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Bayer filter array interpolation and color reconstruction using directional filtering and weighting technique

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Abstract *- Digital cameras usually has a single sensor covered with a color filter array which samples only one color at location of every pixels. The full color image is restored using a demosaicing technique through means of a digital pipeline imaging. Here we propose a novel approach of demosaicing based on the directional filtering and weighting techniques. The contributions this system is doubled. First of all we analyze the limitations and advantages of the existing directional filtering and weighting techniques. Then we improve those two existing techniques in order that it suppresses all the common demosaicing artifacts. In second, we develop new estimation schemes for the color components reconstruction. Through experimentation we show the proposed results can outperform all the recent unique demosaicing algorithms in terms of accuracy and objective measures.*

Keywords: Color filters, Demosaicing, Directional Filtering, Weighting technique, MATLAB, RGB sensor.

I. INTRODUCTION

Nowadays, digital cameras have become wide spread during the last few decades. In every digital camera, a color image is generated using red (R), green (G), and blue (B) color samples at each pixel location. To reduce cost and size, most of the cameras use a single sensor covered with a color filter array (CFA). CFA method measures only one color values at each pixel. The missing remaining two color values at each pixel must be estimated and this process is known as demosaicking [1]. For producing a full color image, there should be at least three color samples at every pixel location. One method is to use beam-splitters in the optical path to project the image onto three separate sensors. An illustration is in Figure 1.

By using a color filter in front of every sensor, three full-channel color images are obtained. This approach is costly since it requires three separate charge coupled device (CCD) sensors and in addition these sensors have to be aligned precisely which is a challenge to mechanical design.

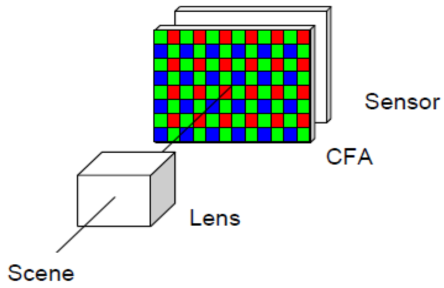

Figure 1: Illustration of optical paths for single-chip digital cameras

A cheaper solution for this is to use a color filter array (CFA) in front of digital image sensor to record only one color component at each pixel and then interpolate the missing two color components [2].22 Because of the mosaic pattern of the CFA, this interpolation process has been widely known as "demosaicing".

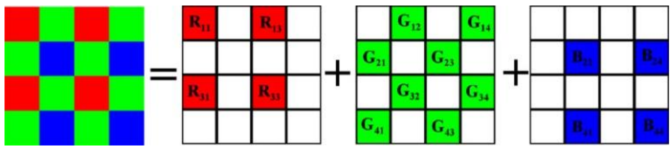

Figure 2: A typical CFA array (Bayer CFA) used in single-chip digital cameras. There are two times more green pixels than red and blue

Among many CFA patterns, the most commonly used one is the Bayer. Bayer's image pattern captures only the green pixels on a diagonal grid with half image quality and the red and blue images on remaining rectangular grids with quarter of the image quality [3]. The green channel is measured at a higher sampling rate than the other two because of peak sensitivity of the human visual system (HVS) lies in the medium wavelengths which is corresponding to the green portion of the light spectrum. Till date there are many CFA patterns have been in existence. The most common pattern is the Bayer CFA. Here we only consider the Bayer pattern illustrated in Figure. The G values are sampled on a diagonal grid and the R and B values are sampled on rectangular grids [4].

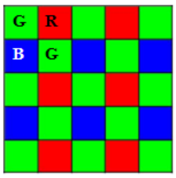

Figure 3: Bayer color filter array

De-Bayering Process

All the images and videos recorded through a digital color camera are recorded through these tiny color filters placed over every pixel in the color filter array (CFA).

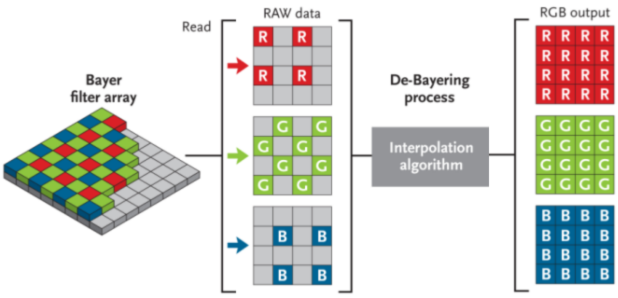

Figure 4: De-Bayering Process

A special de-bayer software algorithm process and separates the individually filtered pixels into their corresponding color channels, and then fill with the missing pixels in every color using an interpolation algorithm. Thus the final color result is generated [5].

II. PROPOSED METHODOLOGY

The main objective of this system is to analyze efficiently to improve and combine the existing directional filtering and weighting technique (DFWT) and overcome the drawbacks of common demosaicing artifacts. Hence the DFWT almost removes all grid errors in the G plane. The interpolation of the G plane is based on DFWT and for improving the DFWT it consists of various interpolations of the missing G values on weak edges. By performing weighted average of two orthogonal directional G values successively and because of EECI it can commendably suppress false colors. Our interpolations methodology in R and B planes has a same weighting scheme as that of EECI, and our main improving of EECI consists in weights calculation on the color difference planes [6].

The algorithm proposed here has included two steps which are initial step and refinement steps. In the initial step all initial estimation of R, G and B plane values are computed. Then in the refinement step all G plane values can be further refined using initially estimated R and B plane values and vice versa. The detailed principle of this de-bayer algorithm will be further illustrated as following.

III. RGB INTERPOLATION

a) Interpolation of the Green Plane

We have estimated the edge-directed DFWT which almost eliminates the zipper artifacts as mentioned in Fig. 2. Any ways in the textured regions of image, the detected direction of an edge tends to be incorrect. As a result inordinay false colors are producing (Fig. 3). Based on further observations, we are improving the interpolation method of pixels values in G plane in DFWT. Then the missing G values are estimated using DFWT for all explicit horizontal or vertical edges [7]. If not then the G values are estimated using the weighted average calculation of two orthogonally directional G values. The weights of choice are dependent on strength of the values in horizontal and vertical directional edges across every missing pixel. Thus the G plane interpolation composed of two steps which are directional interpolation step and decision step.

1) Directional interpolation step: This step interpolates the missing values of G through an ACPI interpolator in horizontal and vertical directions respectively. Estimating the missing G values at an R pixel values are as mentioned [Fig. 4]. The interpolation at a B pixel can be carried out similarly to calculate G5 at R5 values.

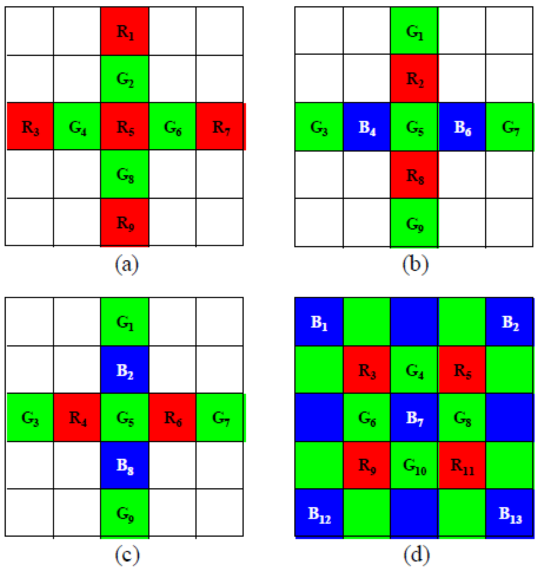

Figure 5: Reference CFA samples

$$\begin{cases} G_5^H = (G_4 + G_6)/2 + (R_5 - R_3 + R_5 - R_7)/4 \\ G_5^V = (G_2 + G_8)/2 + (R_5 - R_1 + R_5 - R_9)/4 \end{cases}$$

2) Decision step: After the interpolation of G plane along both horizontal and vertical directions then the two G images will have been produced. It is essential to select a best direction

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from the two directions for each pixel. Therefore a two color difference images are calculates as:

$$C_H(i,j) = \begin{cases} R_{i,j} - G^H_{i,j}, & \text{if } (i,j) \text{ is a red location} \\ B_{i,j} - G^H_{i,j}, & \text{if } (i,j) \text{ is a blue location} \end{cases}$$

$$C_V(i,j) = \begin{cases} R_{i,j} - G^V_{i,j}, & \text{if } (i,j) \text{ is a red location} \\ B_{i,j} - G^V_{i,j}, & \text{if } (i,j) \text{ is a blue location} \end{cases}$$

Whereas the row and column of the pixel (i; j) i and j indicated respectively. Then after the gradients of CH and CV are calculated as DH(i; j) = jCH(i; j)CH(i; j +2)j and DV (i; j) = jCV (i; j)CV (i+2; j)j.s

Consequently all two classifiers H(i; j) and V (i; j) are defined as the sum of the DH and DV I gradients vales as a 5x5 neighborhood centered at pixel (i; j). The strength of any directional edge is now inversely proportional to the directional gradient. The weights w1 and w2 can be considered as the directional gradients reciprocals. We compute the horizontal and vertical gradients as described in this method. The calculations of the weights w1 and w2 have two cases. The location (i; j) of the missing G pixel is an R pixel or a B pixel. Here again calculating w1 and w2 at an R pixel will be considered as which the location 5 corresponds to the location (i; j) of the missing G pixel. The calculation at a B pixel can be carried out as same way above.

b) Interpolations of the Red and Blue Planes

After the fully estimation of the G plane values, it will be used to assist the successive interpolations of the R and B planes. Since the estimated G values can be considered known then it has also been seen that of a directional filtering. Then the G plane can significantly suppress remaining zipper artifacts, and such as EECI methods based on weighting can effectively suppress false colors than the edge-directed ones (Fig. 3). Considering that the interpolations of the missing R and B pixel components uses a weighted method. The proposed systematic procedure has a similar weighting scheme to EECI. However we calculate weights of the color difference planes and EECI calculates weights on the mosaic image [8].

Final outcome of this procedures justify that color difference in images are smooth than other primary color planes. This demosaicing algorithm is well known to provide the smooth regions of an image with satisfactory results. Three different cases are there for the interpolation of all the R pixel values (Fig.5). R pixel values missing at the B positions will be estimated first because every B pixel has four adjacent R pixels at their diagonal directions. G plane after populating has the color difference KR = G R which is later computed at all other positions of R pixel. After every R pixel missing can be estimated by color different values of four adjacent pixels. Here c is defined as constant factor for adjusting the effect of weighting. The principle of computing is weighted similar to the one method.

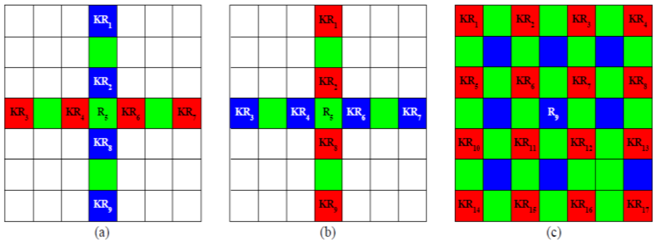

Figure 6: Three cases of the missing central red pixel values. Missing red value R5 at a green location (a) and (b) ; Missing red value R9 at a blue location (c)

R pixel value missing at the G position will be estimated next. Every G pixel has four adjacent R pixels values available at horizontal and vertical directions. Then after wise R pixels are interpolated at every B pixel positions [Figs. 5(a) and (b)]. Here obtained will be two R pixels in the horizontal or vertical direction after estimation. Formula to estimate the missing R5, will be

Similarly,

$$KR_5 = \frac{w_2 * KR_2 + w_4 * KR_4 + w_6 * KR_6 + w_8 * KR_8}{w_2 + w_4 + w_6 + w_8}$$

Where $KR_i = G_i - R_i (i = 2, 4, 6, 8)$

c) Refinement

The three color pixels are fully populated and their estimated values can be further refined after the initial interpolation step.

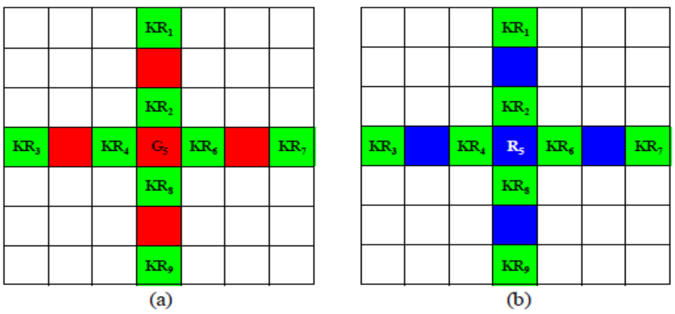

Figure 7: The missing central pixels need be estimated. The missing green value G5 at a red location; the missing red value R5 at a blue location (b)

With the usage of all populated R and B planes then G plane will be refined. G plane pixel values are then used to refine remaining R and B planes again. Estimated sample values obtained later will be refined and the original CFA-sampled color values at every pixel are not altered [9]. Our refinement is only performed once as additional to the above steps.

Because of a spectral correlation between color planes the refinement is to exploit the correlation data is it is overused. As a result the Demosaicing results will later become worse.

Refining the G value at each R pixel will be taken for refinement of each green plane. Refinement of a B pixel can be carried out similarly. Then refinement of G5 values at R5 is calculated [Fig. 6(a)]. G5 = R5 +KR5, where KR5 is computed and those weights are computed.

Refinements of the red and blue planes: R and B planes can be further refined with the values of refined G plane. The B plane refined as similarly to refining of each R plane. Here considered is only the refining of R plane. Then R values that require refining will be are the ones at the sampling G or B positions. R values that are initially populated at both G and B pixel positions are used to have four adjacent R values in the horizontal and vertical directions. Each G pixel position has two of the adjacent R values that are from original CFA samples and remaining two ones are estimated values. Four of the adjacent R values are all estimated values for every pixel position.

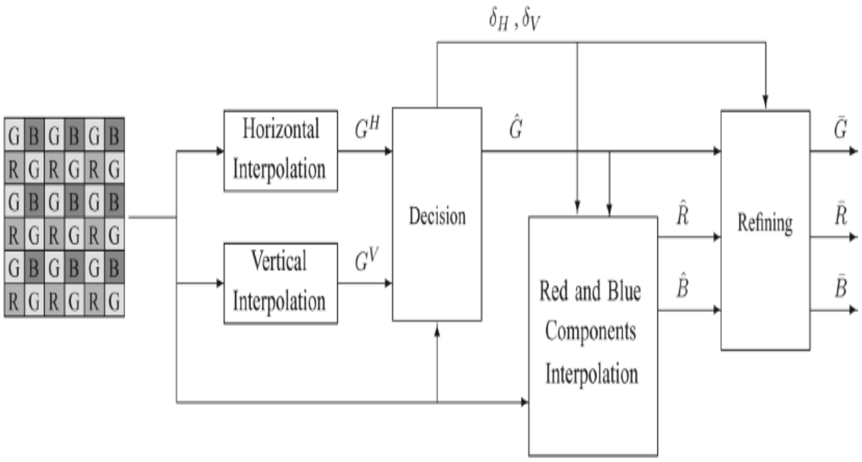

Figure 8: Complete scheme of the proposed algorithm

Refinements procedures for R values at the G and B positions are performed later using the six novel demosaicing algorithms in terms objective and subjective measures over the images under test.

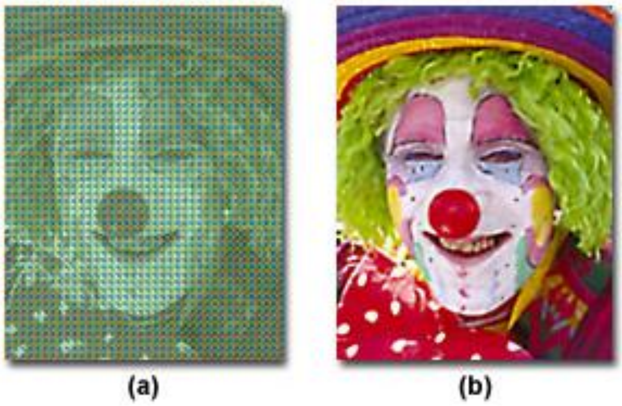

Figure 9(a): Raw Bayer pattern image,
Figure 9(b): Results obtained with DFWT algorithm after processing

IV. CONCLUSION

In this article a novel algorithm for color demosaicing is proposed. It is found to improve accuracy by combining ACPI based on weighting and DFWT based on directional filtering scheme. For estimation of missing red and blue pixels interpolated via weighted average technique is implemented. The interpolations of the missing green pixels are the done at the strong edge regions. Later, the missing green pixels are interpolated via the weighted average in weak edge or smooth regions. Finally the interpolations of all missing red and blue pixels are done and are performed in the difference color planes with usage of effective weighing scheme. The tested results of the proposed algorithm prove that this technique has outperformed the recent demosaicing algorithms.

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