JOURNAL OF PURE AND APPLIED MICROBIOLOGY, Aug. 2015. Vol. **9**, p. 209-214
SPECIAL ISSUE ON RECENT RESEARCH CHALLENGES IN BIO-MEDICAL APPLICATIONS

Optimal Sampling Pattern for Extraction of Quality Image from CFA with Color Artifacts

D.R. Ramji[1] and K. Parimala Geeetha[2]

[1]Electronics and Communication Engineering Department, Narayanaguru College of Engineering, Manjalumoodu, Kanyakumari District,629151, Tamil Nadu, India.
[2]Electronics and Communication Engineering Department, Ponjesly College of Engineering, Nagercoil, Kanyakumari District, 629003, Tamil Nadu, India.

(Received: 02 February 2015; accepted: 10 May 2015)

In Photography, a Color Filter Array (CFA), or Color Filter Mosaic (CFM), is a periodic Array of small color filters placed over the pixel sensors of an image sensor to capture color information. To capture image from Small electronic handheld device, single sensor CFA array technique is used. Extraction process of color component Red, Green and Blue from the output of single sensor CFA raw data called Demosaicing. The extraction of good quality image from CFA with color artifact is a challenging task. The color artifacts like Edge blurring, Zipper Effect, Aliasing and False coloring are the major artifacts (noise) arise at the time of Demosaicing. This paper presents, design of optimal sampling patten and demosaicing algorithm to extract good color component from noisy CFA data source. Result show that our method yield good result in terms of PSNR values and Human Visual System HVS with state-of-the-art of other recent works.

Key words: Color Filter Array(CFA), Demosaicing, Artifacts, Edge blurring and PSNR.

In commercial professional cameras there are three sensors are used to capture the image or video for single pixel value. Due to this setup the hardware cost increased and size become large. However, to capture image from Small electronic handheld device, single sensor CFA array is placed above the Charge Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) photo detector. As a result the missing other two color components such as Red-Blue (R-B) or Blue-Green (B-G) or Green-Red (G-R) determined, the process called CFA demosaicing or CFA Interpolation[3,4].

Fig. 1. (a) Shows Bayer Color Filter Array CFA pattern, this is the most widely used pattern[1]. The Bayer CFA array of 5X5 matrix pattern consists of Red sample Contribute 25% , Green Sample contribute 50% and Blue sample contributes 25% they shown in Fig. 1. (b), Fig. 1. (c) and Fig. 1. (d). respectively. In general image development model, the CFA is placed in between the photo detector and scene,[2]. The construction of image using single sensor camera image shown Fig. 2

Finally the signal obtained at the photo detector is given by

$$c = \int_{\lambda min}^{\lambda max} F(\lambda)D(\lambda)\ X(\lambda)L(\lambda)D\ \lambda + N \qquad ...(1)$$

where L(λ) spectral power distribution, F(λ) spectral transmittance of CFA, λmin & λmax wavelength ranges for photo detector and N noise appeared in photo detector. The noise or color artifacts such as Edge blurring, Zipper Effect, Aliasing and False coloring are the major source of noise in CFA raw image.

Most of the demosaicing methods have been proposed are noise free CFA[14-16].

The noise less assumption is invalid in practice. In[17] Cok presents simple spectral

* To whom all correspondence should be addressed.
Tel; (0)9790540004;
E-mail: ramjidr@gmail.com

correlation between different color planes with in the image region, ratio between red green values are similar.

In this paper, a novel Edge preserve non threshold demosaicing algorithm is proposed. This algorithm aims to estimate the missing colors from the noisy CFA raw data. It is followed by Hybrid Edge-adaptive median demosaicing Artifact filtering is used to remove unfiltered noise from previous stage. So that, the proposed method outperform conventional demosaicing algorithms.

The remainder of this paper is organized as follows. In section 2, various demosaicing noises are discussed. In section 3 presents the detail of our proposed CFA Design Optimization and Model Description. In section 4, presents Proposed Edge preserve non threshold demosaicing algorithm and Hybrid Edge-adaptive median demosaicing Artifact filtering, and in section 5, presents simulation results in terms of peak-signal-to-noise-ratio (PSNR) and comparison. Conclusions are drawn in section 6.

Demosaicing Artifacts

Zippering Artifact

At the time of demosaicing Zippering artefact occurs along the edges, it is known as blurring or zipper effect. Edge blurring that occurs in an on/off pattern along an edge. It results algorithm averaging pixel values across an edge mostly in red and blue planes producing a blur. This can be prevent by interpolate along, rather than edges[5].

False color artifact

The artefact along edges a result where abrupt or unnatural shift in color occur as result of misinterpretation across, rather than along an edge [5].

Moire artifact

The most common artifact is moiré, which may appear as repeating patterns, color artifacts or pixels arranges in an unrealistic maze-like pattern:

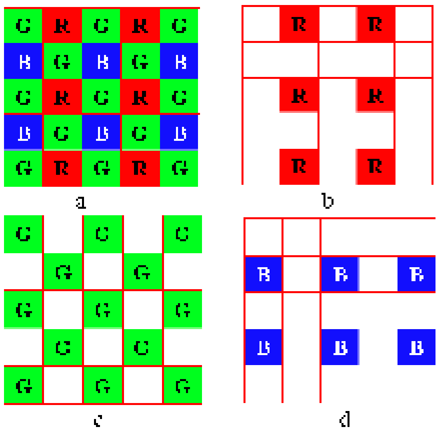

Fig. 1. (a) Bayer patternened CFA (b) Red sample,(c) Green sample and (d) Blue sample.

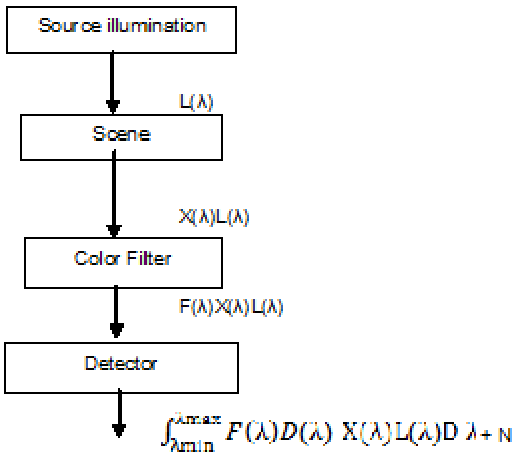

Fig. 2. Model for image development

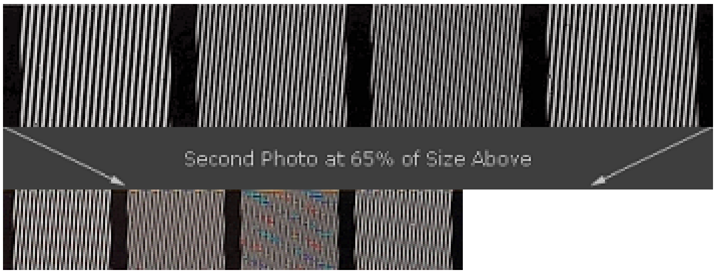

Fig 3. Moire artifact

CFA Design Optimization and Model Description

The Bayer pattern is the one which is widely used image sensor. It has red, green and blue pixel surrounded by green pixel in vertical and horizontal direction respectively fig 4 a). This leads to crosstalk signals from green to blue and red pixel so red and blue pixels are affected and similarly red and blue pixels are affected by cross talk. However this cross talk reduces original signal for each of the blue red and green pixel [11][2].

The accuracy of color acquisition device increased by increasing the sampling of distinct colors[2]. The different types of CFA arrangement used in[12,13] commercially. In our new optimal proposed color filter array, we added two additional color pixel between every two main pixel in the Bayer pattern. The additional color pixel values are obtained by adding the two red/blue green Bayer pattern colors [Cyan = Green + Blue ; Yellow = Red + Green]. Cyan pixel is placed centre of blue and green pixel and yellow pixel is placed centre of red and green pixel. Fig 4b)

The proposed CFA pattern have five different core colors rather than three in the Bayer pattern. To produce effective R,G,B channels that can be utilize conventional tristimulus 3x3 matrices. If we combine channels to produce nR, nG and nB where

$$nR = \frac{R + Y - G}{2} \quad ...(2)$$

$$nG = \frac{G + Y - R + C - B}{3} \quad ...(3)$$

$$nB = \frac{B + C - G}{2} \quad ...(4)$$

Spectral sensitivity function for RGBYC pattern is show in Fig 5. a) & b). The wavelength is in nm.

The proposed RGBYC Pattern, for simulation the pixel response was determined using

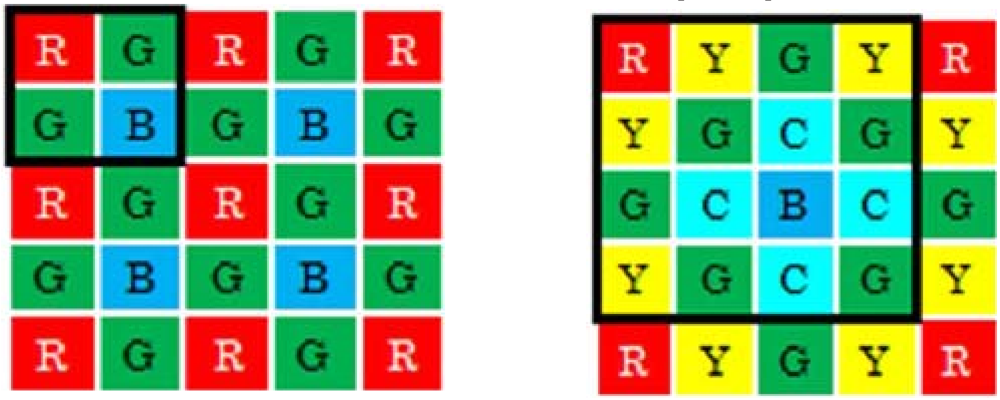

Fig. 4. a). Bayer Pattern b). Proposed RGBYC Pattern

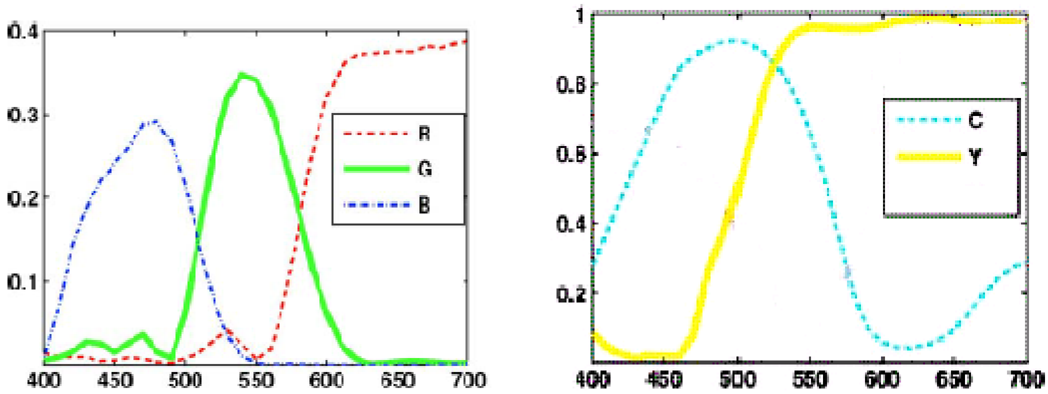

Fig 5. Proposed RGBYC pattern color filter sensitivity function. a). Sensitivity function for R, G and B colors b). Sensitivity function for Cyan and Yellow colors

the incident photo flux L(λ) spectral reflectance X(λ), and the spectral transmittance CD(λ). The output signal received at each pixel is given as,

$$C(\lambda) = K.\, L(\lambda).\, X(\lambda).\, CD(\lambda) + N \qquad ...(5)$$

where N is noise parameter (different color artifacts). It includes color artifacts such as Edge blurring, Zipper Effect, Aliasing and False coloring.

Proposed Edge preserve non threshold demosaicing algorithm

Our Edge preserve non threshold demosaicking methods are based on an assumption that the difference between the red/blue pixel and the green pixel is a low pass signal. The difference between red and green signal is $\Delta_a = G_a - R_a$. Extract missing samples by $G_a = R_a + \Delta_a$.

The difference between horizontal and vertical directions red and green pixels are given as.

$$\Delta_a^h = \frac{1}{2}(G_{-1}^h + G_1^h) - \frac{1}{4}(2.R_a + R_{-2}^h + R_2^h) \qquad ...(6)$$

$$\Delta_a^v = \frac{1}{2}(G_{-1}^v + G_1^v) - \frac{1}{4}(2.R_a + R_{-2}^v + R_2^v) \qquad ...(7)$$

Next step is to calculate weights W_h and W_v. Δ_a is the color difference of Δ and Δ are given as.

$$\Delta_a^h = \Delta_a + v_a^h \text{ and } \Delta_a^v = \Delta_a + v_a^v \qquad ...(8)$$

Where noises vand vare estimation errors of “and “. For optimal weight for vertical and horizontal direction is given as,

$$W_h = \frac{\sigma_v^2}{\sigma_h^2 + \sigma_v^2},\quad W_v = \frac{\sigma_h^2}{\sigma_h^2 + \sigma_v^2} \qquad ...(9)$$

For high frequency components measurement noises vand vaffects. Then we measure gradient of red pixel at R_o given in equ 10 i.e.

$$d_a^h = R_o - \frac{R_{-2}^h + R_2^h}{2}, \text{ and } d_a^v = R_o - \frac{R_{-2}^v + R_2^v}{2} \qquad ...(10)$$

Fig. 6. Test Image set a) Img 1. b) Img 2. c) Img 3. g) Img 4. e) Img 5.

Table 1. PSNR (dB) for Bayer RGB CFA pattern with proposed demosaicing algorithm comparison

Image	Channel /Algorithm	Bilinear Interpolation	Alternative Projection	Successive approximation	Frequency Selective	Adaptive Filtering	Our proposed
Img 1	Red	26.70	37.72	36.22	36.25	37.70	38.97
	Green	31.05	40.53	41.40	41.45	40.74	41.89
	Blue	27.00	37.28	42.67	36.67	36.85	39.70
Img 2	Red	30.81	39.25	38.75	36.73	39.98	40.23
	Green	34.57	42.72	40.34	38.59	40.14	42.89
	Blue	30.45	38.01	37.22	36.60	43.58	43.23
Img 3	Red	26.40	36.99	36.98	36.41	37.25	38.89
	Green	29.38	39.78	36.79	39.28	41.21	42.45
	Blue	25.29	36.81	36.13	35.34	37.42	37.11
Img 4	Red	28.89	38.07	37.08	36.79	38.65	39.91
	Green	33.01	41.52	41.33	40.75	42.16	42.26
	Blue	27.99	38.12	37.38	36.45	38.45	37.34
Img 5	Red	31.45	40.54	40.45	38.68	34.54	41.46
	Green	35.72	43.26	43.33	39.35	41.32	43.89
	Blue	31.48	41.43	41.36	41.45	38.45	42.11

Table 2. PSNR (dB) for RGBYC CFA pattern and Bayer RGB Patern with proposed demosaicing algorithm comparison

Image	Channel/ Algorithm	Bayer RGB With proposed demosicing	RGBYC With proposed demosicing
Img 1	Red	38.97	39.23
	Green	41.89	42.13
	Blue	39.70	39.94
Img 2	Red	40.23	41.27
	Green	42.89	42.99
	Blue	43.23	44.11
Img 3	Red	38.89	38.45
	Green	42.45	42.67
	Blue	37.11	37.87
Img 4	Red	39.91	40.45
	Green	42.26	42.67
	Blue	37.34	38.56
Img 5	Red	41.46	41.56
	Green	43.89	44.74
	Blue	42.11	42.11

Hybrid Edge-adaptive median demosaicing Artifact filtering

To point out the edge regions in an image, we apply 5x5 Median filter on the color difference to attenuate false edge generated by demosaicing artefact. Discrete Laplacian filter with median-filtered color difference planes G_d convolved to track the edge regions, it is defined as,

$$H = \begin{bmatrix} 0.0909 & 0.8182 & 0.0909 \\ 0.8182 & -3.6364 & 0.8182 \\ 0.0909 & 0.8182 & 0.0909 \end{bmatrix} \quad ...(11)$$

The convolution output $E=G_d*H$ is compared with binary edge map as

$$eB(i,j) = \begin{cases} 1 & \text{if } |E(i,j)| > T \\ 0 & \text{otherwise} \end{cases} \quad ...(12)$$

where T is for identifying threshold image regions

Simulation results

To evaluate the actual performance of this proposed color interpolation method, simulation was carried out with ten digital color images and compare with other demosaicing technique such as bilinear interpolation[6], color plane interpolation using alternate projection[7], successive approximation[8], frequency selective demosaicing[9], adaptive filtering[10]. However PSNR was used as a measure to analyse the performance of a demosaicing algorithm. The observed results are recorded in Table I & Table II. The good results highlighted in bold characters. Table I shows PSNR values of Bayer RGB pattern and Table II shows proposed RGBYC pattern PSNR values. Set of test images are shown in Fig 6

CONCLUSION

In this paper, we proposed a new RGBYC CFA pattern along with Edge preserve non threshold demosaicing algorithm. RGBYC CFA pattern having five channels in the core. It gives good results in compared to the bayer RGB pattern with our proposed demosaicing algorithm. Simulation result shows our proposed demosaicing algorithm extract good quality image from RGBYC pattern in compared to number of existing CFA pattern in the presence of color artefact.

REFERENCES

1. B. Bayer "Color imaging array," *U.S. Patent No.* 1976; **3**; 971 065.
2. M. Parmar and S. J. Reeves, "Selection of Optimal Spectral Sensitivity Functions for ColorFilter Arrays" *IEEE Trans. Image Process.*, 2010; (12): pp. 3190–3203.
3. B. K. Gunturk, J. Glotzbach, Y. Altunbask, R. W. Schafer, and R. M. Mersereau, "Demosaicing

: Color filter array interpolation", *IEEE Signal Process. Mag*., 2005; **22**(1): pp.44-54.

4. H. J. Trussell and R.E. Hartwig, "Mathematics for demosicing," *IEEE Trans. Image Process*., 2002; **11**(4): pp. 485–492.
5. Robert A. Maschal, Jr., S. Susan Young, Joseph P. Reynolds, Keith Krapels, Jonathan Fanning, and Ted Corbin, "New Image Quality Assessment Algorithms for CFA Demosaicing" *IEEE Sensors Journal*, 2013; **13**(1): pp. 371-378.
6. T. Sakamoto, C. Nakanishi, and T. Hase, "Software pixel interpolation for digital still camera suitable for a 32-bit MCU," *IEEE Trans. Consum. Electron*, 1998; **44**(4): pp.1342-1352.
7. B. K. Gunturk, Y. Altunbask, and R. M. Mersereau, "Color plane Interpolation using alternating projection", *IEEE Trans. Image Process. Mag.*, 2002; **11**(9): pp.991-1013.
8. X. Li, "Demosaicing by successive approximation," *IEEE Trans. Image Process*, 2005; **14**(3): pp.370-379.
9. D. Alleysson, S. Susstrunk, and J. Herault, "Linear demosaicing inspired by human visual system" *IEEE Trans. Image Process*., 2005; **14**(4): pp.439-449.
10. Nai-Xiang Lian, L.Chang, Y.Tan, VitaliZ, "Adaptive Filtering for color filter array Demosaicing," *IEEE Trans. Image Process*, 2007; **16**(10): pp.2515-2525.
11. Pengwei Hao, Yan Li, Zhouchen Lin and Eric Dubois, "A Geometric Method for Optimal Design of Color Filter Arrays", *IEEE Transactions on Image Processing*, 2011; **20**(3).
12. M. Parmar and S. J. Reeves, "A perceptually based design methodology for color filter arrays," in *Proc. IEEE Int. Conf. Acoust., Speech, Signal Process*., 2004; **3**: pp. 473–476.
13. W. Zhu, K. Parker, and M. A. Kriss, "Color filter arrays based on mutually exclusive blue noise patterns,"*J. Vis. Commun. Image Represent*., 1999; **10**: pp. 245–247.
14. K. Hirakawa and T.W. Parks, "Adaptive homogeneity-directed demosaicing algorithm." *IEEE Trans. Image Process*., 2005; **14**(3): pp.360-369.
15. D. Menon and G. Calvagno, "Regularization approaches to demosaicking" *IEEE Trans. Image Process.*, 2009; **18**(10): pp.2209-2220.
16. L. Zhang and X.Wu. "Color demosaicking via directional linear minimum mean square-error estimation," *IEEE Trans. Image Process.*, 2005; **14**(12): pp. 2167-2177.

17 D. Cok, "Signal processing Method and Apparatus for Producing Interpolated Chrominance Values in a Sampled Color Image signal," U.S. Patent 4642678, 1987.