IJCTA, 9(10), 2016, pp. 4715-4724

Color Filter Array Interpolation Using Gaussian Filter

***S. Janani **Dr. J. Satheesh Kumar**

Abstract : Most of the digital cameras will not capture full color components of natural images. Instead of that it will capture only one or two color component from the primary colors. Interpolation is one of the best methods to reconstruct missing color samples to make a complete full color image. In this paper a multi-scale gradient method is implemented without any threshold value to improve the quality of an image in Bayer pattern. The Gaussian filter is used for the refinement process in red and blue color samples. Simulation results show that proposed method outperforms many existing methods in terms of Color Peak Signal Noise Ratio.

***Keywords* :** Color Filter Array (CFA) interpolation, Demosaicing, multi-scale Gradient, Gaussian refinement

1. INTRODUCTION

In image acquit ion pipeline, demosaicing is a backbone of digital image sensor based color filter array which is used to increase the color pixels. Demosaicing is the process of interpolating each missing color plane of input image and reconstruct it with best quality by reducing the computational cost. This problem could formulate nature error-prone of digital cameras and it will replicate by textual guesses. Demosaicing input image can be classified into two different categories such as single frame and multi frame input image. In multi frame images like video same scene will be captured by multiple times, the color information missed in one part may be captured in another part. By using joint demosaicing on a set of images accurately are recovered the missed color channels. Single frame RGB image cannot accurately form the missed color channels it will use color demosaicing concept by interpolating the color channel educated guesses [1].

Demosaicing is also used to recover the pixel correlation using spatial and spectral correlation. Spectral correlation depends on pixel values of different color planes in small region of the image and spatial correlation tendency assumes similar color values of the small regions. Spectral correlation is always weak in the object boundaries because high spectral correlation may fail in edges. It might be reproduced by directional interpolation demosaicing which helps to make efficient high Frequency artifact (Zippering) effects and robust to reduce the noise in low resolution image. Moreover low resolution imaging system is still be utilizing in many ways for interpolation method that can be deterministic as bilinear interpolation, cubic interpolation and edge based interpolation which will exploit a good result in the color artifacts mainly focuses high frequency features on the regions. In figure 1 the color filter of four pixels, two pixels consist of green channel and one pixel consist of red/blue channel respectively. The green channel sampling frequency is always higher than Red and Blue channel [2-4].

Lei et.al proposed directional filtering techniques to green-red and green-blue channels [5][6]. This method mainly focuses on the primary difference signals (PDS) of all primary channels and adaptively focuses on the horizontal and vertical directions which can interpolate the missing green channel by PDS filter in both direction and optimally followed by other two channels.

* Research scholar Department Of Computer Application Bharathiar University, sjanarul@gmail.com

** Assistant Professor, Department Of Computer Application Bharathiar University, jsathee@rediffmail.com

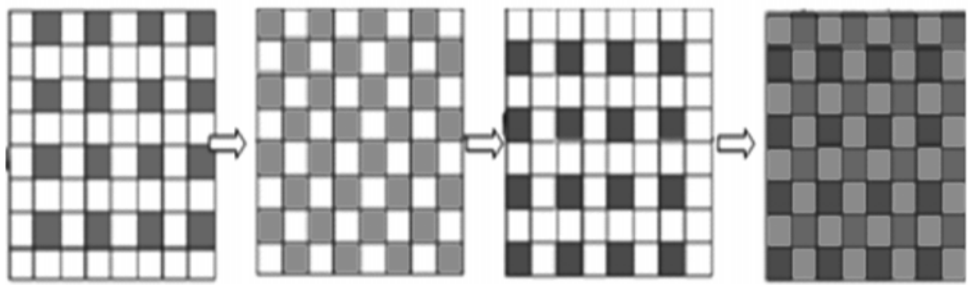

Fig. 1. Bayer color filter array.

Lei Zhang et al[7] introduced the local directional interpolation and non local adaptive thresholding algorithm based on the SSD algorithm. In this technique directional filter algorithm is used interpolate the missing channels which filter is fused on the gradient algorithm to reconstruct the smooth and high quality image. Green channel has high sampling frequency so that it will interpolate G channel using LDI algorithm. Interpolated G channel is again processed by Non Adaptive thresholding algorithm to make an enhanced image.

Daniele et.al[8] used regularization approach for demosaicing process to recreate a complete resolution RGB image from the given input image which is acquired by a digital capturing sensor. Using this algorithm some useful prior knowledge can be gathered about natural color images, such as smoothness of each single color component and correlation between different color channels. Quadratic strategy is adaptively used for the analyzing the improved restoration images near the boundaries and the discontinuities of the image. Demanding iterations can provide a novel strategy that avoids computational efforts. Ibrahim et.al (2011) [9] proposed demosaicing algorithm which has limit for recording number of channels at each pixel location in Bayer pattern. Image should contain three color channels for each pixel. For this reason demosaicing Color filter array (CFA) interpolation can be generated to reconstruct a full three color channel image from a single color channel. An easy method of edge strength filter concept is derived to interpolate the missing color values adaptively and same concept is also used for the Lukac pattern.

Brice et.al[10][11] proposed inter color correlation method for rendering a color image this gives an efficient result when compared to the existing algorithm such as Least Minimum Mean Square Error (LMMSE) which provides a good trade off on quality and computational cost. Wiener demosaicing used a novel stacked super pixel notation of a super pixel RGB channels with efficient computing than compared to the computational cost in the embedded system. In this method chrominance signal act as a low pass signal and luminance filter is used as high order.

Lukac and Plataniotis et.al proposed a color Demosaicing method which use edge-sensing mechanism to defend the sharp edges and high frequency details of the captured image [12]. Vector-spectral model is consider the spectral distinctiveness of RGB channels for the true visual scene in this work. In a comparable edge-directed approach is discussed and it is applied to estimate the full resolution color difference signals (R-G and B-G) based on the prior known information from the interpolated full resolution G channel. Then G channel is added rear to pick up the R and B color channels. Yuk et al introduced the new color demosaicing concept based on adaptive interpolation direction which adaptively selects the color difference spaces which are similar and produce a potential direction which has higher similarity Score while selecting the direction.

Wu et.al[14] developed a primary-consistent soft-decision (PCSD) approach for color demosaicing. It will maintain the consistency of singular interpolated color channels and also multiple estimates of the missing color pixel value were calculated under different assumptions on edge directions. Then an optimal statistical technique is adopted to select the best one based on the testing results of different interpolation assumptions. Even though in the flat region assumption holds within the boundary of an image and also widely it applied for both Red and Blue color channels in the interpolation.

The rest of the paper is summarized as follows. Section II elaborately discuss about the proposed work. Section III presents the experimental result and Section IV it concludes the paper.

2 PROPOSED ALGORITHM

A. Algorithm Background

The framework is implemented by combining which three plane to produce the reconstructed color image by interpolating the missing color channels with gradient algorithm.

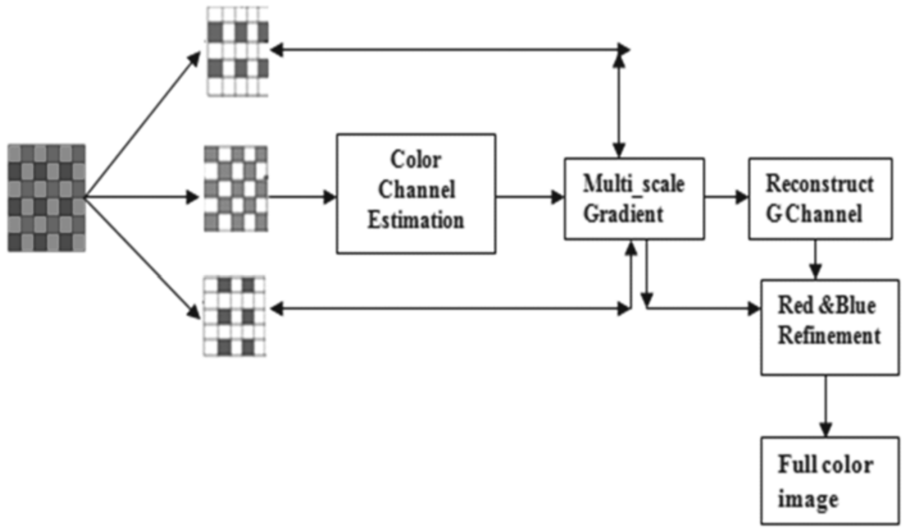

Fig. 2. Framework of Proposed Method.

Multi-scale gradient algorithm is suitable to provide robust edge directed algorithm that efficiently remove the blur and extract the directional information from the digital images [15]. The directional color filter array [16] produces the adaptive valuable color difference estimation by vertically and horizontally for a local window.Before interpolation process we need to separate the color channels as red, green, blue from the Bayer color filter array of an input image by using equation (1)(2)and(3).

R_org = input_im(:, :, 1); ….. (1)

G_org = input_im(:, :, 2); ….. (2)

B_org = input_im(:, :, 3); …..(3)

After separation process the green channel is passed to the color channel estimation process in the first interpolation part only green channel is obtained because it has high sampling frequency compared to other two color channel.

B. Color Channel Estimation

In the initial stage, color channel estimation is used to increase the quality of an image by taking the lead of correlation between the channels. This process helps to shift the algorithm to know about color difference and also estimate the true color channel in every pixel location. The green color is comprised with channel red and blue color which is used to notify the missing pixel values of red and blue position. By calculating this missing pixel values the rows and column of Bayer pattern is depicted and used to find the missing green and red pixel value in the input Bayer mosaic pattern using red and green rows and column as shown in figure 3.

There are two types of interpolation correlation models are used for color estimation model such as color difference rule and color ratio rules. The color intensity difference can be assert between the three channels red, green and blue which is locally near to the constant value and it may also build the interpolation color difference easier by containing the low- frequency components. Color ratio is used to represent the ratio between the color constant over the local region. The Lambert’s law states if two colors have equal chrominance then the ratios between the intensities of three color components are equal. For calculating missing green and red color pixels directional channel estimation method is used, which is calculated using the formula,

$$GH_{(i,j)} = \frac{(G\_org\,(i,\ j-1) + G\_org(i,\ j+1)}{2} + \frac{2(R\_org(i,\ j) - R\_org(i,\ j-2) - R\_org(i,\ j+2)}{4} \quad (4)$$

$$GV_{(i,j)} = \frac{(G\_org\,(i-1,\ j) + G\_org(i+1,\ j)}{2} + \frac{2(R\_org(i,\ j) - R\_org(\ i-2,\ j) - R\_org(i+2,\ j)}{4} \quad (5)$$

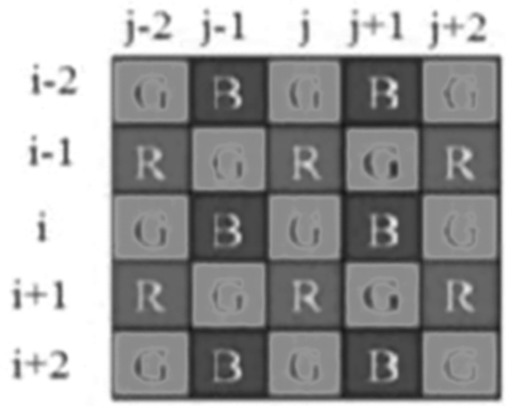

Fig. 3. Bayer Pattern assigns the row and column (*i, j*).

Similarly the same process is used in red and green column for estimating the color channel values. After finding the green pixel values at red position and blue position it takes horizontal (H) and vertical (V) green color channel at red and blue position. $GH_{(i,j)}$ produce the horizontal green color channel estimation at red position and same as $GV_{(i,j)}$ vertically construct the green color channel estimation at red position . Using color channel estimation formula the directional color difference is taken out and the green channel interpolation is carried out.

The quality of the image can be increased by combining the color channel estimation and taking the color difference. This process produces the correlation between the colors channels in which every pixel own true color value. The color difference estimation is mainly used to determine the weights for each direction in a successful manner. It is a great ability to reconstruct the green channel.

C. Multi scale Gradient

Multi-Scale gradient algorithm is an interpolation method used to reconstruct the missing color channels and bring more sophisticated image. Instead of collecting one pixel the proposed algorithm will collect the data value away from its target pixel by doing the operation. For example using multi gradient concept to find the green channel it can be calculated as horizontally and vertically as shown in figure 4.

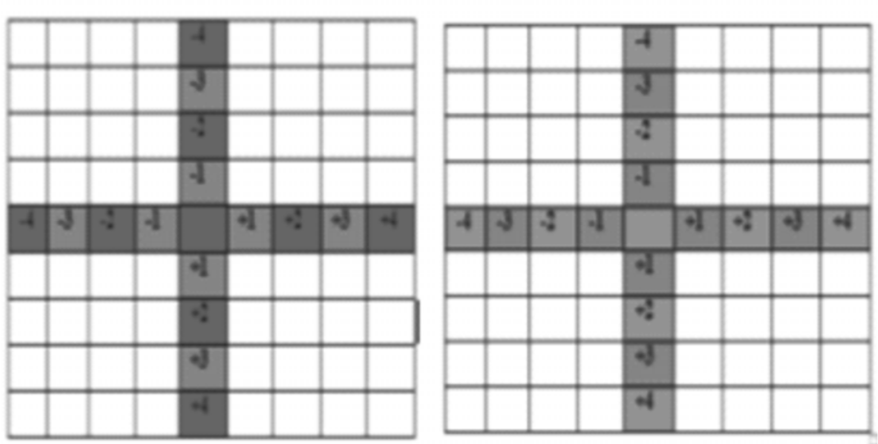

Fig. 4. G-R samples and G-B samples.

Multi-scale gradient uses the normalized term to find the distance of their operands and their term used in the denominators helps to optimize the Values. In the proposed algorithm normalized terms assume the values N1 = 4, N2 = 6, N3 = 8. Similarly, same formula is again executed to the green and blue channel pixel. After processing gradient step it allows the local color dynamics for better resolution. After reconstructing the color channel the interpolated channel can be combined in all the direction by using next reconstructed green channel.

$$MG^{H}(i,j) = \left|\frac{G\_org\,(i,\, j+1) - G\_org\,(i,\, j-1)}{2}\right| - \left|\frac{G\_org\,(i,\, j+2) - R\_org\,(i,\, j-2)}{N1}\right| + \left|\frac{G\_org\,(i,\, j+3) - G\_org\,(i,\, j-3)}{N3}\right| - \left|\frac{R\_org\,(i,\, j+4) - R\_org\,(i,\, j-4)}{N3}\right| + \ldots$$

$$MG^{V}(i,j) = \left|\frac{G\_org\,(i+1,\, j) - G\_org\,(i, 1,\, j)}{2}\right| - \left|\frac{R\_org\,(i+2,\, j) - R\_org\,(i-2,\, j)}{N1}\right| + \left|\frac{G\_org\,(i+3,\, j) - G\_org\,(i-3,\, j)}{N2}\right| - \left|\frac{R\_org\,(i+4,\, j) - R\_org\,(i-4,\, j)}{N3}\right| + \ldots \quad (6)$$

$$MG^{H}(i,j) = \left|\frac{G\_org\,(i,\, j+1) - G\_org\,(i,\, j-1)}{2}\right| - \left|\frac{B\_org\,(i,\, j+2) - B\_org\,(i,\, j-2)}{N1}\right| + \left|\frac{G\_org\,(i,\, j+3) - G\_org\,(i,\, j-3)}{N2}\right| - \left|\frac{B\_org\,(i,\, j+4) - B\_org\,(i,\, j-4)}{N3}\right| + \ldots$$

$$MG^{V}(i,j) = \left|\frac{G\_org\,(i,\, j+1) - G\_org\,(i,\, j-1)}{2}\right| - \left|\frac{B\_org\,(i,\, j+2) - B\_org\,(i,\, j-2)}{N1}\right| + \left|\frac{|G\_org\,(i,\, j+3) - G\_org\,(i,\, j-3)}{N2}\right| - \left|\frac{B\_org\,(i,\, j+4) - B\_org\,(i,\, j-4)}{N3}\right| + \ldots \quad (7)$$

D. Reconstruct the Green Channel

In addition to improve the green channel multi-scale gradient interpolation algorithm and color estimation difference value is renewed to update the closet neighbor of the target pixel which has its own weight. The target pixel can be calculated from the four directions north, south, east, west respectively which is calculated value from the multi-scale color gradients over a local window. In this part the previous color estimation and color difference value is combined adaptively by using the formula as follows,

$$GR_{,(i,j)} = [wv * F * CV(i-1 : i+1, j) + wH * F1 * CH(i, j-1 : j+1)]/WC \quad (8)$$

Where, $WC = WV + WH$, $F = \begin{bmatrix} \frac{1}{4} & \frac{2}{4} & \frac{1}{4} \end{bmatrix}$, $F1 = \begin{bmatrix} \frac{1}{4} & \frac{2}{4} & \frac{1}{4} \end{bmatrix}$ and $GR_{,(i,j)}$ represents the initial green channel interpolation at red pixel location. The weighting function W = 0.01 assumes the 5 × 5 window. Green channel is updated again by using the same multi-scale gradient algorithm in all the direction as shown in figure 5,

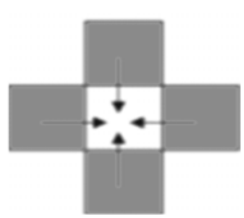

Fig. 5. Green channel Updating.

Updating green channel in all directions gives the best improvement in the reconstructed image. Weight of the target pixel can be calculated by multi color gradient local window in up, down, right and left direction respectively (W_u, W_d, W_r, W_l). It is shown in below equation,

$$W_U = \frac{1}{\left(\sum_{m=i-4}^{i} \sum_{n=j-1}^{j+1} MG^{V(m,n)}\right)^2} + 1$$

$$W_D = \frac{1}{\left(\sum_{m=i-2}^{i+4} \sum_{n=j-1}^{j+1} MG^{V(m,n)}\right)^2} + 1$$

$$W_R = \frac{1}{\left(\sum_{m=i-1}^{i+1} \sum_{n=j-4}^{j} MG^{H(m,n)}\right)^2} + 1$$

$$W_L = \frac{1}{\left(\sum_{m=i-1}^{i+1} \sum_{n=j}^{j+4} MG^{H(m,n)}\right)^2} + 1$$

$$W^T = W_U + W_D + W_R + W_L$$

To complete the process and get the reconstructed green channel, the updated color value is added to the target pixels to produce full color image.

E. Red and Blue Refinement

The refinement part is mainly used to increase the image quality and ensure smooth and noise free reconstruction process for red and blue pixels. The reconstructed G1 image is taken as input to the red and blue color refinement process by using Gaussian filter. Image smoothing produces the brightness of color intensity and reduces the effect of blur in the image. Fspecial Gaussian filter is proposed with the matrix multiplication and window horizontally value is assumed as "hsize=8". H represents as scalar square matrix with local window size (8×8) and this filter can be applied to red and blue pixel. Refinement part takes all the red and blue color samples and finally the three color channel should be combined to produce a superior image quality.

To improve the quality of demosaicing result refinement process is compared to all existing methods to obtain better results. Interpolated green samples based on that red and blue color samples are taken for refinement. The local gradients as the weights of estimated samples can be refined by the reciprocal of neighboring samples.

3. EXPERIMENTAL RESULTS

To evaluate the performance of proposed algorithm Kodak dataset is used it is shown in figure6. The test images of size 768×512 pixels are down sampled using Bayer pattern and this test dataset is taken for reconstruction process using the proposed method to produce the full color image. The quality of the image is improved without undergoing any hard decisions and thresholds.

Fig. 6. the 24 Uncompressed images in Kodak Dataset.

The result of our proposed method is compared to different existing demosaicing methods. CPSNR quality metrics is compared to alternating Projections (AP) [16], Variance of Color Differences (VCD) [17], Directional Linear Minimum Mean Square-Error Estimation (DLMMSE) [12], Gradient Based Threshold Free demosaicing (GBTF) [23], Multi-scale Based Demosaicing [15]. The proposed algorithm shows the highest CPSNR value for each image in the data set which is shown in the table 1. In particular CPSNR (Color Peak Signal Noise Ratio) is alculated using Mean Square Error which shows the difference between original and reconstructed images.

Table 1. Comparison of CPSNR Value with Existing Demosaicing Methods in the Bayer Pattern

S.No	*AP*	*VCD*	*DLMMSE*	*GBTF*	*MGBD*	*Proposed*
1	37.80	38.61	38.52	39.62	39.87	42.64
2	39.65	40.42	40.93	41.53	41.77	58.44
3	41.63	42.71	42.75	43.30	43.72	57.66
4	40.16	40.62	40.57	40.70	41.13	44.40
5	37.58	37.97	38.10	38.42	39.05	40.47
6	38.64	40.09	40.27	41.05	41.38	45.03
7	41.84	42.26	42.39	42.90	43.51	48.24
8	35.16	36.40	36.08	37.02	37.56	33.15
9	41.89	43.14	43.14	43.62	43.96	44.08
10	42.00	42.48	42.53	42.93	43.20	43.83
11	39.26	39.96	40.09	40.89	41.36	47.13
12	42.64	43.57	43.53	44.15	44.45	50.56
13	34.38	34.92	34.81	35.49	36.00	37.78
14	35.84	37.06	37.03	37.22	37.97	45.87
15	39.43	39.84	39.87	40.02	40.30	47.46
16	41.89	43.75	43.83	44.48	44.86	53.15
17	41.32	41.49	41.79	42.09	42.32	42.60
18	37.19	37.18	37.52	37.84	38.22	44.87
19	39.53	41.03	41.04	41.82	42.17	42.74
20	40.72	41.17	41.27	41.83	42.16	45.95
21	38.79	39.23	39.17	39.77	40.31	43.93
22	37.72	38.21	38.46	38.85	39.05	49.26
23	42.02	43.05	43.30	43.65	44.02	54.27
24	34.74	35.15	35.52	35.62	35.69	43.33
Average	**39.24**	**40.01**	**40.10**	**40.62**	**41.00**	**46.11**

A. Quality Metrics

To measure the quality of reconstructed image the processed image can be denoted as R (i, j) and then compared to the original image which represents as I (i, j) in dB (decibels). The structure of each image denotes the size of each image as row and column as MxN defined in below formula,

$$\text{MSE} = \frac{1}{\text{MN}}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[\text{I}(i,\ j) - \text{R}(i,\ j)]^2 \tag{10}$$

$$\text{CPSNR} = 20.\log_{10}\left(\frac{\text{MAX}_\text{I}}{\sqrt{\text{MSE}}}\right) \tag{11}$$

The maximum pixel value is calculated as 8- bit per Pixel which is assume as (28-1) 255. In our algorithm the three color planes of mean squared error is executed separately and PSNR value is also reported for each color channel for the color image. The sample image of input and full reconstructed image is given in figure 7,

(*a*) Input image

(*b*) Reconstruct image

Fig. 7. Comparison on input Bayer Pattern image and reconstructed center Full color Image Using Proposed Method.

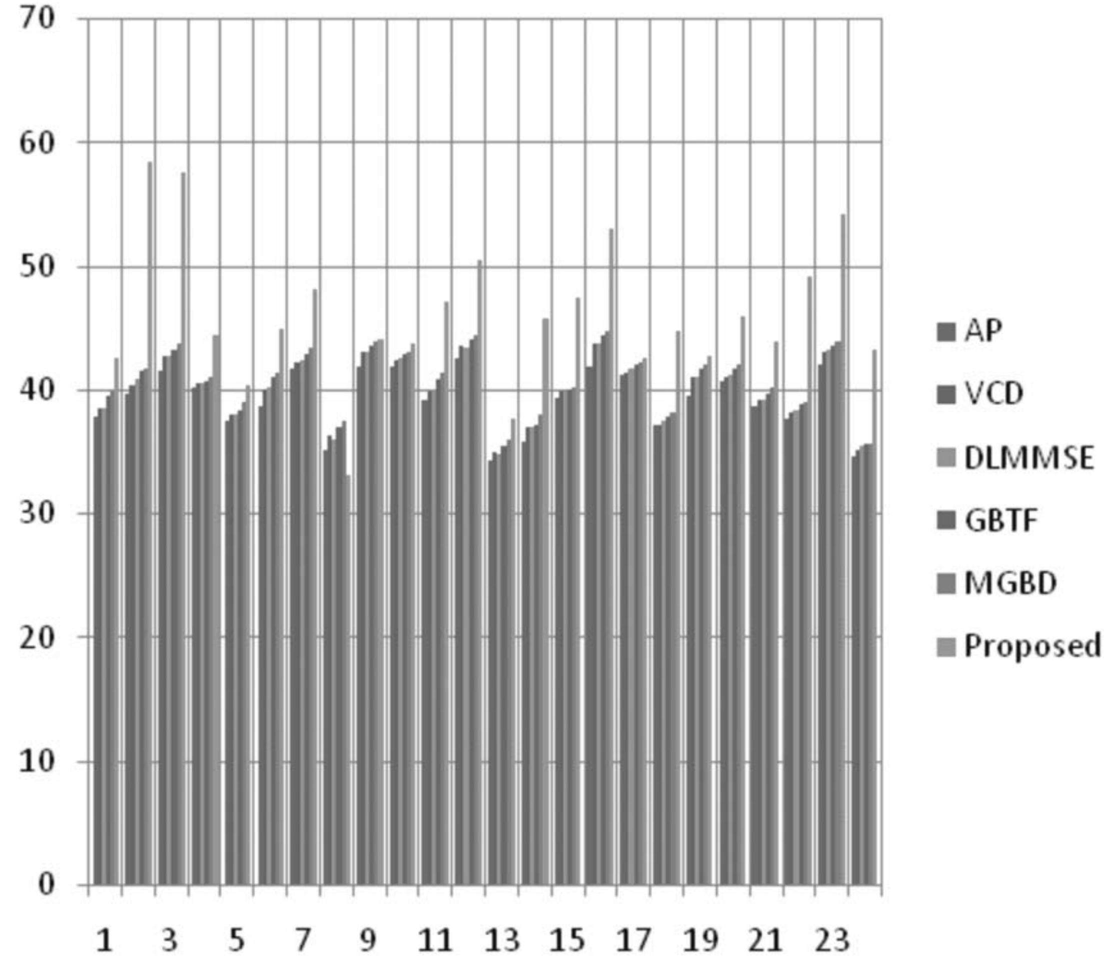

Fig. 8. Performance Comparative Image with existing methods

4. CONCLUSION

In this paper, a new novel algorithm is demonstrated to reconstruct the full color image using demosaicing CFA interpolation method with the help of Multi-scale Gradient algorithm. Gaussian filter is used for the red and blue refinement process to bring better quality image in visual perception by increases quality measures compared to some state of art existing demosaicing algorithm. In further this algorithm can process in all images processing application because still low resolution image is used in digital image processing area.

5. REFERENCES

1. Buades, B. Coll, and J. M. Morel, “A review of image denoising algorithms, with a new one”, Multisc.Model. Simulat, vol. 4, (No. 2), pp: 490.530, 2005.
2. Ron Kimmel, “Demosaicing: Image Reconstruction from Color CCD Samples”, IEEE Transactions On Image Processing, Vol. 8, (No. 9), September 1999.
3. Lei Zhang and Xiaolin Wu, “An Edge-Guided Image Interpolation Algorithm via Directional Filtering and Data Fusion”, IEEE Transactions On Image Processing, Vol. 15, (No. 8), August 2006.
4. Rastislav Lukac and Konstantinos N. Plataniotis, “Data Adaptive Filters for Demosaicking: A Framework**”,** IEEE Transactions on Consumer Electronics, Vol. 51, (No. 2), May 2005.
5. Henrique S. Malvar, Li-Wei He, and Ross Cutler, “High-Quality Linear Interpolation for Demosaicing of Bayer-Patterned Color Images”.
6. Lei Zhang, Xiaolin Wu and David Zhang, “Color Reproduction From Noisy CFA Data of Single Sensor Digital Cameras”, IEEE Transactions On Image Processing, VOL. 16, (No. 9), September 2007.

7. Xin, L. and Orchard, M. T, “New edge-directed interpolation,” IEEE Transactions on Image Processing, vol. 10, pp. 1521-1527, 2001.
8. Xin Lia, Bahadir Gunturkb and Lei Zhangc , “Image Demosaicing: a Systematic Survey”.
9. D. Menon and G. Calvagno, “Regularization Approaches to Demosaicking,” in IEEE *Transactions on Image Processing*, vol. 18, (no. 10), pp. 2209-2220, Oct. 2009.doi: 10.1109/TIP.2009.2025092.
10. I. Pekkucuksen and Y. Altunbasak, “Edge Strength Filter Based Color Filter Array Interpolation,” in *IEEE Transactions on Image Processing*, vol. 21,(no.1), pp.393-397,Jan.2011 doi: 10.1109/TIP.2011.
11. Brice Chaix de Lavar‘ene, David Alleysson and Jeanny H´erault, “Practical Implementation of LMMSE Demosaicing Using Luminance and Chrominance Spaces”, Computer Vision And Image Understanding · July 2007.
12. R. Lukac and K.N. Plataniotis, “Data adaptive filters for demosaicking: a framework”, IEEE Transactions on Consumer Electronics, 51(2):560–570, May 2005.
13. R. Lukac, K.N. Plataniotis, D. Hatzinakos, and M. Aleksix., “A novel cost effective demosaicing approach”, I EEE Transactions on Consumer Electronics, 50(1):256–261, 2004.
14. Xiaolin Wu and Ning Zhang, “Primary-consistent soft-decision color demosaicking for digital cameras (patent pending)”, in *IEEE* Transactions on Image Processing, vol. 13, no. 9, pp. 1263-1274, Sept. 2004.
15. R. W. Lucky, “Automatic equalization for digital communication”, *Bell Syst. Tech. J.*, vol. 44, no. 4, pp. 547–588, Apr. 1965.
16. Ibrahim Pekkucuksen and Yucel Altunbasak, “Multiscale Gradients- Based Color Filter Array Interpolation,” IEEE transactions on image processing, vol. 22, no. 1, January 2013.
16. B. K. Gunturk, Y. Altunbasak, and R. M. Mersereau, “Color plane Interpolation using alternating projections” ,*IEEE Trans. Image*
17. K.-H. Chung and Y.-H. Chan, “Color demosaicing using variance of color differences,” *IEEE Trans. Image Process.*, vol. 15.
18. L. Zhang and X. Wu, “Color demosaicking via directional linear minimum mean square-error estimation” ,*IEEE Trans. Image* Process., vol. 14, no. 12, pp. 2167–2178, Dec. 2005.