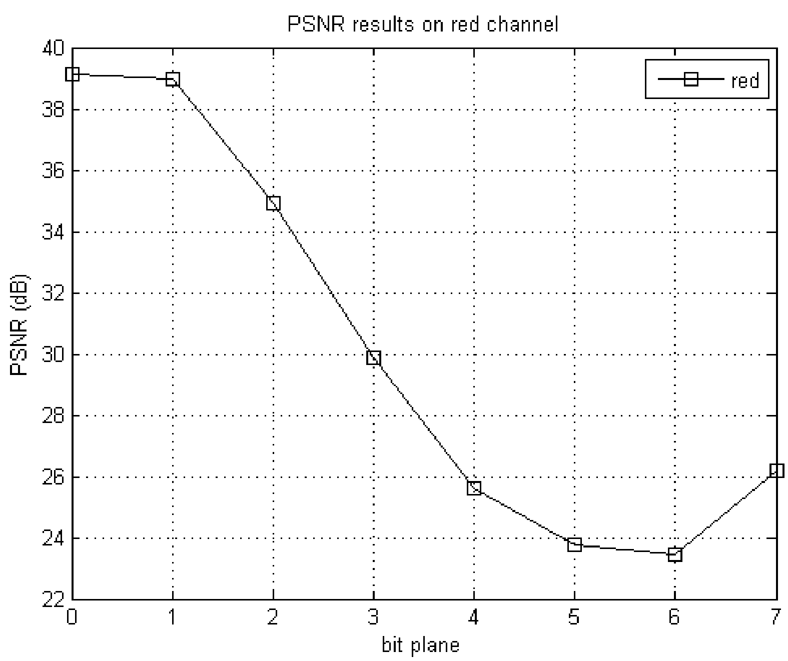


Figure 5. Average PSNR result in red channel for different β_i

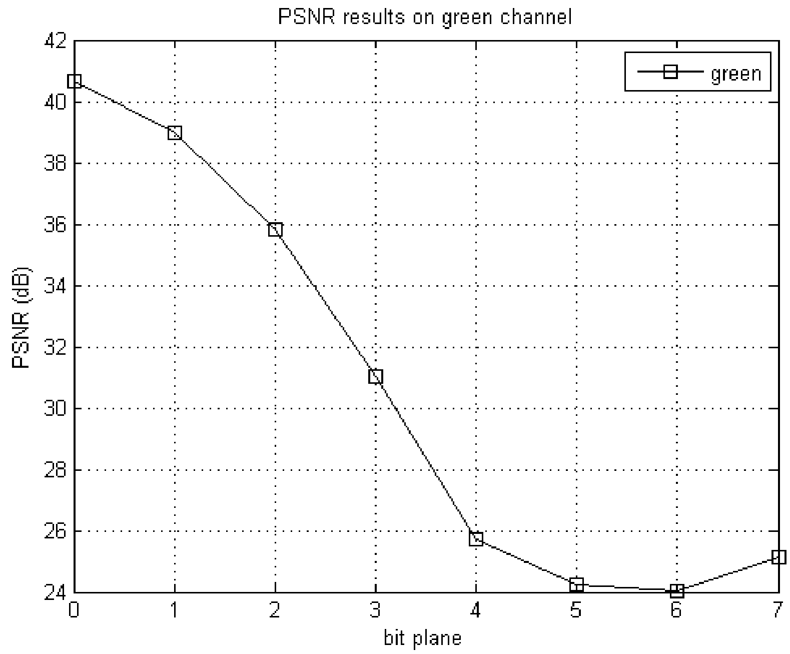


Figure 6. Average PSNR result in green channel for different β_i

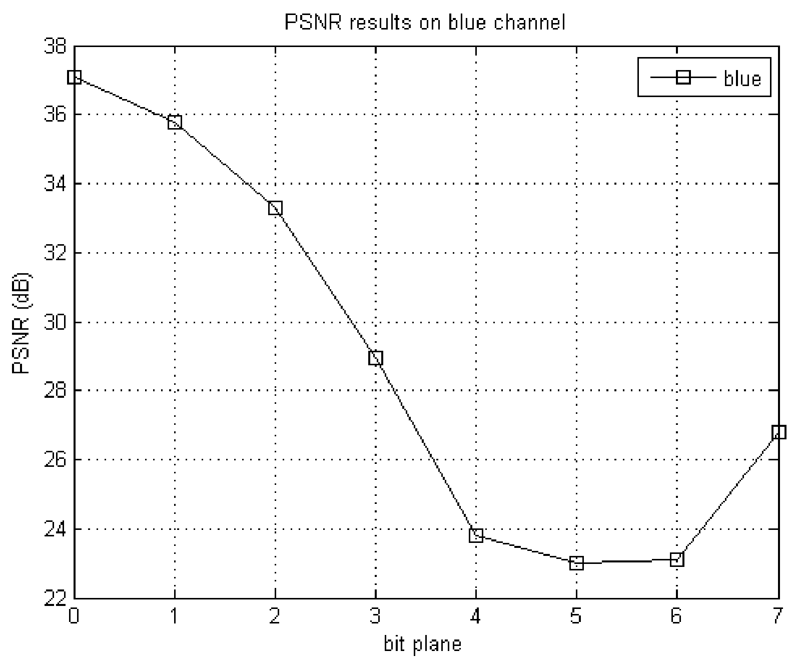


Figure 7. Average PSNR result in blue channel for different β_i

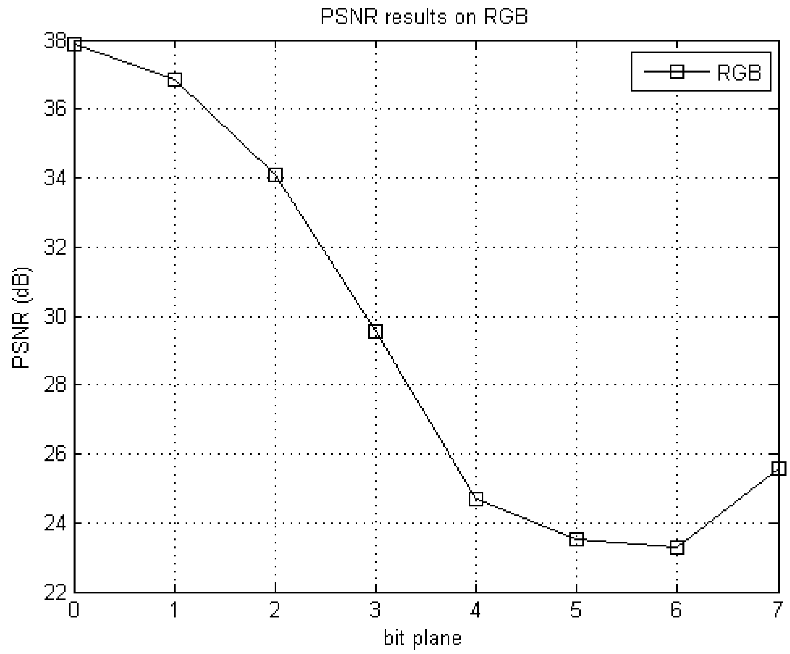


Figure 8. Average PSNR result in RGB color image for different β_i

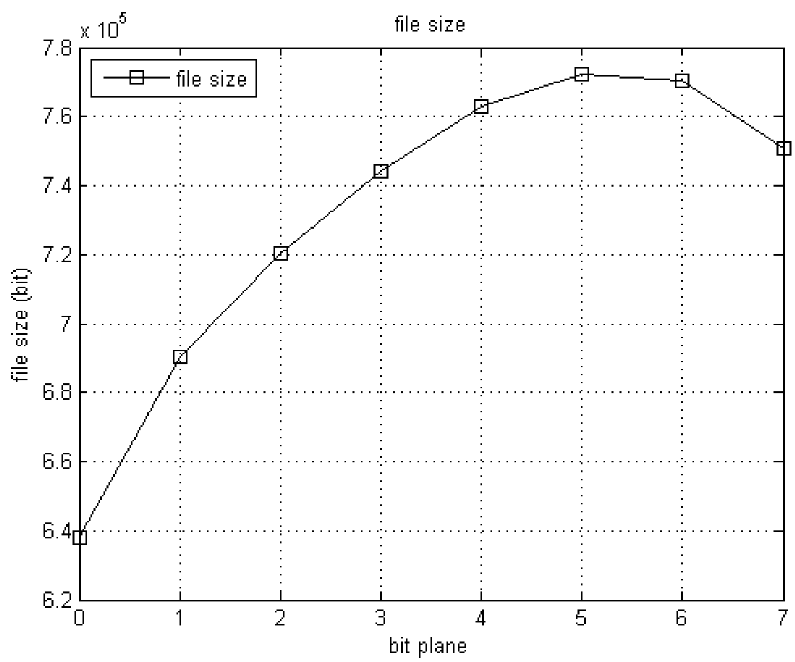


Figure 9. Average file size in RGB color image for different β_i

In this section, we conducted bit plane experiments on 150 still color images with dimension of 540×720 which are found here [28].

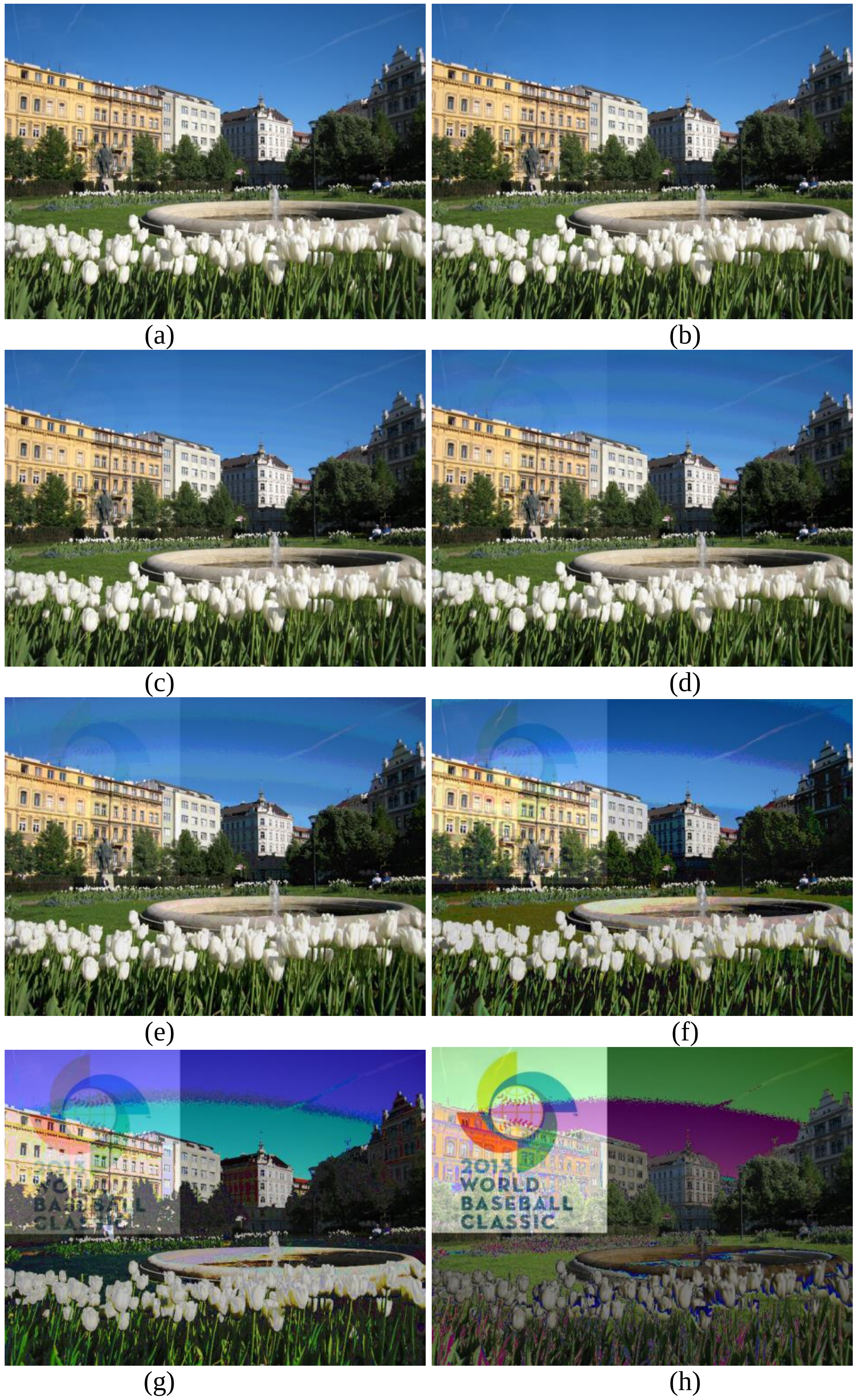
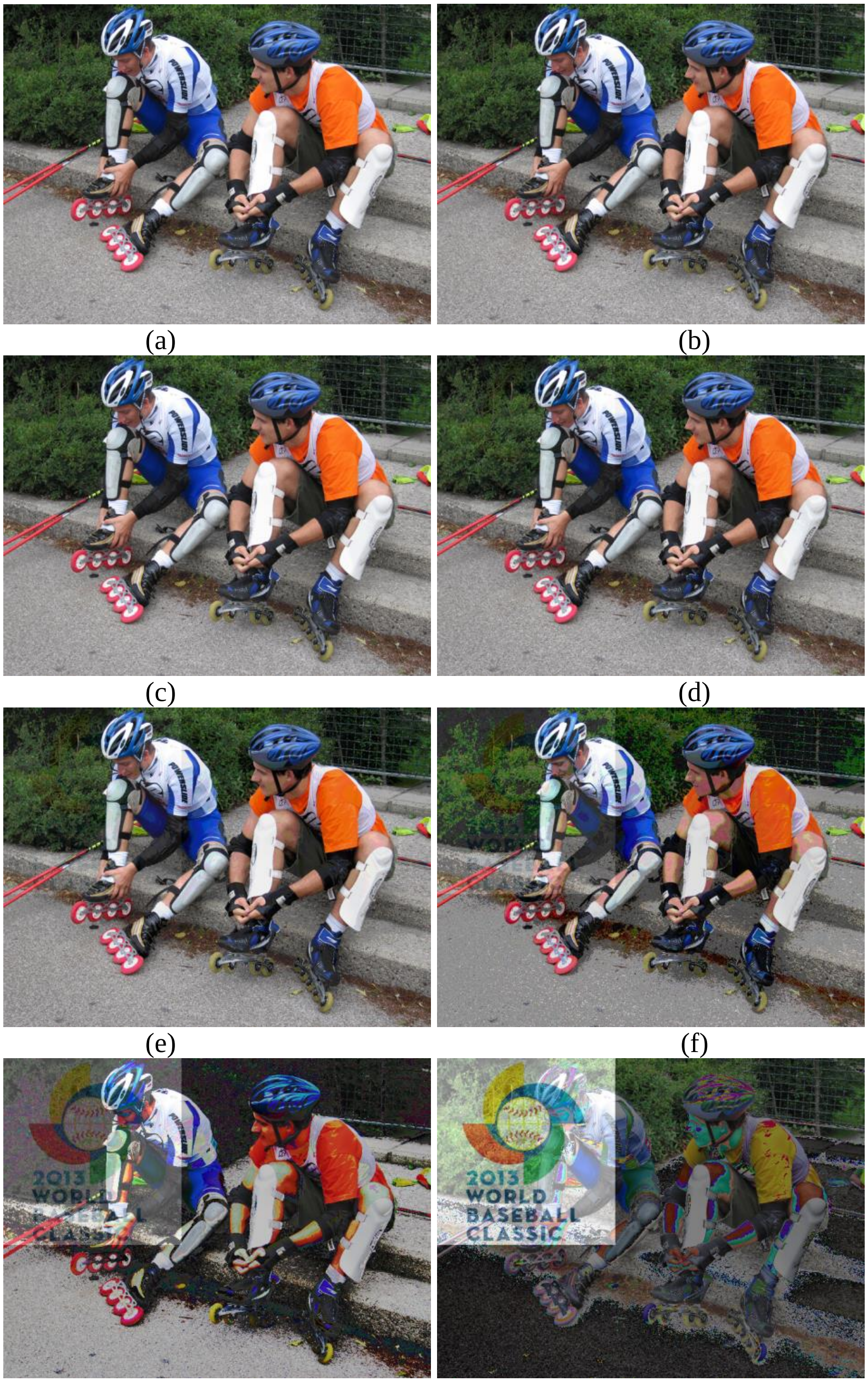


Figure 4. Restored images with watermarking symbol: (a) β_0, (b) β_1, (c) β_2, (d) β_3, (e) β_4, (f) β_5, (g) β_6, and (h) β_7



(a) (b) (c) (d) (e) (f) (g) (h)

Figure 5. Restored images with watermarking symbol: (a) β_0, (b) β_1, (c) β_2, (d) β_3, (e) β_4, (f) β_5, (g) β_6, and (h) β_7

Table 1. Simulation results of MSE and filesize results for different β_0

	Red	Green	Blue	RGB	filesize
β_0	675.3772	672.6097	757.5969	701.8613	638,200
β_1	413.9517	411.7230	510.2228	445.2992	690,390
β_2	289.2085	285.5488	429.8558	334.8710	720,500
β_3	199.1782	172.3839	338.0926	236.5516	744,220
β_4	251.3440	266.8341	691.8907	403.3562	763,080
β_5	308.2963	262.9494	354.9389	308.7282	772,460
β_6	349.8597	277.7686	339.7654	322.4645	770,190
β_7	168.6782	237.7893	159.9303	188.7993	750,830

In the subsections to follow extensive analysis is carried out to evolve the optimal combination of bit planes (image and watermark) to achieve desirable properties after watermarking. The PSNR results are provided for each combination of the bit planes. We adopt a well-known dissimilarity criterion called peak signal-to-noise ratio (PSNR) in decibels (dB)

$$MSE(im_1, im_2) = \sum_{i=1}^{width} \sum_{j=1}^{height} \frac{(im_1(i,j) - im_2(i,j))^2}{width \times height} \quad (3)$$

$$PSNR(im_1, im_2) = 10 \log_{10} \frac{255^2}{MSE(im_1, im_2)} \quad (4)$$

where im_1 and im_2 are the original and watermarked images, respectively. Also Cox watermarking method and CRC are widely used.

$$sim(im_1, im_2) = \frac{\langle im_1, im_2 \rangle}{\sqrt{\langle im_1, im_1 \rangle}} \quad (5)$$

$$CRC = \frac{\sum_{n=1}^{256} \sum_{m=1}^{256} W(m,n) \cdot W^*(m,n)}{\sqrt{\sum_{n=1}^{256} \sum_{m=1}^{256} \times W(m,n) \cdot \sum_{n=1}^{256} \sum_{m=1}^{256} \times W^*(m,n)}} \quad (6)$$

When CRC=0, we assume it is less robust watermarking. Figures 5-8 show the average PSNR results for three color channels and RGB images. Table 1 shows the average MSE results for eight β_i. As we can see, applying watermark in the least significant bit is always good. The performance goes worse as the i increases, however the β_7 is better choice then β_6. Figure 10 and Figure 11 show watermarked images. From the images we found that β_3 are always good selection for watermarking.

5. Conclusions

In this paper we presented a new bit plane-based watermarking method. The procedure is to include a symbol in the least significant bit plane of the original image. The performance comparison was conducted and found to be LSB is the best candidate to be used for watermarking. Experimental results section informs that th4e proposed method is the most reliable for watermarking.

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