NOVEL ALGORITHM FOR COLOR IMAGE DEMOSAIKCING USING LAPLACIAN MASK

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Abstract

Images in any digital camera is formed with the help of a monochrome sensor, which can be either a charge-coupled device(CCD) or complementary metal oxide semi-conductor(CMOS). Interpolation is the base for any demsoaicking process. The input for interpolation is the output of the Bayer Color Filter Array which is a mosaic like lattice structure. Bayer Color Filter Array samples the channel information of R,G and B values separately assigning only one channel component per pixel. To generate a complete color image, three channel values are required. In order to find those missing samples we use interpolation. It is a technique of estimating the missing values from the discrete observed samples scattered over the space. Thus Demosaicking or De-bayering is an algorithm of finding missing values from the mosaic patterned output of the Bayer CFA. Interpolation algorithm results in few artifacts such as zippering effect in the edges. This paper introduces an algorithm for demosaicking which outperforms the existing demosaciking algorithms. The main aim of this algorithm is to accurately estimate the Green component. The standard mechanism to compare the performance is PSNR(Peak Signal to Noise Ratio) and the image dataset for comparison was Kodak image dataset. The algorithm was implemented using Matlab2009B version.

Keywords: *Demosaicking, Interpolation, Bayer CFA, Laplacian Mask, Correlation.*

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1. INTRODUCTION

In cameras, there resides a sensor which is used to capture the image information. Using these sensors resulted in contributing 15-25% of the price of the camera. In order to reduce the price of cameras, Color Filter Arrays were used. For Demosaicking we use Bayer Color Filter Array[13]. This is the best known CFA which replaced the monochromatic sensors which was used separately for Red, Green and Blue channels resulting in three sensors. Thus Bayer CFA can be assumed as a replacement to the sensors[12].

The typical lattice arrangement of the Bayer pattern makes it possible for being the largely used CFA. The arrangement of this filter is shown in Fig.1. It may be observed that only one color value is assigned out of R,G and B channel per pixel. For any NxN filter there exists 50% of green component and 25%-25% of the red and blue components[1]. Bayer CFA separates the color components and arranges them in the specified pattern of alternate arrangement with the green components. This is a mosaic pattern of incomplete color samples, as for any color image there is R, G and B components. To find those missing color, interpolation is used. Hence termed as De-mosaicking, where missing color components are calculated from the sampled values. Thus demosaicking helps in recontruction of a full color image from incomplete color samples. Due to interpolation, the newly reconstructed image suffers from artifacts like zippering effects or aliasing effect[2][16]. These artifacts are the errors which do not appear in the original image. Demosaciking methods can be divided into two major categories- one being the interpolation on channels separately and the latter being the inter-channel correlation. Inter channel correlation gives better results as compared to interpolation[4],[5].

R1	G2	R3	G4	R5
G6	B7	G8	B9	G10
R11	G12	R13	G14	R15
G16	B17	G18	B19	G20
R21	G22	R23	G24	R25

Fig -1: Bayer CFA

Fig -2: Original image(left) and Output of Bayer CFA(right)

Demosaicking results in formation of artifacts which can be observed in Fig-3. This artifact results in poor quality of restored image.

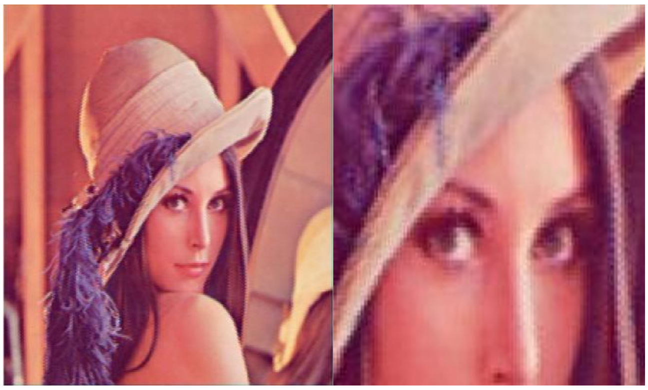

Fig -3: Interpolated image(left)and artifacts zoomed(right)

Few algorithms have been implemented which shows visible artifacts. In this paper, we have proposed a new method which results in 8-10dB improvement of the CPSNR when compared to the original image as well as the previous existing algorithms.

2. EXISTING METHODS

Demosaicking methods has been divided into two parts- (i)Simple Interpolation and (ii) Correlation. In simple interpolation techniques covered are nearest neighbor interpolation, bilinear interpolation, and bicubic spline interpolation. In the first group the zippering artifact appeared at a higher ratio. In the correlation category, edge directed interpolation and smooth hue transition are placed. Interchannel correlation resulted in better images[3]. Gunturk et.al proposed a method with a combined approach of bilinear interpolation applied to red and blue channels and edge directed interpolation applied for green channel separately [3]. Another algorithm proposed by Kimmel used an iterative scheme where edge directed interpolation was combined with smooth hue transition[5]. The main steps of this algorithm were- (i) interpolate green channel, (ii) compute red and blue values using using this green information. A new algorithm was proposed, which was same as the above algorithm, after interpolation a third step was added that was the correction stage[6]. It was a high quality algorithm which eliminated the zippering effects. Few algorithm exists which has a high degree of complexity for the green channel interpolation especially. A combination of Kimmel algorithm and Optical Recovery resulted in better image restoration due to high complexity of the green channel, named as Aqua-2 algorithm If the color direction vector coincides with the gray color axis, in that case Alternating Projection method works well. All the advantages of these methods were combined altogether and when implemented produced better results[6]. Table-I shows the PSNR comparisons measured in dB.

There exists high correlation between R,G and B channels, therefore color correlation was preferred for Demosaicking. Due to this cross correlation between the channels was calculated and range was from 0.25 to 0.99, having average values 0.86 for red/green, 0.92 for green/blue and 0.79 for red/blue[7]. A model suggested by J.E Adams. Jr[8], two new constants were introduced K_B and K_R . They can be calculated by K_B =G-B and K_R =G-R . Instead of calculating the values domain-wise, it was transformed into the terms of new constants. The results outperformed with improvement in the green channel of 6.34dB over the bilinear method and an average of 7.69dB development on the R,G and B channels[7].

Table -1: PSNR comparison of above mentioned algorithms

Method	PSNR
Bilinear	27.5
Kimmel	33.5
Aqua-2	34.63
Alternating projections	35.24
High-quality algorithm	37.1

As suggested by Freeman, the algorithm was Median-based interpolation comprising of two steps. First step consisted of linear interpolation and second step was using a median filter of 3x3 window[9]. Another algorithm suggested by Laroche et. al, used a gradient based concept which has calculated the color difference between the red/green and blue/green channel and then was interpolated[10]. Adaptive color plane interpolation suggested by Hamilton and Adams[11] was a modification of the gradient based interpolation where classifiers, α and β were used and depending on the value of these classifiers suitable value could be assumed for that particular channel. Lei Zhang et. al proposed a method assuming the Primary Difference signal between the green and the red/blue channels and estimating the values both in horizontal and vertical directions. There was significant improvement in the PSNR value[16]. The same author proposed an algorithm which fused the local directional interpolation and non local adaptive thresholding[17]. The algorithm outperformed the state-of-the-art demosaicking methods.

3. METHODOLOGY

3.1 For Red Channel

The input image is taken and Bayer pattern is generated. Color difference interpolation is applied for green pixel and this is the guide image. Compute tentative estimate of Horizontal Red-pixel($\widetilde{R^H}$) by applying guide filter to the guide image obtained and Bayer pattern of Red pixel image(R). Compute the residual Red-pixel image (R-$\widetilde{R^H}$) by minimizing the laplacian energy. Apply bilinear interpolation in residual domain obtained in residual-red pixel image to get the final Red channel Horizontal image. Similarly vertical red channel values is calculated.

3.2 For Blue Channel

The input image is taken and converted to Bayer Pattern array. Color difference interpolation method is applied for Green Pixel and considered as guide image. Now calculate the tentative estimate of horizontal Blue-pixel($\breve{B}^H$) by applying guide filter to the guide image obtained and Bayer pattern of Blue pixel image(B). Compute the residual Blue-pixel image (B-$\breve{B}^H$) by minimizing the laplacian energy. Apply bilinear interpolation in residual domain obtained to get the final Blue channel Horizontal image. Similarly vertical blue pixel value is calculated.

4. RESULTS

Table -2: Result of Kodak Dataset

Image	Proposed Method			
	RED	**GREEN**	**BLUE**	**CPSNR**
kodim1	35.9907	38.44812	36.35484	36.80436
kodim2	38.41384	43.88	41.83973	40.78352
kodim3	42.43939	45.81395	41.71374	42.99188
kodim4	38.20758	44.30077	42.82978	40.96257
kodim5	37.29591	39.90501	36.47861	37.66519
kodim6	38.96318	41.09398	37.92634	39.13763
kodim7	42.35421	45.28166	41.68563	42.85047
kodim8	34.09049	37.20012	34.096	34.9042
kodim9	41.67074	44.55918	41.51579	42.37561
kodim10	41.40061	44.94254	41.31518	42.25849
kodim11	38.39765	41.05125	38.92885	39.31696
kodim12	42.22411	46.01401	42.5024	43.27399
kodim13	33.14832	34.43473	32.16007	33.14954
kodim14	36.47877	40.40548	36.9419	37.62566
kodim15	37.12953	42.44894	40.05859	39.34019
kodim16	42.61606	44.68774	41.83687	42.88918
kodim17	41.01202	42.55487	40.02356	41.07533
kodim18	36.03399	37.91994	35.899	36.52496
kodim19	39.2145	41.75231	39.25909	39.92499
kodim20	41.48291	43.16091	38.63451	40.68346
kodim21	38.1504	40.16923	36.86723	38.19116
kodim22	38.19407	40.73273	37.54817	38.62325
kodim23	42.63697	46.25818	43.34106	43.81984
kodim24	35.36084	36.85233	32.81754	34.68463

Table- 2 shows the results of the proposed algorithm when applied to 24 images of Kodak Dataset [13]. Table -3 shows the results when the same algorithm was applied to the 18 images of IMAX database (McMaster Database) [15]. Table- 4 shows the comparison of the Previous algorithms with the proposed algorithm on IMAX Dataset.

Table -3: Result of IMAX Dataset

	Proposed Method			
Image	**RED**	**GREEN**	**BLUE**	**CPSNR**
IMAX1	29.21229	32.42841	26.9258	28.97315
IMAX2	34.66927	39.26991	33.3025	35.1003
IMAX3	34.17191	36.78554	31.96751	33.87931
IMAX4	38.30484	41.34507	35.35203	37.67242
IMAX5	36.89551	37.86462	30.85081	34.01581
IMAX6	39.05702	41.83149	35.93489	38.28932
IMAX7	37.542	39.38773	36.1445	37.49397
IMAX8	34.14455	41.68364	38.24871	36.97088
IMAX9	34.20242	41.32974	36.50707	36.46461
IMAX10	37.62951	42.0721	37.59404	38.65739
IMAX11	39.0232	41.9884	39.38727	39.94764
IMAX12	40.25507	42.15243	37.75307	39.67949
IMAX13	42.23337	44.91082	37.64852	40.55644
IMAX14	39.33683	42.85624	36.42193	38.79168
IMAX15	36.91814	42.46938	39.09144	38.93668
IMAX16	34.38471	35.24319	35.74638	35.08797
IMAX17	31.25378	36.96613	31.52874	32.58689
IMAX18	34.99269	37.61057	36.16048	36.12495

Table -4: Comparison of IMAX Dataset with other algorithms

	PSNR			
Algorithms	**Red**	**Green**	**Blue**	**CPSNR**
Hirakawa	33.00	36.98	32.16	33.49
LMMSE	34.03	37.99	33.04	34.47
NAT	36.28	39.76	34.39	35.20
Proposed	36.34	39.89	35.36	36.62

The proposed algorithm results in better images of the Imax dataset as shown in Table-4 and as shown in Chart 1, the proposed method results in significant improvement in the PSNR as compared to the bilinear method,which is a basic method. The evaluation of algorithm was done on the basis of Mean Square Error(MSE) whereas Peak Signal to Noise Ratio(PSNR) can be calculated as PSNR=$10\log_{10}$ [255^2/MSE]. Table-5 also shows the comparison of the results as presented by S.C Pei et.al[7]. Comparing the PSNR channel wise on the specified image, the proposed method performed well with a significant improvemnt 7-8dB in the PSNR values.

5. CONCLUSION

In this paper we proposed a novel method for color image demosaicking which can be one of the alternative to the various currently used algorithms. Using a laplacian mask helps to minimize the error formation in the demosaicked image. Experimental results show that the proposed algorithm outperforms the various above mentioned algorithms on the Kodak as well as IMAX dataset.

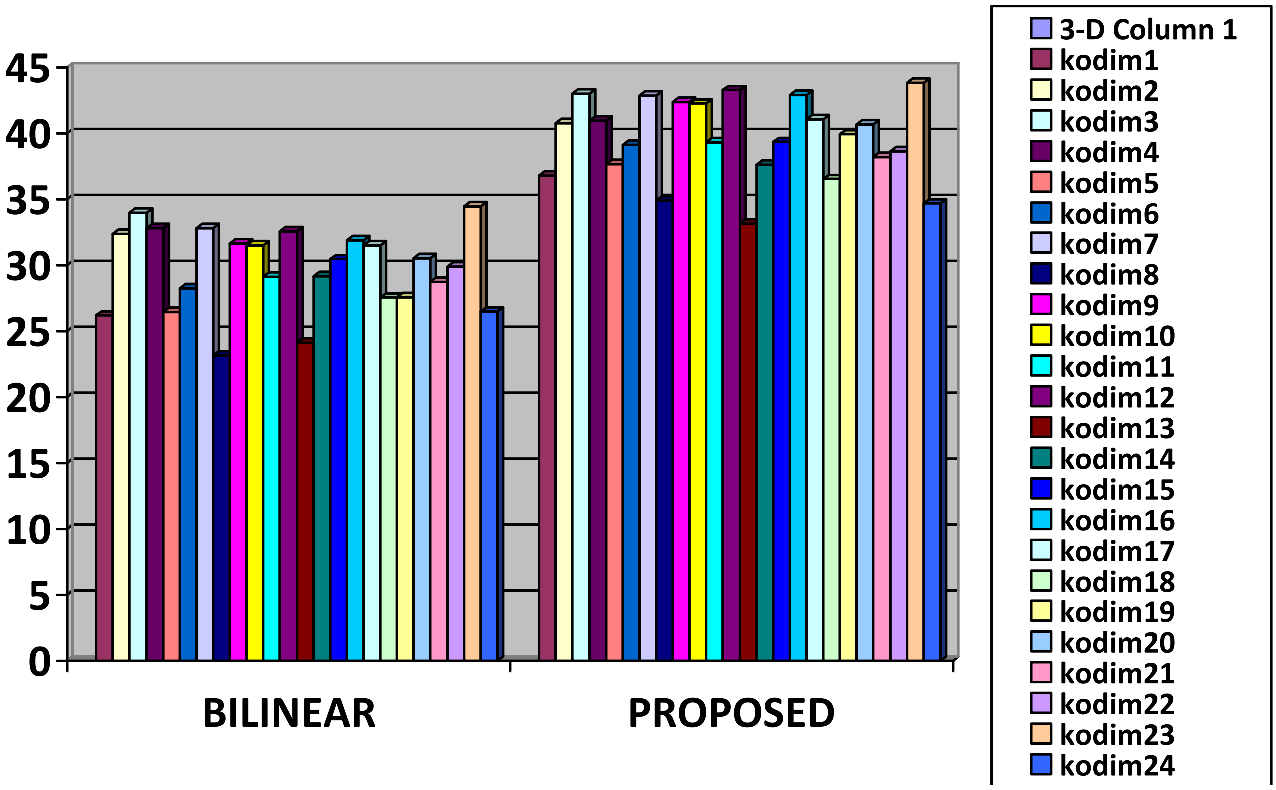

Chart -1: Results of 24 Kodak Images compared to Bilinear

Table -5: Comparison of Kodak Dataset with other algorithms

Image	E	S	M	S	C	M	PROPOSED		
	r	g	b	r	g	b	r	g	b
Cap	30.8	35.5	31.3	35.7	41.2	35.0	42.4	45.8	41.7
Motor	22.6	27.5	24.2	30.1	34.7	29.7	37.2	39.9	36.4
Airplane	29.5	32.9	28.2	33.8	38.4	32.6	41.4	43.1	38.6
Parrot	30.9	36.3	32.9	35.8	41.9	36.6	42.6	46.2	43.3

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