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Similarity and Variance of Color Difference Based Demosaicing

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Abstract

The aim of the project is to find the missing color samples at each pixel location by the combination of similarity algorithm and the variance of colour difference algorithm. Many demosaicing algorithms find edges in horizontal and vertical directions, which are not suitable for other directions. Hence using the similarity algorithm the edges are found in different directions. But in this similarity algorithm sometimes the horizontal and vertical directions are mislead. Hence this problem can be rectified using the variance of colour difference algorithm. It is proved experimentally that this new demosaicing algorithm based on similarity and variance of colouyr difference has better colour peak signal to noise ratio (CPSNR). It has better o0bjective and subjective performance. It is an analysis study of both similarity and colour variance algorithms.

Keywords: *colour filter array, demosaicing, unified high frequency map, peak signal to noise ratio, acquisition*

1. INTRODUCTION

Digital cameras become and many people are choosing to take pictures with digital cameras instead of film cameras. When a digital image is recorded, the camera needs to perform a significant amount of processing to provide the user a viewable image. This processing includes white balance adjustments, gamma correction, compression and more. Most consumer digital cameras capture colour information with a single light sensor and a colour filter array (CFA). The CFA is compound by a set of spectrally selective filters, arranged in an interleaved mosaic pattern, so that in each pixel samples only one of the components of the colour spectrum is captured instead of capturing three color samples(typically red,green,and blue) at each pixel location ,these camera capture a so called 'mosaic' image, where only one color is sampled at each location. The two missing colors must be interpolated from the surrounding sample. A very important part of this image processing is called color filter array interpolation or demosaicing.

A color image requires atleast three color samples at each pixel location. Computer images often use red, blue and green. A camera would need three separate sensors to completely measure the image. Using multiple sensors to detect different parts of the visible spectrum requires splitting the light entering the camera, so that the scene is image onto each sensor. Precise registration is then required to align the three images. These additional requirements add a large expense to the system. Thus, many cameras use a single sensor with a color filter array. The color filter array allows only one part of the spectrum to pass to the sensor so that only one color is measured at each pixel. This means that the camera must eliminate the missing two color values at each pixel. This process is known as demosaicing. The choice of the best color filter array is very important for the final image quality and different solution. The best color filter array is the bayer pattern which is proved as the standard pattern. The sample bayer pattern is shown below in Figure 1.

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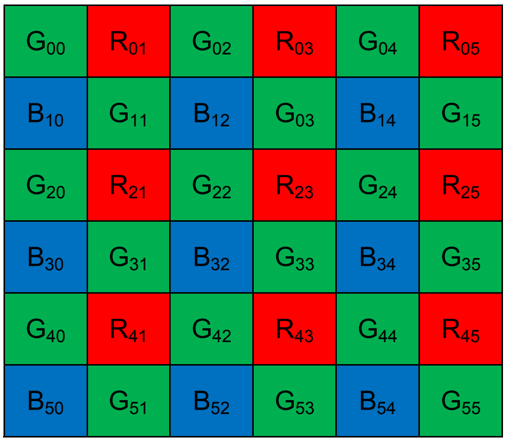


Figure 1. Bayer pattern

Digital still color cameras are based on a single charge coupled device(CCD) array or complementary metal oxide semiconductor (CMOS) sensors and capture color information by using three or more color filters, each sample point capturing only one sample of the color spectrum. In a three-chip color camera, the light entering the camera is split and projected on to each spectral sensor. Each sensor requires its proper driving electrons, and the sensors have to be registered precisely. These additional requirements had a large expense to the system. To reduce cost and complexity, digital camera manufacturers use a single CCD/CMOS sensor with a color filter array (CFA) to capture all the three primary colors (R,G,B) at the same time.

Color filter arrays containing one or more colors for liquid crystal displays and other opto-electronic devices are made by using a laser to ablate portions of a coating on either a colored or transparent substrate. Color filter material are placed into the ablated openings and cured. The number of laser–ablated openings in the coated substrate varies, depending on the quality and type of color desired.

2. Review of Similarity Based Demosaicing Algorithm

Similarity based demosaicing algorithms has two forms. one is the without refinement form and the other is the with refinement form. In this UHF map acquisition and similarity based interpolation comes under without refinement and global edge classification of horizontal and vertical direction comes under with refinement method. In the without refinement method we calculate the map index using the high frequency components and using this map values we are interpolating the missing pixels in horizontal and vertical direction using global edge classifier separately in the refining method. This further gives better color peak signal to noise ratio (CPSNR) value. This is the similarity based demosaicing algorithm.

In this algorithm the unified high frequency map is formed by taking the average of every sample of red, blue and green components independently and then every sample values are independently subtracted from the average value. Then we have to note that these values are larger than zero or lesser than zero. If the values larger than zero then we have to plot that particular value as one and if the differenced value is lesser than zero then we have to plot the value as zero. Like this the unified high frequency map is formed. Based on this the direction of the edge is found out and the missing samples are interpolated.

$$\Lambda(i,j)=\begin{cases}0, h(i,j) < 0\\ 1, otherwise\end{cases} \quad (1)$$

Where $\Lambda(i,j)$ is the map index to be calculated and h(i,j) is the difference between the individual pixels and the average of the total pixels. The map index calculations are shown below in Figure 2.

	153		134		208
	145		151		178
	40		83		147

145		161		197	
	147		165		203
75		98		159	
	69		101		160
23		68		95	
	19		62		93

63		139		155	
28		65		99	
18		33		69	

(a) Map Index calculations

1	1	1	1	1	1
0	1	1	1	1	1
0	1	0	1	1	1
0	0	0	0	1	1
0	0	0	0	0	1
0	0	0	0	0	0

(b) Unified High Frequency Map

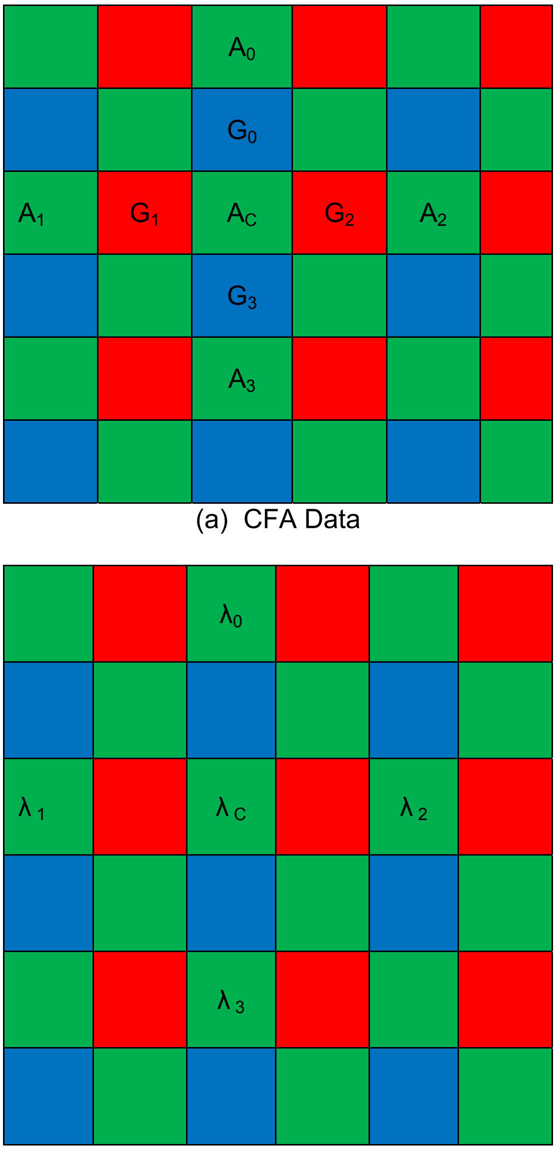
Figure 2. Flow chart of map index calculations

In the above figure the map value for each pixel is found out by taking the difference between the individual pixels and the average of the total pixels are shown. While plotting the map in the differenced value is greater than zero then the particular map value is plotted as 1 and if the differenced value is less than zero then that particular value is plotted as 0.

Now after forming the map the missing pixels are interpolated using the map direction. Initially the green samples are interpolated by using the comparison of the map values of the neighboring green samples. If they are same then the formula to find the missing green samples are given below.

$$G_c = \frac{1}{4}\sum_{l=0}^{3}\{\theta_l[G_l + A_c - A_l/2] + \tilde{\theta}_1.\rho\}$$
$$\theta_l = \begin{cases} 1, & if\ \lambda_1 = \lambda_c \\ 0, & otherwise \end{cases} \quad (2)$$

The diagram for interpolating the missing green samples are shown below in Figure 3 in which $\lambda 1$ and λcvalues are the same then the green values are interpolated by using the formula (2).



(b) UHF Map
Figure 3. Interpolation of missing green sample

If the map values are not the same then we have to interpolate the missing green samples as below.

$$\rho = \frac{1}{4}\sum_{l=0}^{3}[\mathrm{Gl} + \frac{\mathrm{Ac}-\mathrm{Al}}{2}] \quad (3)$$

After interpolating the missing green samples, the missing red and blue samples are interpolated by comparing the map values. The missing red and blue samples are interpolated as by interpolating the missing red and blue samples in the green samples which are already present. Then the missing red samples are interpolated in the blue samples present and then the missing blue samples are interpolated in the red samples which are already present. The missing red and blue samples are interpolated as by the formula given below.

Now the missing red samples in the blue samples present and the missing blue samples in the red samples present are interpolated using the formula given below.

$$x(s,t)_k = x(s,t)_\phi + \frac{1}{4}\sum_{(i,j)\epsilon\xi}[\theta(i,j).\{x(i,j)_k - x(i,j)_\varphi\} + \tilde{\theta}(i,j).\rho]$$
$$f(x) = \begin{cases} 1, if\ \lambda(i,j) = \lambda(s,t) \\ 0,\ otherwise \end{cases} \quad (4)$$

Here also if the map values are not the same then we have to interpolate the missing samples as below:

$$\rho = \frac{1}{4}\sum_{(i,j)\epsilon\xi}\{x(i,j)_k - x(i,j)_\varphi\} \quad (5)$$

Now the missing red and blue samples in the green samples, which are already present are obtained using the formula given below.

a(s,t)=G(s,t)+{(A(s,t-1)-G(s,t-1))+(A(s,t+1)-G(s,t+1))}/2 (6)

a(s,t)=G(s,t)+{(A(s-1,t)-G(s-1,t))+(A(s+1,t)-G(s+1,t))}/2 (7)

3. Review of Variance of Color Difference Algorithm

In this variance of color difference algorithm the missing green samples are interpolated in raster scan manner as shown below. Initially the green sample is interpolated in a raster scan manner and then the missing red and blue components are interpolated based on the green samples which we already interpolated. Figure 4 shown below is the bayer pattern with red as centre,blue as centre and green as centre respectively using which the missing green samples are interpolated in a raster scan manner.

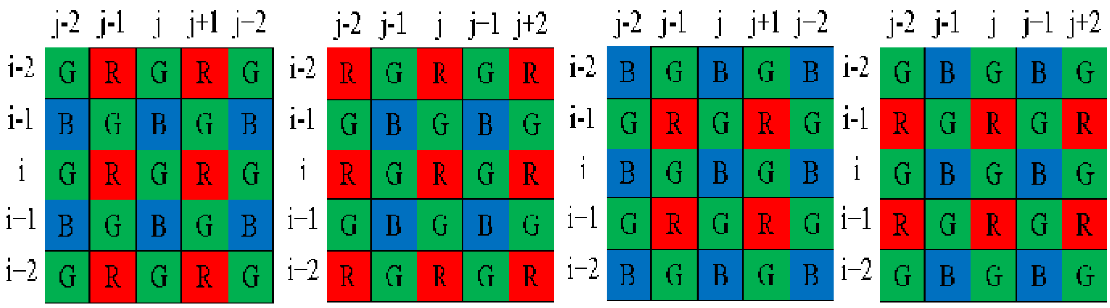


Figure 4. Interpolation of missing green samples in raster scan manner

To find the missing green samples in a raster scan manner it is necessary to find the edge direction which may be horizontal or vertical. If the edge direction is horizontal then the green samples are interpolated according to the formula (8) below.

$$g_{i,j} = \frac{G_{i,j-1}+G_{i,j+1}}{2} + \frac{2R_{i,j}-R_{i,j-2}-R_{i,j+2}}{4} \quad (8)$$

In this equation small g represents the green samples to be interpolated and the G represents the green samples which are already present. If the edge direction is vertical then the formula to find the missing green sample is shown Equation (9).

$$g_{i,j} = \frac{G_{i-1,j}+G_{i+1,j}}{2} + \frac{2R_{i,j}-R_{i,-2,j}-R_{i,+2,j}}{4} \quad (9)$$

After interpolating the missing green samples according to the edge direction, the missing red and blue samples are interpolated. The formula to find the missing red and blue samples is given below in the Equation (10) and (11) respectively.

$$r_{i,j} = G_{i,j} + \frac{R_{i-1,j}-G_{i-1,j}+R_{i+1,j}-G_{i+1,j}}{2} \quad (10)$$

$$b_{i,j} = G_{i,j} + \frac{B_{i,j-1}-G_{i,j-1}+B_{i,j+1}-G_{i,j+1}}{2} \quad (11)$$

In the above equation r and b represents the missing red and blue samples to be interpolated. G,R,B represents the green, blue, and red samples which are already present.

4. Proposed Algorithm

In the similarity based demosaicing algorithm the missing color samples are interpolated in horizontal,vertical and in diagonal direction. But it sometimes mislead the horizontal and vertical directions. In variance of color difference algorithm only the horizontal and vertical directions are detected. So in this algorithm it is the analysis of the both similarity based demosaicing algorithm and variance of color difference algorithm in which by combining both the algorithm a new algorithm called demosaicing based on similarity and variance of color difference is found out.

In this new algorithm initially the unified high frequency map is formed and based on that the edge directions are detected. After detecting the edge direction the missing green samples are interpolated based on the similarity algorithm and the missing red and blue samples are interpolated according to the same similarity algorithm. Now using the variance of color difference algorithm again the missing green samples are interpolated in a raster scan manner, trhen the missing red and blue samples are interpolated according to the interpolated green samples using the variance of color difference algorithm.

The new method by combining the similarity based demosaicing algorithm and the variance of color difference algorithm given below in Equation (12), (13).

Similarity image=merged image (12)

Merged image=reconstructed color variance image (13)

In this new algorithm by combining the similarity based demosaicing algorithm and the variance of color difference algorithm the edge directions are detected perfectly without any misleading in any edge directions. Using this analysis of both similarity and color variance algorithm the edge directions are detected in horizontal, vertical and diagonal directions.

5. Experimental Results

The experimental results of the demosaicing based on similarity and variance of color difference are shown below. The peak signal to noise ratio of this new algorithm is shown below. The formula used to find the peak signal to noise ratio is shown below in Equation (14).

$$CPSNR = 10\log_{10}\frac{255^2}{\frac{1}{ST}\sum_{s=0}^{s-1}\sum_{t=0}^{T-1}\left(o(s,t)-x(s,t)\right)^2} \quad (14)$$

Where o(s,t)=[o(s,t)0,o(s,t)1,o(s,t)2] and the x(s,t)=[x(s,t)0,x(s,t)1,x(s,t)2] denoted the co-ordinates (s,t) of original and restored image respectively. The comparison tabulation of the similarity algorithm, variance of color difference algorithm and the proposed algorithm are shown.

The test images used for the analysis are shown above in the Figure 5. In this the 24 images are tested for the three algorithms and experimentally it is proved that the proposed algorithm has the better result when compared to the similarity and color variance algorithm.

Figure 5. Kodak test images used for experiment

In the tabular column below it is proved that the proposed algorithm has the better result for the red, green, blue samples. The best values are marked in bold.

Table 1. Comparison of similarity algorithm, color variance algorithm and proposed algorithm

Image number	Similarity based demosaicing algorithm			Variance of color difference algorithm			Proposed method		
	R	G	B	R	G	B	R	G	B
1	34.02	34.48	34.04	25.23	33.48	26.36	34.02	34.48	34.04
2	36.43	39.52	37.98	15.02	39.82	25.36	40.44	43.41	43.81
3	39.78	41.27	39.67	23.28	41.13	20.48	44.12	45.07	43.38
4	36.75	40.38	40.08	18.49	40.36	30.39	40.13	43.52	44.84
5	34.48	34.11	34.33	25.65	34.58	25.33	39.46	38.16	38.98
6	35.31	35.86	35.29	28.61	34.42	23.23	40.49	39.33	39.40
7	39.62	40.25	39.02	26.40	40.75	24.35	43.96	43.88	42.53
8	31.03	32.17	31.17	26.56	31.01	26.83	37.10	36.01	37.73
9	38.09	40.30	39.75	30.70	40.18	27.07	43.88	44.28	44.22
10	39.07	40.25	39.63	29.98	39.93	31.06	43.77	44.00	43.74
11	36.14	36.89	36.74	25.46	36.19	28.90	40.10	40.37	41.08
12	39.75	40.96	39.94	27.12	40.50	23.92	44.23	44.69	43.71
13	31.93	31.48	31.47	28.75	30.17	23.08	37.14	34.32	35.11
14	34.17	36.20	34.23	24.30	36.35	21.07	38.81	39.87	39.49
15	36.48	39.25	38.76	20.16	38.23	27.85	39.84	42.66	43.84
16	38.56	39.32	38.48	33.18	38.04	28.46	44.67	42.94	42.50
17	38.86	39.27	38.71	32.36	38.54	30.96	43.39	42.30	42.62
18	34.37	35.56	35.34	25.89	33.00	23.52	38.87	38.20	39.21
19	35.36	36.58	36.23	28.63	34.89	25.28	39.70	40.47	40.44
20	38.67	39.13	37.84	32.64	37.58	24.41	43.68	42.20	41.72
21	36.02	36.32	35.63	26.59	34.71	27.00	40.68	39.43	39.68
22	35.81	37.33	35.84	26.01	36.27	23.43	39.64	40.48	40.44
23	39.74	41.52	40.32	20.16	39.17	19.17	44.23	45.36	45.44
24	33.39	33.99	32.32	29.01	32.42	26.00	38.81	36.85	36.58

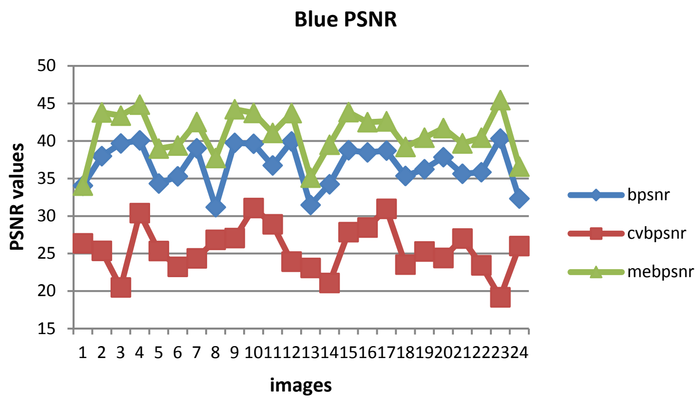


Figure 7. PSNR comparison of blue samples for similarity, color variance and proposed algorithms

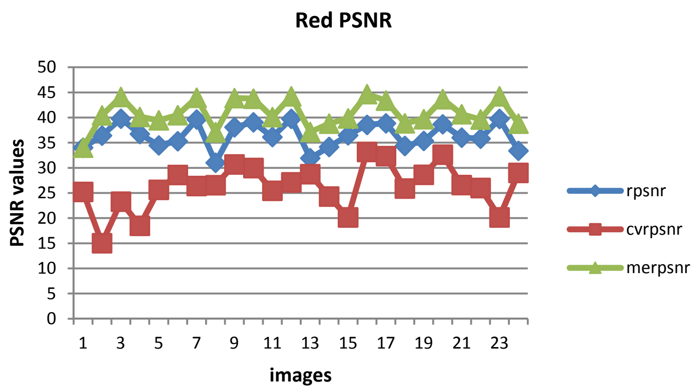


Figure 8. PSNR comparison of red samples for similarity, color variance and proposed algorithms

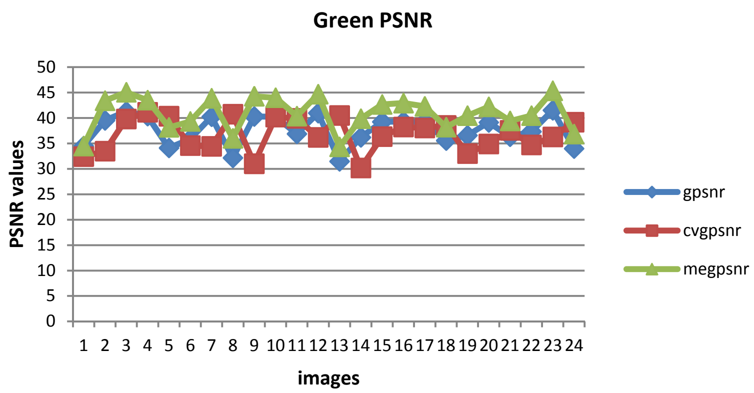


Figure 9. PSNR comparison of green samples for similarity, color variance and proposed algorithms

The graphs comparing the similarity algorithm, color variance algorithm and the proposed algorithm are shown in below. Figure 7 shows the comparison of blue sample for three algorithms. Figure 8 shows the comparison of red sample for three algorithms. Figure 9 shows the comparison of green sample for three algorithms.

6. Conclusion

In this paper, we introduce a new algorithm by combining similarity and color variance algorithms called similarity and color difference based demosaicing.we confirmed through the experiments that the proposed algorithm has better quality improvement than the similarity and color variance algorithms. Exploration of the proposed algorithms with the situation identifying the parameters in which similarity and color variance algorithms are adaptively implemented in real life is worth for further investigation.

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