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Directional Color Difference Based Demosaicing

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ABSTRACT— *Digital cameras are using a single CCD/CMOS sensor to capture images. The color filter array is places in front of the sensor and the CFA sense only one color component at each pixel location. The three primary colors used in CFA are red, green and blue and the process of estimating the missing two color components at each pixel location is known as demosaicing. To reduce artifacts and to increase the image quality, the proposed system uses the color difference and gradient based method for green plane interpolation. The red and blue planes are interpolated using the estimated green plane and the bayer CFA pattern is used to demonstrate this interpolation technique. The image quality performance is measured using the CPSNR value.*

keywords—color filter array (CFA), demosaicing, color peak signal-to-noise ratio (CPSNR), charged coupled device (CCD), Bayer CFA.

1,INTRODUCTION

A Digital camera market has grown rapidly because peoples are choosing to take their pictures with digital camera's instead of film camera's. A full color image is composed of three primary colors such as red, green and blue. The earlier digital still cameras use beam splitter which split the three primary color in three separate sensors and a color filter is placed in front of the three sensors(Fig. 1a). This approach is costly because it required three charge-coupled device(CCD) sensors. In order to reduce the cost and size of the digital camera, nowadays digital still cameras are using single charged coupled device(CCD/CMOS)with color filter array(Fig.1b). Many CFA pattern are used for demosaicing, some of them are Bayer CFA, Lukac CFA, Plataniotis CFA, Yamanaka CFA and vertical-stripe CFA are shown in Figure. 2. The most popular CFA pattern used for demosaicing is Bayer CFA, it is designed based on the luminance and chrominance level. The CFA samples only one color component at each pixel location and the color arrangement in CFA is alternative color components of red/green and green/blue. In bayer CFA the green component are placed on the quincunx lattice and red and blue component are placed on the rectangular lattice. The green color perceived brightness well because the green color sampled at a higher rate.

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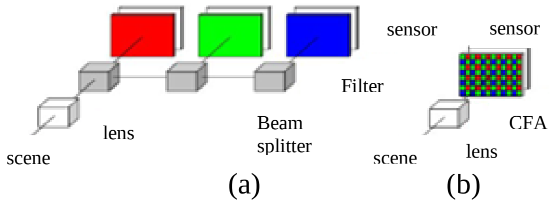

Figure.1 Digital camera system (a) a three sensor device (b) a single sensor device.

The green color occupy most of the pixel location in CFA than the other two color because the human visual system(HVS) is more sensitive to green color than red and blue. Bayer CFA consist of 50% of green color & 25% of red and blue color. To get a full color image from the mosaiced image the missing two color component has to be interpolated at each pixel location. The process of interpolating the missing two color component is known as demosaicing. Demosaicing method is divided into two type, they are iterative method and non-iterative method. The iterative method give higher image quality when compare to non iterative method. Many interpolation techniques are used for estimating the missing two color component. The bilinear interpolation is the simplest and most efficient method used in earlier demosaicing algorithm, but the major two artifacts are occurred in this type of interpolation techniques. The artifacts occurs are blurring and false coloring, due to this reason many new interpolation techniques are implemented, to reduce this kind of artifacts. Later hue based interpolation is implemented is implemented it give better result in avoiding false color, when compare to bilinear interpolation but artifacts are still visible in the border region to overcome this type of interpolation technique edge behavior based interpolation method is estimated. This method give better result in image quality when compare to other interpolation technique.

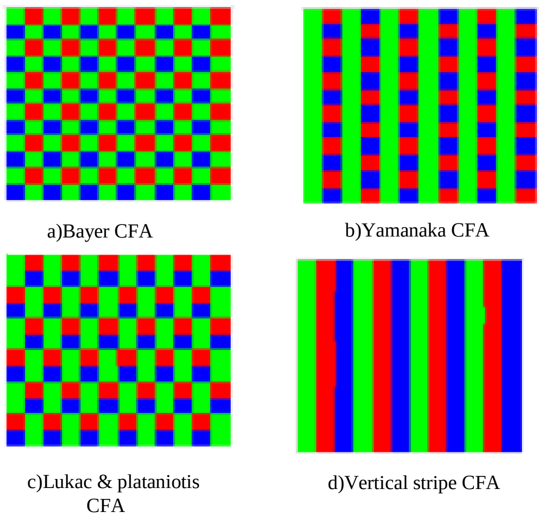

Figure. 2. Different CFA patterns

Another interpolation technique used to reduce artifacts is gradient based method. S.S Vinsley [1] uses edge-directed interpolation, this method concentrate more on the horizontal and vertical direction. Lei

Zhang [2] uses directional based interpolation technique to reduce artifacts. King-Hong Chung [3] uses variance method to estimate green plane and then missing two colors are interpolated using the estimated green plane. In the proposed algorithm color difference and directionally weighted gradient based method is used to estimate the green plane and the estimated green is used to interpolate the missing red and blue plane. This interpolation method give better image quality when compare to other interpolation method discussed above. This paper is organized as follows. Section II describes the proposed methodology for determination of missing red, green and blue pixel values. Section III describes the simulation and results of the proposed algorithm.

2, PROPOSED METHOD

The proposed system consist of three section A) Block diagram, B) Green channel interpolation, C) Red and Blue channel interpolation.

2.1 Block Diagram

The first step of the algorithm starts with the interpolation of green plane. The color difference and multiscale gradient method is used to interpolate the green plane. The next step in the algorithm is interpolation of red and blue plane. Then by combining these three plane the fully reconstructed color images can be obtained. Fig. 3 shows the block diagram for the proposed algorithm.

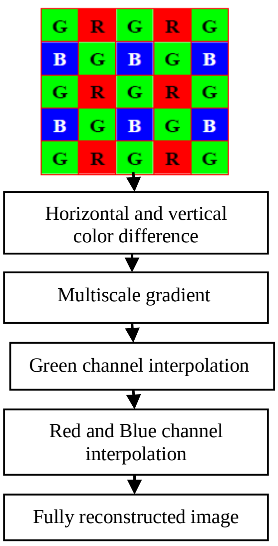

Figure. 3. Block Diagram of proposed system

2.2 Green Channel interpolation

Gradient are used for extracting directional data from the input images. Recently several demosaicing algorithms are make use of this method. The Green channel interpolation is based on the directionally weighted gradient method and the directional color difference is used along with the directional data. The

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bayer pattern consist of red/green rows & columns and blue/green rows & columns. For blue/green rows and columns in the CFA, the directional estimates for the missing blue and green pixel values in horizontal direction are shown in equation (1) & (2).

$$\tilde{G}^h(i,j) = \frac{G(i,j-1)+G(i,j+1)}{2} + \frac{2*B(i,j)-B(i,j-2)-B(i,j+2)}{4} \quad (1)$$

$$\tilde{B}^h(i,j) = \frac{B(i,j-i)+B(i,j+1)}{2} + \frac{2*G(i,j)-G(i,j-2)-G(i,j+2)}{4} \quad (2)$$

where h represents the horizontal direction, $\tilde{G}^h$ and $\tilde{B}^h$ represents the missing green and blue pixel values in horizontal direction. For vertical direction the missing green/blue pixel values are estimated from the equation (3) & (4).

$$\tilde{G}^v(i,j) = \frac{G(i-1,j)+G(i+1,j)}{2} + \frac{2*B(i,j)-B(i-2,j)-B(i+2,j)}{4} \quad (3)$$

$$\tilde{B}^v(i,j) = \frac{B(i-1,j)+B(i+1,j)}{2} + \frac{2*G(i,j)-G(i-2,j)-G(i-2,j)}{4} \quad (4)$$

where v represents the vertical direction, $\tilde{G}^v$ and $\tilde{B}^v$ represents the missing green and blue pixel values and (i,j) denotes the pixel location. Likewise the directional estimates for the missing red and green pixel values are estimated. Now a true value for color channel and two directional data are obtained. After estimated the directional data for missing red/green & green/blue rows and columns, then by taking their difference the directional color difference are estimated from the equation (5) & (6).

$$\tilde{\Delta}^h_{g,b}(i,j) = \begin{cases} \tilde{G}^h(i,j) - B(i,j) & \text{,if G is interpolated} \\ G(i,j) - \tilde{B}^h(i,j) & \text{,if B is interpolated} \end{cases} \quad (5)$$

$$\tilde{\Delta}^v_{g,b}(i,j) = \begin{cases} \tilde{G}^v(i,j) - B(i,j) & \text{,if G is interpolated} \\ G(i,j) - \tilde{B}^v(i,j) & \text{,if B is interpolated} \end{cases} \quad (6)$$

Here $\tilde{\Delta}^h_{g,b}$ and $\tilde{\Delta}^v_{g,b}$ denotes the horizontal and vertical color difference estimates between green and blue color. The equation explained above are similar for red/green rows and columns. The horizontal and vertical color difference are combined and calculated as follows in equation (7).

$$gb(i-1,j) = G(i-1,j) - \frac{B(i-2,j)+B(i,j)}{2}$$

$$gb(i+1,j) = G(i+1,j) - \frac{B(i+2,j)+B(i,j)}{2}$$

$$gb(i,j-1) = G(i,j-1) - \frac{B(i,j-2)+B(i,j)}{2}$$

$$gb(i,j+1) = G(i,j+1) - \frac{B(i,j+2)+B(i,j)}{2} \quad (7)$$

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where (i,j) are pixel locations and R,G,B denotes the input values. After combining the color difference in both horizontal and vertical direction, the weight is calculated along the four direction, to calculate the weight multiscale gradient based method is used. Normally gradient based method is used to extract the directional data by using this directional data along each direction such as north, south, west and east. The weight is calculated as follows shown in equation (8), for green/blue rows and columns.

$$\begin{aligned}
w(i-1,j) &= |B(i-2,j)-B(i,j)| + |G(i-1,j)-G(i+1,j)| \\
w(i+1,j) &= |B(i+2,j)-B(i,j)| + |G(i-1,j)-G(i+1,j)| \\
w(i,j-1) &= |B(i,j-2)-B(i,j)| + |G(i,j-1)-G(i,j+1)| \\
w(i,j+1) &= |B(i,j+2)-B(i,j)| + |G(i,j-1)-G(i,j+1)|
\end{aligned} \tag{8}$$

Here W denotes the weight along each direction. The color difference between green/blue and weight along each direction is used to interpolate the missing green pixel vale. The estimation of green plane are calculated as follows in equation (9) & (10)

$$\begin{aligned}
k1 &= (gb(i-1,j))/(1+w(i-1,j)) \\
k2 &= (gb(i+1,j))/(1+w(i+1,j)) \\
k3 &= (gb(i,j-1))/(1+w(i,j-1)) \\
k4 &= (gb(i,j+1))/(1+w(i,j+1))
\end{aligned} \tag{9}$$

$$\begin{aligned}
kg(i,j) = (k1+k2+k3+k4)/(1+w(i-1,j)) + (1+w(i+1,j) \\
+(1+w(i,j-1)+(1+w(i,j+1)
\end{aligned} \tag{10}$$

The estimated green in blue CFA component is calculated as follows in equation (11).

$$\tilde{G}(i,j) = B(i,j) + kg(i,j) \tag{11}$$

Here $\tilde{G}$ denotes the estimated green plane and B denotes the input blue CFA component. Similarly calculate the estimated green in red component.

2.3 Red and Blue plane interpolation

After estimating the missing green component in the input CFA pattern, the red and blue component missing in CFA pattern are interpolated using the estimated green plane. Figure. 4 shows the possible pixel location of red, green and blue.

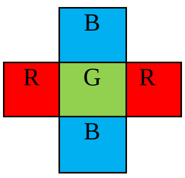

Fig. 4. Green pixel at centre

missing blue pixel at green pixel locations are calculated as follows.

$$\tilde{B} = G(i,j) + \frac{B(i-1,j) - \tilde{G}(i-1,j) + B(i+1,j) - \tilde{G}(i+1,j)}{2} \quad (12)$$

$$\tilde{B} = G(i,j) + \frac{B(i,j-1) - \tilde{G}(i,j-1) + B(i,j+1) - \tilde{G}(i,j+1)}{2} \quad (13)$$

Here $\tilde{G}$ denotes the estimated green pixel value. In the above given formula by changing the blue pixel value as red pixel value, the missing red pixel at green pixels location are estimated. After estimating the missing red and blue at green pixel location, the next step is to interpolate the missing red at blue pixel location and missing blue at red pixel location. Red pixel missing at blue pixels location are calculated as follows.

$$\tilde{R}(i,j) = \tilde{G}(i,j) + \frac{1}{4}\sum_{m=\pm 1}\sum_{n=\pm 1}(B(i+m,j+n) - \tilde{G}(i+m,j+n)) \quad (14)$$

Here $\tilde{R}$ denotes the missing red pixel at blue pixel location and B denotes the input CFA component. At the end of this step the separate red and blue color planes are obtained. By combining the estimated red, green and blue channels the full color image can be obtained.

3, EXPERIMENTAL RESULTS

The proposed work is tested using the 24 Kodak images (shown in fig.5) are used to test performance quality of the proposed demosaicing algorithm. The proposed algorithm is compared with some of the existing algorithm. Three existing algorithm such as bilinear interpolation [4], edge based algorithm [12], and alternate projection[10] are used to compare the performance of the proposed algorithm. The performance is compared with their CPSNR values. The comparison table for the 24 Kodak image with different algorithm is shown in table I. The performance of the proposed algorithm is compared to the existing algorithms.

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Fig. 5. 24 Kodak test images [15]

3.1 Performance Measure

In demosaicing the quality of the image is measured using Color Mean Squared Error (CMSE), Color Peak Signal-to-Noise Ratio (CPSNR), and the International Commission on Illumination's L* a* b* color difference (CIELAB ΔE). Color mean square error value is calculated to determine the CPSNR value. It takes the squared difference between the original image and the reconstructed image. CMSE and CPSNR are very simple techniques. CMSE involves first calculating the squared difference between the reference image and demosaiced image at each pixel and for each color channel. These are then summed and divided by three times the area of the image. CPSNR is then calculated using CMSE. The equations are shown below.

$$I_{CPSNR} = 10\log_{10}\frac{255^2}{I_{CMSE}} \qquad (15)$$

Where I_{CMSE} is a color mean square error value of the image. And its expression is given as,

$$I_{CMSE} = \sum_{i,j}\frac{[I_{org}(i,j) - I_{recons}(i,j)]^2}{3*M*N} \qquad (16)$$

Where $I_{org}(i,j)$ and $I_{recons}(i,j)$ are the original image and reconstructed image, M and N represents the width and height of the image. The image with higher CPSNR indicates the high quality image. The proposed algorithm reduces the color artifacts and blurring effect in the image.

TABLE I

CPSNR COMPARISONS OF PROPOSED ALGORITHM WITH EXISTING ALGORITHM

Image	Bilinear	Edge based	Alternative projection	Proposed Algorithm
1	30.773	31.2458	37.8078	36.81
2	36.6873	37.0425	39.6512	40.42
3	37.6775	38.0647	41.63	41.41
4	37.4213	37.8047	40.16	39.81
5	31.2157	31.8233	37.5869	37.35
6	32.1414	32.5964	38.6455	37.78
7	37.1797	37.6152	41.0256	40.36
8	28.2879	28.7457	35.0158	37.03
9	36.4896	36.9292	41.2609	40.47
10	36.3952	36.8716	40	40.61
11	33.6645	34.1372	39.006	38.93
12	36.9695	37.3912	40.5063	40.86
13	28.6113	29.1087	34.2893	36.01
14	33.469	33.9611	35.7377	37.96
15	35.4486	35.8213	39.4739	40.51
16	35.2366	35.6156	41.2864	39.37
17	36.681	37.2463	40.6912	40.13
18	32.562	33.0611	37.9911	37.08
19	32.7829	33.2797	39.5543	38.72
20	34.6422	34.9845	37.2988	41.08
21	33.0627	33.5363	36.9836	38.03
22	34.9277	35.3907	37.492	39.28
23	38.3544	38.7374	42.7698	42.50
24	31.411	31.8746	34.6036	38.65

IV CONCLUSION

In this paper, color difference and directionally weighted gradient method is used. This method reduce artifacts and give better image quality. The computational complexity of this technique is less. CPSNR value shows that the proposed algorithm is able to produce better demosaicing results, when compare to other algorithm. This shows that the proposed method can prove to be useful for image processing problems.

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