Development of Full Color Images From Gap Camera Mosaic Images By Hybrid Approach

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Abstract: Demosaicking is the process which is used to reconstruct the images taken by the single sensor camera by estimation and restoring the missing pixels. Generalized assorted pixel (GAP) camera, by capturing a single image of a scene, can control the trade-off between spatial resolution, dynamic range and spectral detail. It can be possible to generate variety of images. The GAP camera uses a complex array of color filters. As the captured image is severely under-sampled, the images which reconstructed are with strong aliasing. To eradicate this drawback, the demosaicing concept is used in Generalized Assorted Pixel camera. In this work, a novel GAP demosaicking approach has been proposed which deals with demosaicking by directional filtering and a posteriori decision to construct the high exposure image and demosaicing by directional filtering and a posteriori decision with up-sampling technique to construct the low exposure image. The proposed experimental method produces higher quality images in less computational time than previous methods.

Keywords : Demosaicking, Generalized Assorted pixel camera images, directional filtering, sampling technique, mosaic image

I. INTRODUCTION

Digital cameras are extremely popular and have replaced the traditional film-based cameras in most applications. Digital cameras are used to produce color images by acquiring three color components at each pixel location. This can be achieved by three Charge - Coupled Devices (CCD) or Complementary Metal-Oxide Semiconductor sensors (CMOS). Each sensor receives a specific primary color. As three sensors were needed to acquire color components in each pixel, space for sensors is big. And the cost is also high. To reduce the cost and size, most digital cameras on the market use a single sensor with a Color Filter Array (CFA) [1]. The CFA holds a set of spectrally selective filters that are arranged in an interleaving pattern so that each sensor pixel samples one of the three primary color components.

More number of CFA patterns was developed by researchers. One of the most common patterns for CFA is the Bayer pattern CFA [2]. By using the Bayer pattern CFA, the G pixels are estimated on a quincunx grid, while R and B pixels are estimated on a rectangular grid [14]. In Bayer pattern CFA, the occurrence of G pixels is as twice as that of R or that of B, because the peak sensitivity of Human Visual System (HVS) lies in the wavelength of G light. These sparsely sampled color values are termed mosaic images or CFA images.

To render a full-color image, an image reconstruction process is required to estimate the other two missing color values in each pixel. The process to estimate the missing value is called Demosaicking [1].

The Bayer pattern CFA is commonly used in the demosaicking algorithms which includes the nearest neighbor interpolation [4], bilinear interpolation [4], and bicubic interpolation [5]. By using the linear averaging method, the above demosaicking algorithms generate the other two missing color values at each pixel. They can be widely applied in real-time systems because of the lower computational complexity. For consumer camera, the raw mosaic image can be accessed through saving images in the proprietary raw format. Many algorithms are available for reconstructing the full color image from these sparsely sampled color channels caused by the CFA [16].

The generalized assorted pixel (GAP) camera enables to produce a variety of images with different types from a single captured image of a scene [6]. The captured image is a mosaic image with richer assortment of filters. The existing FIRDEM GAP and CFCDEM GAP color mosaic patterns for GAP filter are shown in Figure 1 and Figure 2. The filters in an assortment can serve to enhance the quality of the image, color reproduction, spectral resolution, dynamic range and sensitivity.

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The Generalized Assorted Pixel (GAP) camera uses the complex array of color filters. Unlike the simple patterns, the GAP mosaic consists of plurality of primary color filters and the secondary color filters. The disadvantages are the captured image is severely under sampled and the reconstructed image has strongly aliased.

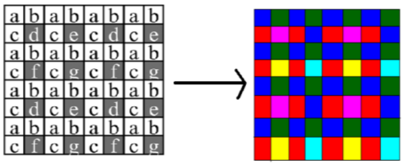

Figure 1. FIRGAP filters

The images with small – scale detail near the resolution limit of the digital sensor makes the demosaicking algorithm producing an unrealistic look known as artifacts. The artifacts depend on both type of texture and the software used to create the raw file.

G	R	G	R	G	R
B	r	B	g	B	r
G	R	G	R	G	R
B	g	B	b	B	g
G	R	G	R	G	R
B	r	B	g	B	r
G	R	G	R	G	R
B	g	B	b	B	g

Figure 2. CFCDEM GAP filter

The images consist of different exposures. An image is said to be high exposure when the bright parts of an image are "washed out" or effectively all white, known as "blown-out highlights" or "clipped whites". In digital cameras the high exposure is measured in Exposure Value (EV). The high exposure has positive exposure [6]. An image is said to be low exposure if the dark areas are muddy or indistinguishable from black. The dark exposure image will have negative exposures. The correct exposure images are called as zero exposure.

The spatial resolution of the image is used to describe the quality of the image. The spatial resolution is a term that refers to the number of pixels utilized in the construction of digital image. The images with low spatial resolution will have lower number of pixels.

High Dynamic Range Imaging [7] (MDR or HDRI) is the set of methods used in imaging and photography to capture the greater dynamic range between the lightest and darkest areas of an image than the current standard digital imaging methods or photographic methods. The dynamic range of an image refers to the range of light to the dark captured by the camera before becoming completely black or completely white. HDR images can represent more accurately the range of intensity levels found in real scene, from direct sunlight to faint sunlight and is often captured by way of plurality of differently exposed pictures of the same subject matter. HDR methods provide higher dynamic range from the imaging process. Images resulting from merging the low dynamic range and standard dynamic range photographs to obtain HDR RGB image and HDR monochrome image.

The GAP mosaic image consists of three primary color filters for high exposure 'RGB' values and four secondary color filters for low exposure 'rggb' values. Color filters are needed because the typical photo sensors detect light intensity with little or no wavelength specificity, and therefore cannot separate color information. The raw image data captured by the image sensor is then converted to a full-color image by a demosaicking algorithm which is tailored for each type of color filter. By using GAP technique, tremendous reduction was attained in cost, size, complexity and storage space.

II. EXISTING APPROACH

To reconstruct images, there are many approaches have been proposed for demosaicking [8]. Some of the demosaicking approaches are (i) by using inter channel correlation and nonlocal self-similarity [9], (ii) Aliasing artifacts reduction with subband signal [10], (iii) Directional Difference Regression and Efficient Regression [11], (iv) Primary-consistent soft-decision [12], (v) Adaptive homogeneity [13], (vi) Directional Residual Interpolation [14] and etc. The existing approach for Generalized assorted pixel is to use demosaicking technique with the help of Frequency Impulse Resonance filter (FIR). Fumihito Yasuma, Tomoo Mitsunaga, Daisuke Iso, and Shree K. Nayar [6] presented a comprehensive optimization method to arrive at the spatial and spectral layout of the color filter array of a GAP camera, developing an algorithm for reconstructing the under-sampled channels of the image while minimizing aliasing artifacts, demonstrating how the user can capture a single image and then control the tradeoff between the spatial resolution to generate a variety of images, including monochrome, High Dynamic Range (HDR) monochrome, RGB and HDR RGB. Finally, the performance of the GAP camera has been verified using extensive simulations that use multispectral images of real world scenes.

Demosaicing generalized assorted pixel camera images (DEMGAP) [15] explains that at each pixel of the GAP Mosaic there is only one primary color measurement which means the other primary colors must be estimated from neighboring pixels in order to produce output image using interpolation. As the bilinear approach is easy to understand, many advanced algorithms still adopt bilinear interpolation as an initial step; additionally, for performance comparison, these advanced algorithms uses the results of bilinear interpolation. The bilinear interpolation method fills the missing color values with weighted averages of their neighboring pixel values. The existing technique uses the bilinear interpolation for estimating the missing primary colors. Initially the high exposure image is estimated, refined and then interpolating the CMY image with strong inter-channel correlation. The HDR images for high exposure and low exposure images were generated by the merging technique.

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III. Proposed Approach

A novel GAP demosaicing approach was proposed which deals with demosaicing by directional filtering and a posteriori decision to construct the high exposure image and demosaicing by directional filtering and a posteriori decision with up-sampling technique to construct the low exposure image.

The New Joint demosaicing and zooming algorithm for color filter array [18] proposed for the Bayer pattern by (a) recovering the G channel to obtain the complete G channel by using the edge-sensing demosaicing algorithm (b) zooming the recovered complete G channel to obtain the zoomed G channel and (c) recovering and zooming R and B channels by using the color difference value to obtain the zoomed R channel and finally (d) after refinement the zoomed full color image can be obtained. Based on the extracted more accurate edge information and the color difference concept, the developed joint demosaicing and zooming algorithm for mosaic images was used. Further, a new refinement method is used which combines the concept of the local color ratios and the proposed proper weighting scheme.

A. *Demosaicing GAP using directional and Zooming technique*

The proposed approach deals both Demosaicing Directional filtering with posteriori decision technique to construct the high exposure image and the Joint Color Demosaicing and Zooming approach to construct the low exposure image. Daniele [16] presented the Demosaicing Directional filtering with posteriori decision technique. Kuo-Liang [18] presented the New Joint Demosaicing and Zooming Algorithm for Color Filter Array.

From the GAP mosaic image R,G,B values were extracted as high exposure image and r, g, g, b as low exposure image. The CFCDEM GAP pattern was used in this proposed approach. The acquired pattern for high exposure mosaic and low exposure image images are shown in Figure 4 and Figure 5.

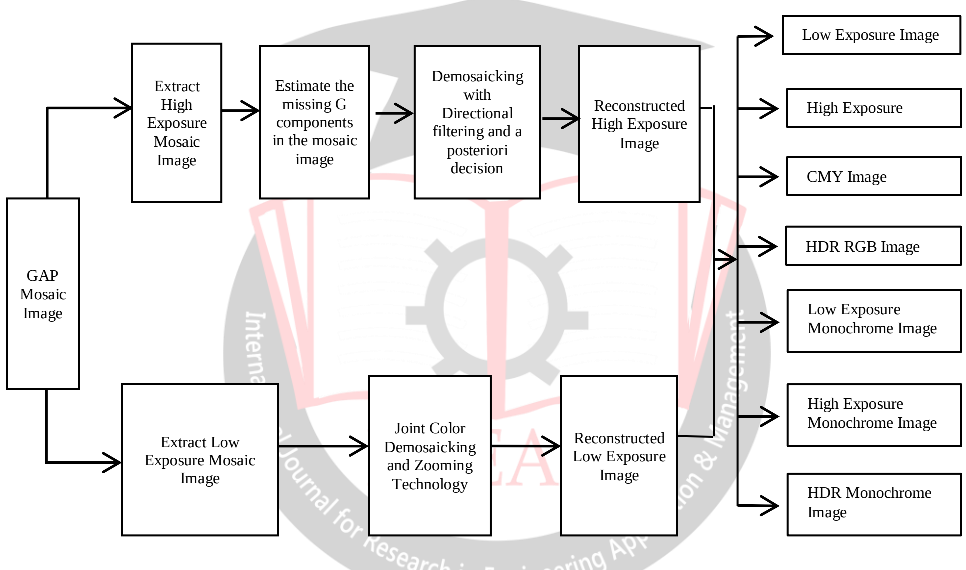

Figure 3. Block diagram of the proposed approach

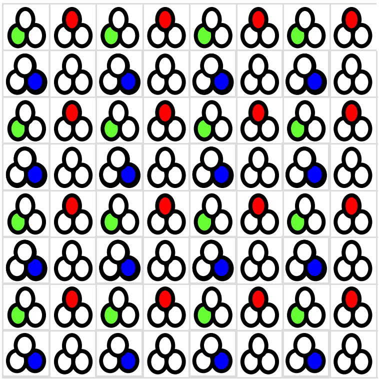
Figure 4. High Exposure Mosaic Image

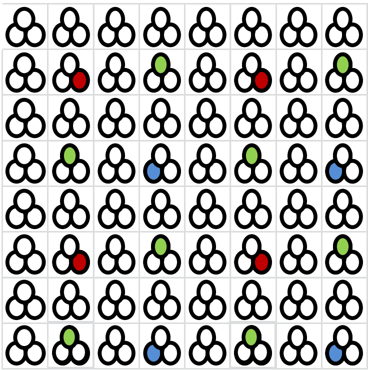
Figure 5. Low Exposure Mosaic Image

A. *Reconstruction of high exposure image*

Directional filtering and a posteriori decision demosaicing technique was adopted to reconstruct the high

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exposure image after estimating the green components in the empty locations.

3.2.1 Estimation of Green component in the empty locations

Initially 25% of the pixel components in the empty locations are estimated. The green component is estimated in the empty location. The green component is estimated by using neighboring green component values. The equation (1) is applied to calculate the missing green components at the empty location. x and y denotes the row and column.

$$\hat{G}(x,y) = \frac{1}{4}(G(x-1,y-1)+G(x-1,y+1)+G(x+1,y-1)+G(x+1,y+1)) \quad (1)$$

Now the high exposure mosaic image is complete and is similar to Bayer mosaic image. So the directional demosaicing technique can be adapted to this complete high exposure mosaic image.

3.2.2 Directional Demosaicing

In Directional demosaicing approach, firstly estimate the green color component using interpolation. Then a decision has to made and lastly estimate the red and blue color components.

3.2.2.1 Directional green interpolation

To reconstruct the green image along horizontal and vertical directions, five coefficient FIR filters are applied to interpolate the Bayer samples. Along a row and the column of the Bayer pattern, the green values are sub sampled by a factor of 2. In the row or column of the Bayer sampled image is represented as follows

….. $R_{-2}G_{-1}R_0G_1R_2$………

where R_k is R(x,y+k) if row sample is considered and

R(x+k,y) if column

Likewise other components are also considered.

The generalized missing green sample G_0 is estimated as

$$\hat{G}_0 = R_0 + \frac{1}{2}\left(G_1 - \frac{R_0+R_2}{2} + G_{-1} - \frac{R_0+R_{-2}}{2}\right) \quad (2)$$

Two green images G_V and G_H are produced using the equation (2) by taking row samples and column samples respectively.

3.2.2.2 Decision

A decision has to be made to select the filtering vertical or horizontal direction that gives the best performance.

The chrominance values R-G^H (or) R-G^V in a red pixel and B-G^H (or) B-G^V in a blue pixel is calculated using the equations.

$C_H(x, y) = R_{x,y} - G^H{}_{x,y}$ if (x, y) is a red location

$C_H(x, y) = B_{x,y} - G^H{}_{x,y}$ if (x, y) is a blue location

$C_V(x, y) = R_{x,y} - G^V{}_{x,y}$ if (x, y) is a red location

$C_V(x, y) = B_{x,y} - G^V{}_{x,y}$ if (x, y) is a blue location

The vertical gradient D_V for chrominance C_V and the horizontal gradient D_H for chrominance C_H are computed as follows.

$$D_H(x,y) = |C_H(x,y) - C_H(x,y+2)|$$

$$D_V(x,y) = |C_V(x,y) - C_V(x+2,y)|$$

The classifiers $\delta_V(x,y)$ and $\delta_H(x,y)$ is computed as the sum of gradients D_V and D_H for the 5x5 window.

For all the red and blue pixels, the green values are estimated as follows.

if $\delta_V(x,y) < \delta_H(x,y)$

then

$$\hat{G}_{x,y} = G^V{}_{x,y}$$

else

$$\hat{G}_{x,y} = G^H{}_{x,y}$$

A full color green image G is estimated by considering the known green samples.

3.2.2.3 Red and blue interpolation

After the green channel has been reconstructed, estimate the red and blue color components. In a blue position, the red color component is estimated as follows:

if $\delta_V(x,y) < \delta_H(x,y)$

then

$$\hat{R}_{x,y} = B_{x,y} + \frac{1}{2}(\hat{R}_{x-1,y} - \hat{B}_{x-1,y} + \hat{R}_{x+1,y} - \hat{B}_{x+1,y})$$

else

$$\hat{R}_{x,y} = B_{x,y} + \frac{1}{2}(\hat{R}_{x,y-1} - \hat{B}_{x,y-1} + \hat{R}_{x,y+1} - \hat{B}_{x,y+1})$$

To estimate the blue values in red pixels, the same strategy is applied.

B. Reconstruction of low exposure image

Directional filtering and a posteriori decision demosaicing technique with up-sampling technique was adopted to reconstruct the low exposure image.

To reconstruct the low exposure image, the following steps were carried out.

3.3.1 Estimation of Green channel

Initially the green channel has to be estimated as per the following steps:

3.3.1.1 Estimation of the missing G components horizontally

The missing green color components (horizontally) can be calculated using the following equation. i and j denotes the row and column.

$$\hat{G}_h(i,j) = \frac{1}{2}(I(i,j+1)+I(i,j-1)) + \frac{1}{4}(2I(i,j) - I(i,j+2) - I(i,j-2))$$

3.3.1.2 Estimation of the missing G components vertically

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The missing green color components (vertically) can be calculated using the following equation.

$$\hat{G}_v(i,j)=\frac{1}{2}(I(i+1,j)+I(i-1,j))+\frac{1}{4}(2I(i,j)-I(i+2,j)-I(i-2,j))$$

where I is the mosaic image

3.3.1.3 Estimation of the missing G components in other positions

The missing green color components in other positions can be calculated using the following equation.

$$\hat{G}_d(i,j)=\frac{1}{2}(\hat{G}_h(i,j)+\hat{G}_v(i,j))$$

3.3.2 Refinement of edge based Green channel

To refine the edge based green component, the horizontal chrominance and the vertical chrominance have to be estimated.

3.3.2.1 Horizontal Chrominance

The horizontal chrominance (C_h) can be calculated using the following equation.

$$C_h(i,j)=\sum_{m=-2}^{2}|I(i+m,j+n)-m(i+m,j)|$$

n=-2,-1,1,2

where I is the mosaic image

3.3.2.2 Vertical Chrominance

The vertical chrominance (C_v) can be calculated using the following equation.

$$C_v(i,j)=\sum_{n=-2}^{2}|I(i+m,j+n)-I(i,j+n)|$$

m=-2,-1,1,2

where I is the mosaic image

3.3.2.3 Finding green on edges

Estimation of green on edges can be calculated using the following criteria.

$$\tilde{G}(i,j)=\hat{G}_v(i,j)$$

$$\tilde{G}(i,j)=\hat{G}_v(i,j)$$

$$\tilde{G}(i,j)=\hat{G}_v(i,j)$$

3.3.3 Zooming Green channel

Zooming the green channel can be implemented using the following steps.

3.3.3.1 Estimation of green

In the gray color shaded locations which is shown in the Figure 6, green color component has to be estimated by using the following equation.

$$\tilde{G}(i,j)=\frac{1}{4}(\hat{G}(i-1,j-1)+\hat{G}(i-1,j+1)+\hat{G}(i+1,j-1)+\hat{G}(i+1,j+1))$$

where i=2,4,…….m

j=2,4,…….n

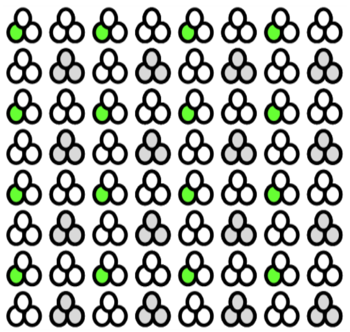

Figure 6. Estimation of Green

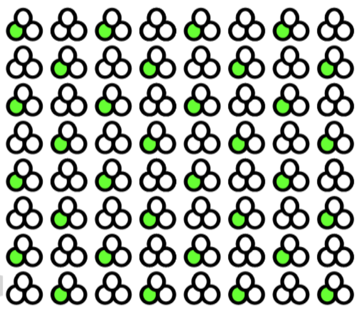

Figure 7. Resulting G color

The output of estimation of green is shown in the Figure 6.

3.3.3.2 Estimation of green in other pixels

In the gray color shaded locations which is shown in the Figure 8, green color component has to be estimated by using the following equation

if ($C_h(i,j)<C_v(i,j)$)

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

where i=1,3,……m

j=2,4,……n

where i=2,4,……m

j=1,3,……n

if ($C_v(i,j)<C_h(i,j)$)

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

if ($C_v(i,j)=C_h(i,j)$)

$$\tilde{G}(i,j)=\frac{1}{4}(\hat{G}(i+1,j)+\hat{G}(i-1,j)+\hat{G}(i,j+1)+\hat{G}(i,j-1))$$

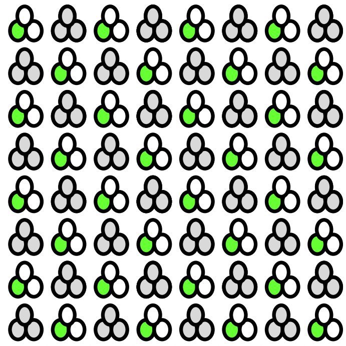

Figure 8. Estimation of G in gray color locations

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The resultant green color mosaic image is shown in Figure 8.

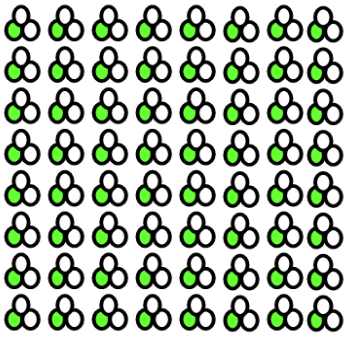

Figure 9. Resultant green color in graycolor locations

3.3.3.4 Estimating and zooming red and blue channel

For estimation and zooming of red and blue channel, color difference concept is used. In the sample block Figure 6, it is known that red and the blue values are in the four corners. The color difference values of the four corner pixels can be calculated using

$$D_r^z(i+m, j+n) = \sum_{\delta 1}\frac{1}{4}(2+\delta_1 n)\sum_{\delta 2}\frac{1}{4}(2+\delta_2 m)D_r^z(i+2\delta_2, j+2\delta_1)$$

where $\delta_1, \delta_2 \in \{-1,1\} - 2 <= m, n <= 2$

IV. Results and Discussion

To evaluate the performance of the proposed method, the standard Mean Square Error (MSE), Peak Signal-to-Noise-Ratio (PSNR) and the Structural Similarity Index (SSIM) were calculated. The test was carried out using MATLAB in the Windows 9 environment. All the compared methods along with the proposed methods share the same sample pictures in the same testing environment. PSNR measures quantitatively the fidelity of the restoration in comparison with the ground truth and the SSIM measures the structural similarity with the ground truth.

4.1. PSNR

PSNR is defined as

$$\text{PSNR} = 10 \log_{10} (255^2/\text{MSE})$$

where MSE is the Mean Square Error

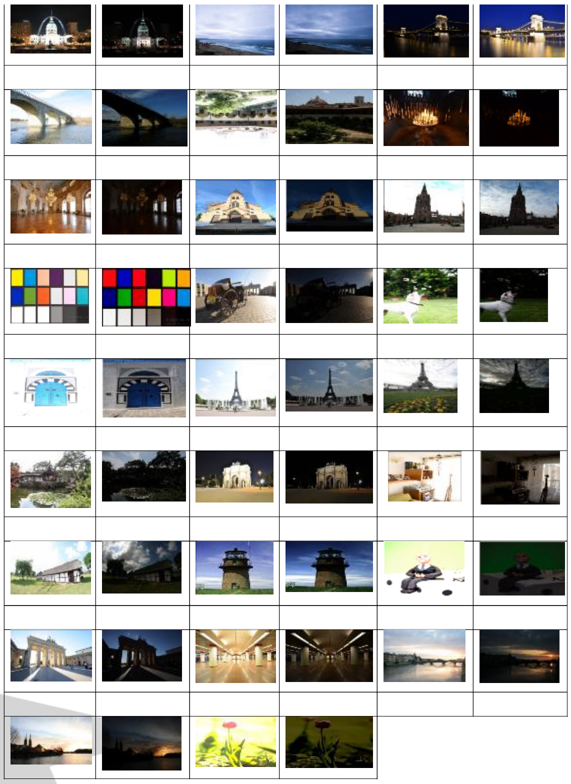

Figure 10. Sample high exposure and low exposure test images

4.2. Mean Square Error

Mean Square Error is defined as

$$\text{MSE}=1/HW \left(\sum_{y=1}^{H} \sum_{x=1}^{W} (I_o(x,y) - I_r(x,y)\right)^2$$

I_0 and I_r represents the original image and reconstructed images of size H x W each.

4.3. Structural similarity Index (SSIM)

Another improved metrics Structural similarity [17] can distinguish between structural and nonstructural distortions, giving results that agree with perception visibly distorted images (supra threshold distortions). The structural similarity index metrics take values from in the range from 0.0 to 1.0, where zero corresponds to a loss of all structural similarity and one corresponds to having an exact copy of the original image. Note that the image domain SSIM implementation can also take negative values when the local image structure is inverted.

The values of the peak signal to noise ratio and the SSIM for the high exposure image and the low exposure image were calculated. The column charts shown in figure (11) to (14) shows the values of CPSNR and CWSSIM measured using the proposed method. It is observed that the quality of the reconstructed image is much improved than the existing methods.

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The computational time is quite efficient than the previous methods. For a 24 bit High exposure and low exposure images need each of 3 x m x n bytes. But for a Generalized Assorted pixel camera images needs m x n bytes only. So the size reduces to 1/6 in size.

Table 1. PSNR & SSIM values

Sl. No.	Picture	High Exposure images			Low Exposure images		
		cpsnr after refined	refined ssim	refined cwssim	cpsnr after refined	zoomed ssim	zoomed cwssim
1	ARCH	38.9822	0.9878	0.9964	31.0801	0.9257	0.981
2	BEACH1	41.1628	0.9776	0.9982	37.1645	0.9429	0.9964
3	BRIDGE	42.2558	0.9521	0.9857	31.7715	0.9262	0.9951
4	BRIDGE1	37.3641	0.9694	0.9978	37.132	0.9716	0.9964
5	BUILDING	38.5037	0.9843	0.9982	31.3736	0.9792	0.9965
6	CANDLE	39.0558	0.9586	0.9872	32.005	0.8348	0.9574
7	CHANDILIER	37.9699	0.9494	0.9948	33.498	0.8282	0.9477
8	CHURCH	37.1055	0.9645	0.996	34.1875	0.8236	0.9586
9	CHURCH1	41.0016	0.9919	0.9987	35.3694	0.9885	0.9984
10	COLOR	40.1742	0.9914	0.9986	34.0556	0.9711	0.9966
11	CYCLE	36.6551	0.9701	0.9956	35.9595	0.9444	0.9917
12	DOG1	37.9514	0.9822	0.9965	34.3951	0.8912	0.9818
13	DOOR	38.4301	0.8455	0.9971	33.2632	0.8745	0.9918
14	EIFFEL	39.1306	0.9263	0.9973	32.9021	0.9247	0.9964
15	EIFFEL1	38.0392	0.9663	0.996	38.3968	0.8267	0.9454
16	GARDEN	36.6148	0.9779	0.9968	32.065	0.9681	0.9938
17	GATE	38.2592	0.9791	0.9964	30.5289	0.8379	0.9755
18	GIRAFFE	38.7676	0.943	0.996	31.2326	0.8634	0.9815
19	HOUSE1	37.7273	0.9715	0.9979	39.8421	0.9903	0.9981
20	LIGHTHOUSE	38.621	0.9696	0.9966	35.6646	0.9484	0.9934
21	MAN	42.3426	0.9513	0.9967	41.0602	0.579	0.8658
22	PILLAR	39.3017	0.9708	0.9969	36.9022	0.883	0.9867
23	PILLARS	37.4068	0.9353	0.9959	36.4964	0.8079	0.9774
24	RIVER	41.0378	0.9838	0.9985	39.2397	0.984	0.9986
25	RIVER1	41.6821	0.9892	0.9985	42.6727	0.9891	0.9989
26	TULIP	39.0481	0.9062	0.995	39.6472	0.5888	0.9759

Table 2. Comparative PSNR analysis of existing methods with the proposed method

	Existing		Proposed	Performance %
	Bilinear	DEMGAP		
High Exposure Image	35.60	37.10	39.02	5.18
Low Exposure Image	32.90	34.70	35.30	1.74

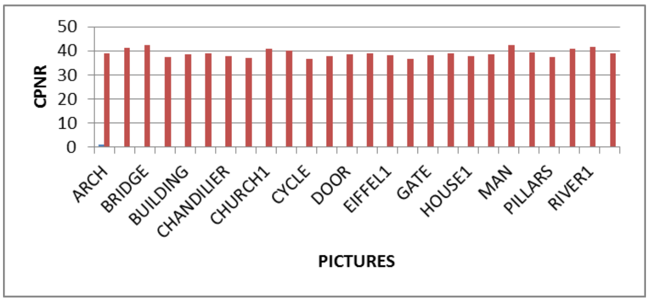

Figure 11. PSNR chart for High Exposure Images

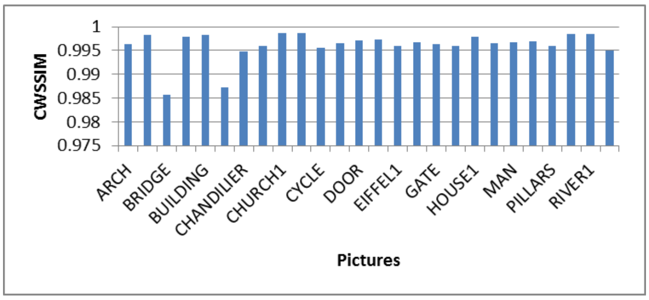

Figure 12. CWSSIM for High Exposure Images

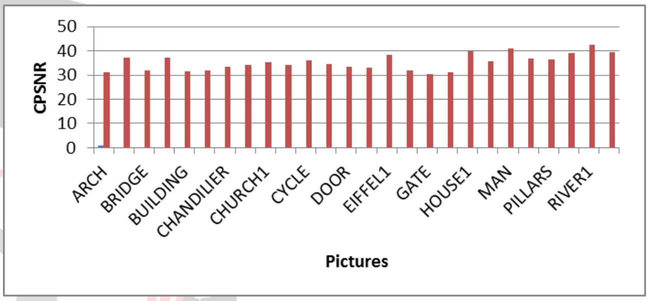

Figure 13. PSNR chart for Low Exposure Images

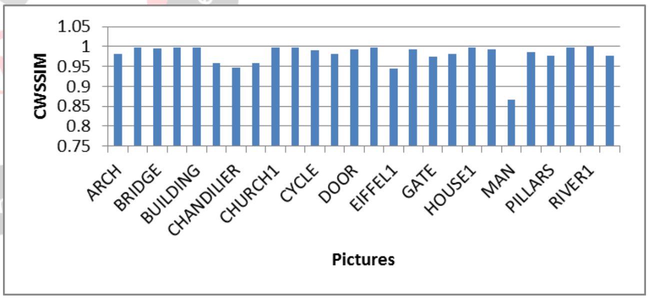

Figure 14. CWSSIM for Low Exposure Images

CONCLUSION AND FUTURE WORK

The proposed approach deals to enhance the quality of the images. Based on twenty-six sets of popular testing high exposure and low exposure mosaic images, experiments have been carried out to demonstrate the quality advantage of the proposed algorithm in terms of CPSNR and CWSSIM when compared with several previous demosaicing algorithms. And also it was noted that the CPSNR values for the low exposure image is less than the high exposure images. In future algorithms can be developed to increase the CPSNR values for the low exposure images.

REFERENCES

[1] Gunturk, B.K.; Glotzbach, J.; Altunbasak, Y.; Schafer, R.W.; Mersereau, R.M. Demosaicking: Color filter

 DOI : 10.35291/2454-9150.2019.0278

array interpolation. IEEE Signal Process. Mag. 2005, 22, 44–54. [CrossRef]

[2] Bayer, B.E. Color Imaging Array. U.S. Patent 3,971,065, 20 July 1976.

[3] Adams,J.E. Interactions between color plane interpolation and other image processing functions in electronic photography. In Proceedings of the SPIE—Cameras and Systems for Electronic Photography and Scientific Imaging, San Jose, CA, USA, 8–9 February 1995; Volume 2416, pp. 144–151.

[4] Longère, P.; Zhang, X.; Delahunt, P.B.; Brainard, D.H. Perceptual assessment of demosaicking algorithm performance. Proc. IEEE 2002, 90, 123–132. [CrossRef]

[5] Yu, W. "Colour demosaicking method using adaptive cubic convolution interpolation with sequential averaging". IEE Proc. Vis. Image Signal Process. 2006, 153, 666–676. [CrossRef]

[6] Fumihito Yasuma, Tomoo Mitsunaga, Daisuke Iso, and Shree K. Nayar, "Generalized Assorted Pixel Camera: Postcapture Control of Resolution, DynamicRange, and Spectrum", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 19, NO. 9, SEPTEMBER 2010 2241

[7] S.K.Nayar and T. Mitsunga, "High dynamic range imaging: Spatially varying pixel exposures" in Proc. IEEE Computer Soc. Conf. Computer Vision and Pattern Recognition, 2000, vol.1, p.1472.

[8] C.-Y. Su and W.-C. Kao:" Effective Demosaicking Using Subband Correlation": IEEE Transactions pp:199-204, 2009

[9] Kan Chang, Pak lun Kevin Ding, Baoxin Li, "Color image demosaicking using inter channel correlation and nonlocal self-similarity", Science Direct, Image Communications : 0923-5965/& 2015 Elsevier.

[10] Ji Yong Kwon, Sang Work park, Min Kyu Park, Moon Gi Kang, "Aliasing artifacts reduction with subband signal analysis for demosaicked images", Digital Signal Processing 2016 Elsevier.

[11] Jiqing Wu, Radu Timofte, and Luc Van Gool, "Demosaicing based on Directional Difference Regression and Efficient Regression Priors" Citation information: DOI 10.1109/TIP.2016.2574984, IEEE Transactions on Image Processing.

[12] X. Wu and N. Zhang, "Primary-consistent soft-decision color demosaicking for digital cameras (patent pending)," IEEE Trans. Image Process., vol. 13, no. 9, pp. 1263–1274, Sep. 2004.

[13] K. Hirakawa and T. W. Parks, "Adaptive homogeneity-directed demosaicing algorithm," IEEE Trans. Image Process., vol. 14, no. 3, pp. 360–369, Mar. 2005

[14] Ke Yu ID , Chengyou Wang * ID , Sen Yang, Zhiwei Lu and Dan Zhao, "An Effective Directional Residual Interpolation Algorithm for Color Image Demosaicking", Appl. Sci. 2018.

[15] A.Boyed Wesley, F.Ramesh Dhanaseelan, Y.Jacob Vetha Raj, Development of HDR Images by Estimating Missing Color Components in Generalized Assorted Pixel Mosaic Camera Images (DEMGAP), International Journal for Research in Engineering Application & Management (IJREAM), ISSN: 2454-9150 Vol-04, Issue-04, July 2018.

[16] Daniele Menon, Stefano Andriani, Giancarlo Calvagno, "Demosaicking with Directional Filtering and a posteriori Decision", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 16, NO. 1, JANUARY 2007

[17] Alan C. Brooks, Xiaonan Zhao, Thrasyvoulos N. Pappas, 2008, "Structural Similarity Quality Metrics in a Coding Context: Exploring the Space of Realistic Distortions", IEEE transactions on image processing, vol. 17, No. 8.

[18] Kuo-Liang Chung, Wei-Jen Yang, Pang-Yen Chen, Wen-Ming Yan, and Chiou-ShannFuh, 2009, "New Joint Demosaicking and Zooming Algorithm for Color Filter Array" IEEE Transactions on Consumer Electronics, Vol. 55, No. 3.

 DOI : 10.35291/2454-9150.2019.0278