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Performance Aware Bit Plane Allocation

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Abstract

This paper discusses bit plane allocation performance. The bit plane images are generated by bit plane slicing. The bit plane slicing is the process of conversion from original image to multilevel image. Normally, the number of multilevel is two. By bit plane slicing, a given image is sliced into n-level planes, where importance of planes is different. For example, the 0^{th} bit plane is the least significant one and the 7^{th} bit plane is the most significant one. Five metrics were used for evaluating bit plane, CMSE, CPSNR, S-CIELAB, FSIM and file size. Simulation results show the performance in each metrics.

Keywords*: image processing, bit plane allocation, digital color image, image size, performance metric, image quality*

1. Introduction

The bit plane slicing method uses a digital discrete image which is a set of bits point to a provided bit plane in each of the binary numbers depicting the signal [1-3]. The principal goal of bit plane slicing is to highlight contribution of given image, rather than highlight the gray level image [4-8]. Gray level images are composed of eight binary planes, which are ranging from 0^{th} to 7^{th} planes.

Separating a digital discrete image into its bit plane is efficient way to analyze importance of bit plane [9,10]. The 0^{th} bit plane is assumed to be the last bit of the image. This bit plane does not provide important information of the image, and therefore it is called as the *least significant bit* (LSB). On the other hand, the most important bit plane is 7^{th} bit, which is called as the *most significant bit* (MSB). There are few applications for bit plane. For instance, in pulse code modulation sound encoding, the first bit in the sample indicates the sign of the function [11-20]. This implies that only 1 bit can determined the sign of the whole signal, and the half of amplitude is depending on particular bit (MSB). However, the last bit of the sample does not much affect the information, and may be considered as '*don't care*' bit. Therefore, it is important to sustain MSB, and pay less attention on LSB. Table 1 shows an example of pulse code modulation [21-23].

In this paper, we analysis the performance of bit plane slicing where CMSE, CPSNR, S-CIELAB, FSIM and file size are provided. The paper is arranged as follows. In Section 2, bit plane slicing and performance metrics are provided. Simulation results are given in Section 3. Finally, in Section 4, we present our conclusions.

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Table 1. Example of Pulse Code Modulation

Bit allocation	Value	Importance of bit
111	7	MSE: 4 (in intensity) LSE: 1 (in intensity) Middle bit: 2 (in intensity)
110	6	
101	5	
100	4	
011	3	
010	2	
001	1	
000	0	

2. Proposed Method

The bit plane slicing method slices given *n*-bit image into *n* binary planes. The least and the most significant bits are *bit plane 0* and *bit plane 7*, which are depicted as Figure 1.

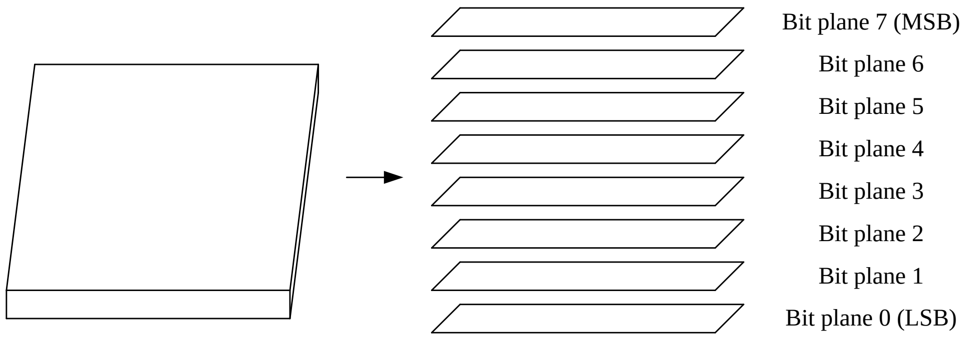


Figure 1. Bit Plane Slicing Representation of an Image (*N*=8)

It is obvious that the intensity value of each pixel is described by an *n*-bit binary plane vector (*bpv*): bpv_7, bpv_6, bpv_5, bpv_4, bpv_3, bpv_2, and bpv_1.It is noted that channel resolution *n* in Figure 1 is 8. As *bv* is represented as binary value, the intensity of *bpv* is either 0 or 1. And these values are accumulated in *n* bit planes. Each bit plane can be considered as 2-level images that are described by a binary matrix.

The *bpv* value is represented as Eq. (1).

$$bpv_n(i,j) = remaining\left(\frac{floor\left\{ \frac{image(i,j)}{2^n} \right\}}{2} \right), \tag{1}$$

Here, *image*(*i*,*j*) is original image at (*i*,*j*) pixel location. Parameter 'bpv_n' is bit plane information, and '*remaining*' means remainder operator. Finally, '*floor*(*k*)' is round the elements to *k* nearest integers less than or equal to *k*.

The file size quantifies the size of the output file. Generally, it is described in the form of bytes. The real amount of disk space assesses by the file conditional upon the file system. Table 2 shows file size analysis, where Number of bytes allocated to the file is described. For instance, file size of bit plane *A* to bit plane *B* (BP_{AB}) has following file size.

Figures 2 and 3 show the accumulated bit plane example of bit plane slicing on 8-bit color image and Figure 3 shows separate plane example of bit plane slicing on 8-bit color image, respectively.

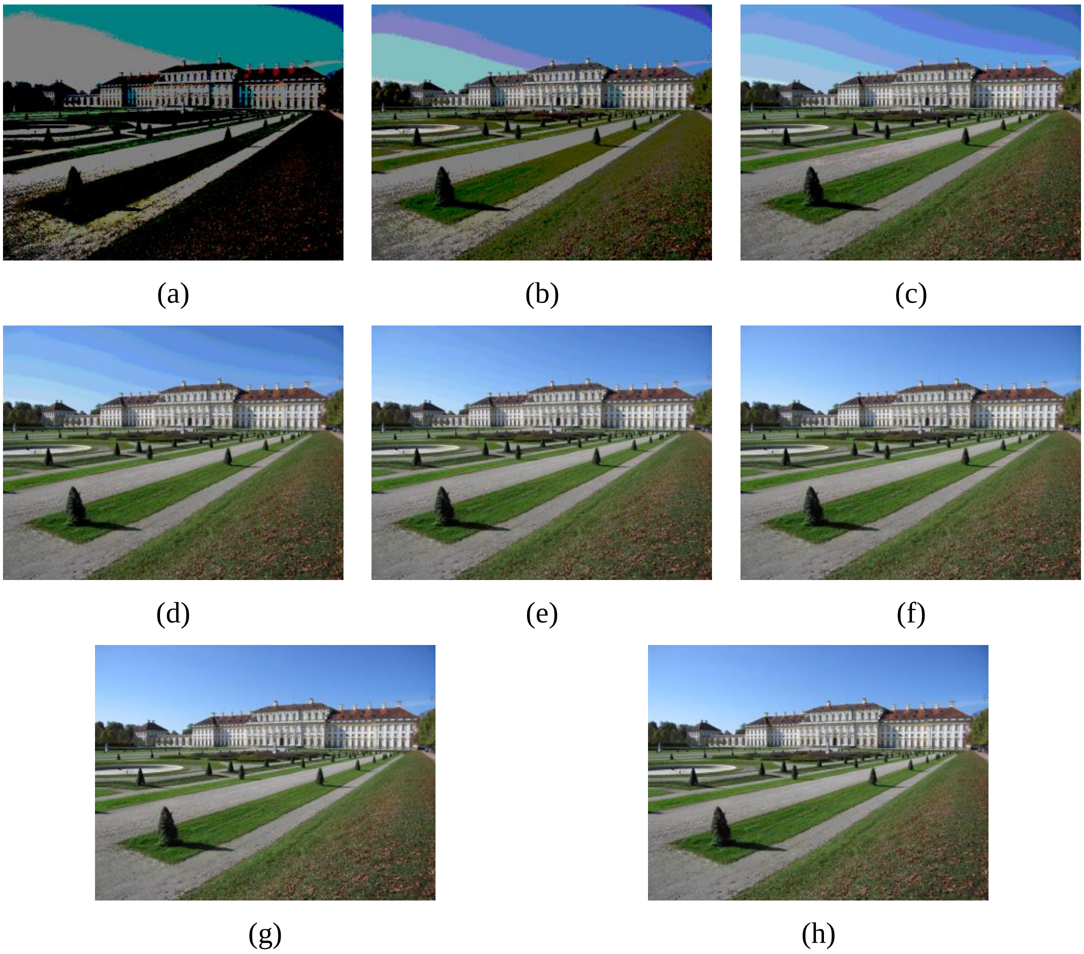
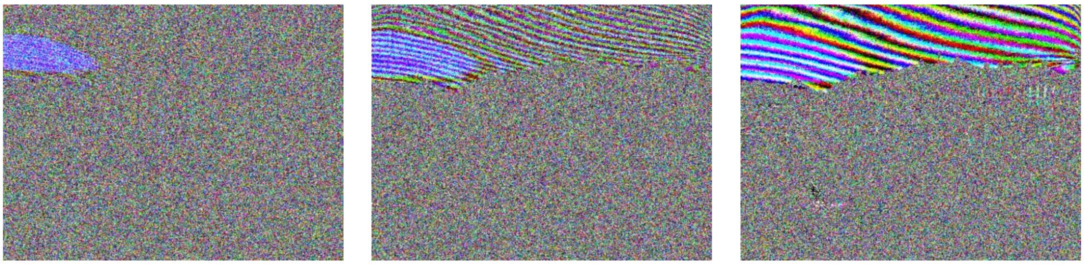
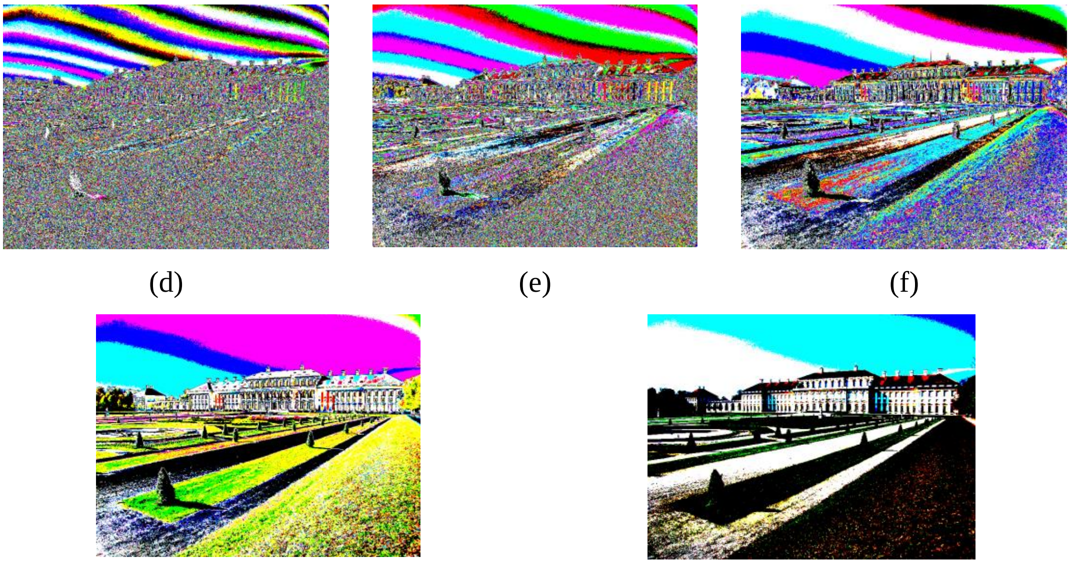


Figure 2. Accumulated Bit Plane Example of Bit Plane Slicing on 8-Bit Color Image: 31st LC Image: 31st LC Image: (A) Bit Plane 1 (LSB), (B) Bit Plane 1, (C) Bit Plane 2, (D) Bit Plane 3, (E) Bit Plane 4, (F) Bit Plane 5, (G) Bit Plane 6, And (H) Bit Plane 7 (MSB)



(a) (b) (c)



(d) (e) (f)

(g) (h)

Figure 3. Separate Plane Example of Bit Plane Slicing on 8-Bit Color Image: 31st LC Image: (A) Bit Plane 1 (LSB), (B) Bit Plane 1, (C) Bit Plane 2, (D) Bit Plane 3, (E) Bit Plane 4, (F) Bit Plane 5, (G) Bit Plane 6, And (H) Bit Plane 7 (MSB)

Figure 4. Shows MSB Bit Plane in Three Channels: Red, Green, and Blue.

(a) (b) (c)

Figure 4. Red, Green, and Blue Channels of MSB: (A) Red, (B) Green, and (C) Blue

Table 2. File Size Of #31 LC Image

BP_{AB}	File size
BP_{77}	49927
BP_{67}	122652 (=4.0496 times of BP_{77})
BP_{57}	202183 (=2.4566 times of BP_{77})
BP_{47}	293043 (=5.8694 times of BP_{77})
BP_{37}	393672 (=7.8850 times of BP_{77})
BP_{27}	512669 (=10.2684 times of BP_{77})
BP_{17}	642987 (=12.8785 times of BP_{77})
BP_{07}	719613 (=14.4133 times of BP_{77})

Traditional metric was assessed by gradient magnitude. The gradient operators can be expressed convolution masks, and their filters are shown in Table 3.

Table 3. Gradient Magnitude Filters

	$G_x(k)$	$G_y(k)$
Sobel	$\frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} * f(k)$	$\frac{1}{4}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} * f(k)$
Prewitt	$\frac{1}{3}\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} * f(k)$	$\frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} * f(k)$
Scharr	$\frac{1}{16}\begin{bmatrix} 3 & 0 & -3 \\ 10 & 0 & -10 \\ 3 & 0 & -3 \end{bmatrix} * f(k)$	$\frac{1}{16}\begin{bmatrix} 3 & 10 & 3 \\ 0 & 0 & 0 \\ -3 & -10 & -3 \end{bmatrix} * f(k)$

In [24], authors proposed perceptual color difference metric, which is S-CIELAB, also known as perceptual color fidelity metric. In general, color difference is esteemed by a lot of factors: cone sensitivity of the eyes, ambient illumination, and spatial pattern of the targets. The S-CIELAB computation has two components, color transformation and the spatial filtering steps. Then, results are sent to CIELAB Delta E calculation.

$$\Delta E^*_{ab} = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}. \tag{2}$$

Another metric is Feature SIMilarity Index (FSIM) [25-27]. In general, image quality assessment metrics pursue to utilize computational models to assess the image quality correctly with visual evaluations. There have been few well known metrics such as structural-similarity (SSIM), which is pixel-based method and assess structure. However, SSIM considers black and white image, and rather is not suitable for multi-channel (color) image. The FSIM is based on human visual system (HVS). Output of FSIM ranges from 0 (poorest) to 1 (best). In this work, we use FSIM to assess the performance of each bit plane. We used LC imageset. The equation of $FSIM_C$ is determined as follows,

$$FSIM_C = \frac{\sum_{x\in\Omega} S_{PC}(x) S_G(x) \left\{ S_I(x) S_Q(x) \right\}^{\lambda} PC_m(x)}{\sum_{x\in\Omega} PC_m(x)} = \frac{\sum_{x\in\Omega} S_L(x) \left\{ S_L(x) \right\}^{\lambda} PC_m(x)}{\sum_{x\in\Omega} PC_m(x)}. \quad (3)$$

where $\lambda > 0$ is the parameter used to adjust the importance of the chromatic components.

3. Simulation Results

In this section, we used 20 LC images, which have 540×720 resolution. Used images are #41 to #60 LC images. There are four metrics in this work, ($Metric_1$) file size, ($Metric_2$) CPSNR, ($Metric_3$) FSIM, and ($Metric_4$) S-CIELAB. BP_{AB} is the restored images with A^{th} BP to B^{th} BP, where plane number B is more important than plane number A. We generated seven BPs. BP_{17}, BP_{27}, BP_{37}, BP_{47}, BP_{57}, BP_{67}, and BP_{77}.

Tables 4-7 shows the CMSE, CPSNR, S-CIELAB, and FSIM results for 20 images with seven BPs conditions.

Table 4. CMSE Results for 41 To 60th LC Images

Image number	BP_{77}	BP_{67}	BP_{57}	BP_{47}	BP_{37}	BP_{27}	BP_{17}
41	39752.23	6537.08	624.12	21.52	1.20	0.36	1.50
42	36273.57	15689.62	4819.63	1356.74	164.44	11.33	1.20
43	34890.27	8300.98	2904.36	881.89	135.30	8.57	1.50
44	52853.66	40976.72	23028.02	3825.57	770.33	214.91	60.13
45	37397.23	15457.92	1248.59	118.64	8.03	2.10	0.42
46	42728.88	23263.02	11708.30	4541.47	1219.04	146.39	11.63
47	37622.88	13023.44	5166.01	1353.86	123.01	2.88	0.48
48	43836.60	21542.52	9918.38	2752.21	585.87	52.09	4.92
49	38794.44	14155.08	5682.64	2554.98	453.21	21.58	1.74
50	30739.12	10280.64	3063.88	566.15	49.58	3.78	0.54
51	51314.80	32803.25	12919.49	3046.31	637.67	186.38	54.31
52	29492.87	19299.15	6379.12	344.34	0.66	98.67	28.36
53	38968.17	21429.75	8747.54	1333.78	23.80	0.78	0.18
54	37962.72	13423.17	3148.70	244.59	59.29	7.43	1.20
55	34581.00	17392.26	8251.89	2102.67	219.89	10.97	2.40
56	28344.56	8685.73	2032.59	677.83	88.84	2.40	0.48
57	44072.79	14500.50	3968.13	690.18	6.35	0.60	0.24
58	36518.22	20688.50	11073.70	2369.20	210.48	9.41	1.08
59	41860.24	15238.28	3289.10	271.74	17.09	2.58	0.42
60	32577.96	8341.21	827.70	16.49	0.54	0.06	0.06
Avg.	38529.11	17051.44	6440.09	1453.51	238.73	39.16	8.64

(a) (b) (c)

Figure 5. S-CIELAB Maps for the (A) 2^{nd}, (B) 1^{st}, and (C) 0^{th} Bit Planes

Table 5. CPSNR Results for 41 to 60^{th} LC Images

Image number	BP_{77}	BP_{67}	BP_{57}	BP_{47}	BP_{37}	BP_{27}	BP_{17}
41	2.137	9.977	20.178	34.802	47.343	52.572	46.374
42	2.535	6.175	11.301	16.806	25.971	37.588	47.343
43	2.704	8.940	13.500	18.677	26.818	38.800	46.374
44	0.900	2.005	4.508	12.304	19.264	24.808	30.340
45	2.402	6.239	17.167	27.389	39.082	44.912	51.902
46	1.824	4.464	7.446	11.559	17.271	26.476	37.475
47	2.376	6.984	10.999	16.815	27.231	43.541	51.322
48	1.712	4.798	8.166	13.734	20.453	30.963	41.215
49	2.243	6.622	10.585	14.057	21.568	34.790	45.729
50	3.254	8.011	13.268	20.602	31.178	42.360	50.811
51	1.028	2.972	7.018	13.293	20.085	25.427	30.782
52	3.434	5.275	10.083	22.761	49.939	31.578	37.557
53	2.224	4.821	8.712	16.880	34.365	49.214	55.582
54	2.337	6.852	13.149	24.246	30.401	39.419	47.343
55	2.742	5.727	8.965	14.903	24.709	37.729	44.332
56	3.606	8.743	15.050	19.820	28.645	44.332	51.322
57	1.689	6.517	12.145	19.741	40.100	50.353	54.332
58	2.506	4.974	7.688	14.385	24.899	38.394	47.800
59	1.913	6.301	12.960	23.789	35.805	44.018	51.902
60	3.002	8.919	18.952	35.960	50.811	60.353	60.353
Avg.	2.328	6.266	11.592	19.626	30.797	39.881	46.510

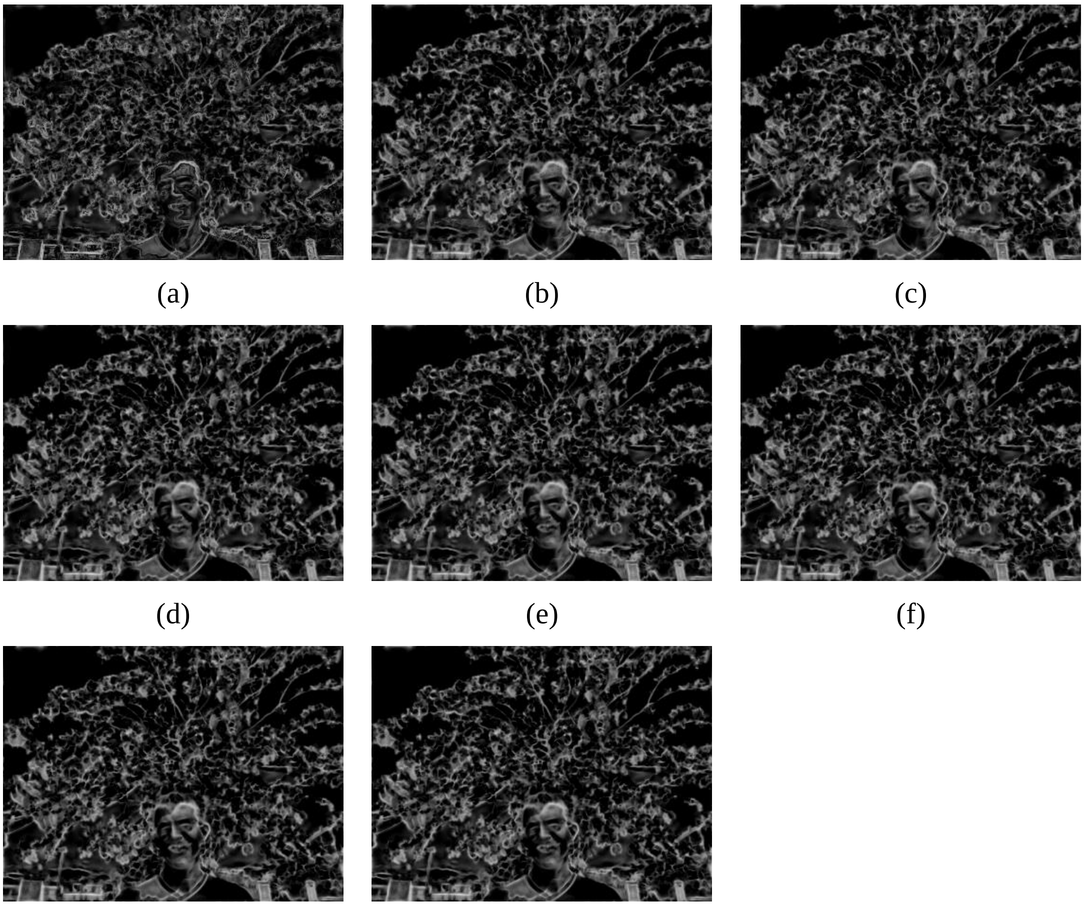
Figure 5 shows three S-CIELAB maps for the 2^{nd}, 1^{st}, and 0^{th} bit planes of the test image. Figure 6 shows FSIM maps for all bit planes.

Table 6. S-CIELAB Results for 41 to 60th LC Images

Image number	BP_{77}	BP_{67}	BP_{57}	BP_{47}	BP_{37}	BP_{27}	BP_{17}
41	0.3166	0.4777	0.8169	0.9508	0.9862	0.9932	1.0000
42	0.5183	0.5965	0.7423	0.8664	0.9396	0.9669	0.9893
43	0.3826	0.5332	0.8125	0.9024	0.9493	0.9796	0.9964
44	0.6756	0.4994	0.5006	0.6800	0.9087	0.9658	0.9871
45	0.4913	0.4104	0.7309	0.8710	0.9383	0.9759	0.9906
46	0.5109	0.5326	0.5673	0.7727	0.8617	0.9177	0.9734
47	0.4395	0.5975	0.7770	0.8406	0.8662	0.9647	0.9902
48	0.4904	0.5413	0.6628	0.7813	0.8970	0.9588	0.9913
49	0.3756	0.4383	0.6893	0.7918	0.8113	0.8411	0.9389
50	0.3972	0.5037	0.7009	0.9044	0.9461	0.9859	0.9979
51	0.5183	0.4524	0.5252	0.7239	0.8695	0.9684	0.9875
52	0.6098	0.5399	0.6648	0.8299	0.9433	1.0000	1.0000
53	0.3542	0.3362	0.4259	0.7448	0.8730	0.9052	0.9451
54	0.3253	0.4373	0.6321	0.8798	0.9434	0.9750	0.9942
55	0.4101	0.4949	0.6007	0.8079	0.9284	0.9689	0.9780
56	0.5381	0.6161	0.8565	0.8974	0.9242	0.9823	0.9943
57	0.3931	0.4347	0.7395	0.8474	0.8938	0.9788	0.9947
58	0.5300	0.5068	0.5493	0.7457	0.8931	0.9299	0.9763
59	0.3797	0.4160	0.6628	0.9086	0.9707	0.9904	0.9978
60	0.5300	0.5068	0.5493	0.7457	0.8931	0.9299	0.9763
Avg.	0.4593	0.4936	0.6603	0.8246	0.9118	0.9589	0.9850

Table 7. Fsim Results for 41 To 60th Lc Images

Image number	BP_{77}	BP_{67}	BP_{57}	BP_{47}	BP_{37}	BP_{27}	BP_{17}
41	70.505	11.671	0.987	0.034	0.003	0.001	0.000
42	58.768	28.010	9.214	2.404	0.228	0.015	0.003
43	70.963	16.587	6.288	1.711	0.221	0.014	0.003
44	84.683	72.044	35.941	5.579	1.163	0.332	0.100
45	92.043	29.826	2.412	0.288	0.022	0.006	0.001
46	71.830	40.861	19.267	7.211	1.913	0.185	0.016
47	71.299	22.820	9.533	2.486	0.178	0.004	0.001
48	95.087	35.529	16.899	4.811	0.922	0.065	0.009
49	77.114	25.854	10.106	4.664	0.768	0.024	0.003
50	51.404	15.640	4.698	0.895	0.059	0.006	0.001
51	98.194	86.814	42.889	9.590	1.918	0.555	0.157
52	47.305	32.308	10.656	0.453	0.001	0.000	0.000
53	66.628	37.226	16.807	2.366	0.037	0.001	0.000
54	66.962	24.630	5.201	0.420	0.092	0.013	0.002
55	57.464	29.345	13.852	3.310	0.324	0.016	0.005
56	47.775	15.106	3.740	1.248	0.121	0.004	0.001
57	76.928	24.671	6.857	1.060	0.008	0.001	0.000
58	62.936	44.364	21.413	3.969	0.303	0.014	0.002
59	71.585	31.865	5.817	0.431	0.037	0.007	0.001
60	67.838	16.607	2.060	0.035	0.002	0.000	0.000
Avg.	70.366	32.089	12.232	2.648	0.416	0.063	0.015



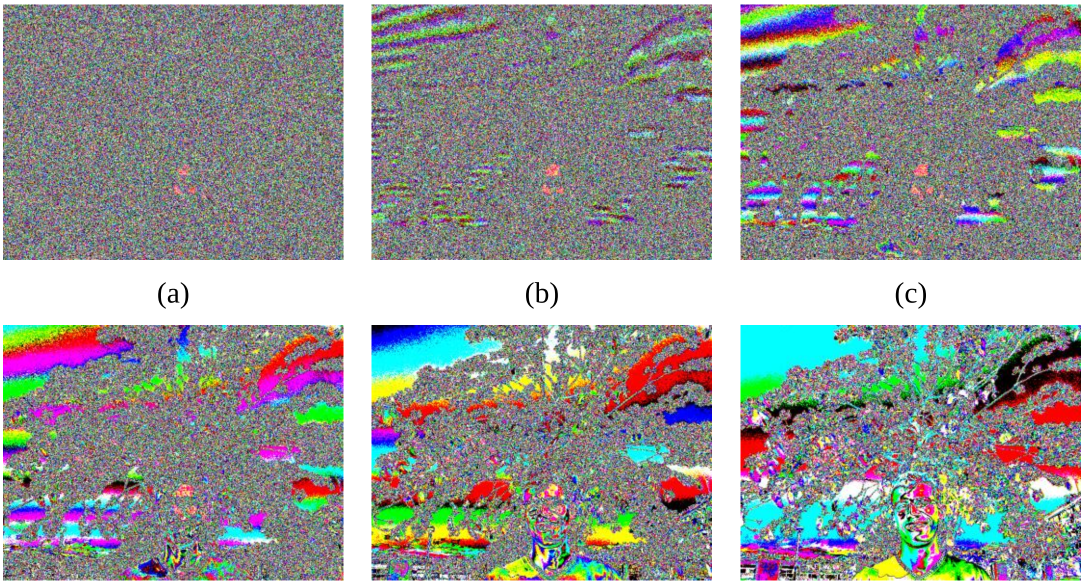
(a) (b) (c)

(d) (e) (f)

(g) (h)

Figure 6. FSIM Maps with A^{th} BP To B^{th} BP on 80^{th} LC Image: (A) BP_{77}, (B) BP_{67}, (C) BP_{57}, (D) BP_{47}, (E) BP_{37}, (F) BP_{27}, (G) BP_{17}, And (H) BP_{07}.

Figure 7 shows independent bit plane image while Figure 8 shows visual comparison of BP_{07} to BP_{77} result images.



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 7. Bit Plane Image: (A) 0th Bit Plane, (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, And (I) Original Image.

4. Conclusions

When signals are described in digital format, signal can be decomposed in sliced bits. This paper analyzed the tradeoff between image size and performance. The performance was measured by four metrics CMSE, CPSNR, S-CIELAB, and FSIM. Experimental results show the performance in each metrics.

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(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 8. Restored Images with A^{th} BP To B^{th} BP on 80^{th} LC Image: (A) BP_{77}, (B) BP_{67}, (C) BP_{57}, (D) BP_{47}, (E) BP_{37}, (F) BP_{27}, (G) BP_{17}, (H) BP_{07}, And (I) Original Image

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