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COLOR IMAGE DEMOSAICKING USING RESIDUAL INTERPOLATION

R. VAISHNAVI[a1] AND I. NELSON[b]

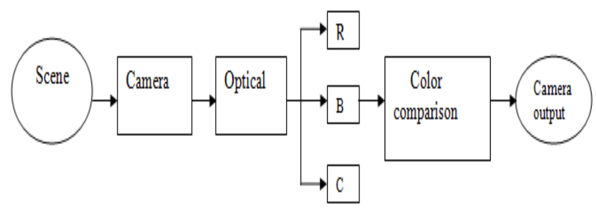
[a]PG Scholar, Department of ECE, SSN College of Engineering, Kalavakkam, Tamilnadu, India
[b]Assistant professor, Department of ECE, SSN College of Engineering, Kalavakkam, Tamilnadu, India

ABSTRACT

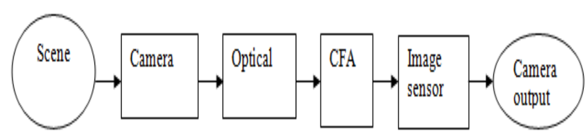
Color filter array is one of the key components in an image signal processing pipeline. The Bayer's pattern is the popular color filter array for low-cost implementation with only one color channel captured at each pixel; the other two missing colors are estimated by the operation known as demosaicking. The demosaicking can be implemented by various interpolation techniques like bilinear interpolation techniques, bicubic interpolation techniques. However, this output image suffers from visible artifacts and lower performance. The solution to the above problem can be addressed by using the residual interpolation techniques. In residual interpolation technique, the estimate of an image is generated by the guided upsampling process. Using this estimate of the image, the performance of the residual interpolation technique is compared with that of conventional interpolation techniques. The simulation results reveal that the residual interpolation techniques achieve better color peak signal to noise ratio for CDM and Kodak datasets when compared to conventional interpolation methods.

KEYWORDS: Color Filter Array, Demosaicking, Residual Interpolation, Guided Upsampling.

A single sensor element, such as a digital camera captures only one intensity value at each pixel location. [Bayer, 1976] As a result, the camera needs to approximate the other two intensity values at each pixel location .The image that is obtained from the sensor elements called “raw image”. It contains jut one red, green, blue value at each spatial location. In order to obtain the image in a viewable format, the missing color elements need to be estimated. In order to achieve this, We use the process of demosaicking. [Gunturk, et.al., 2005 and Menon, 2011]. Demosaicking is the process of translating the Bayer’s array of primary color values into a final image which contains the full color information at each pixel location. This process uses the interpolation technique to determine the missing color values from the obtainedimage. Basically, Interpolation is defined as the process of estimating the unknown values from a given set of known values.[Kimmel, 1999]. The reconstructed image is typically accurate in uniform-colored areas, but has a loss of resolute and has edge artifacts .In order to avoid these problems, we use various interpolation techniques. The aim of a demosaicking algorithm is to reconstruct a full color image from the spatially under sampled color channels output from the CFA. The algorithm should have the following such as Avoidance of the introduction of false color artifacts, such as chromatic aliases, zippering (abrupt unnatural changes of intensity over a number of neighboring pixels) and purple fringing, Maximum preservation of the resolution, Low computational complexity for fast processing or efficient in-camera hardware implementation, Amenability to analysis for accurate noise reduction.



(a)



(b)

Figure 1: Digital camera system (a) a three sensor device (b) a single sensor device

A Bayer filter mosaic is a color filter array (CFA) for arranging RGB color filters on a square grid of photosensors. Its particular arrangement of color filters is used in most single chip digital image sensors used in digital cameras, camcorders, and scanners to create a color image. The filter pattern is 50% green, 25% red and 25% blue, hence is also called RGBG, GRGB, or RGGB. Bayer Array has many green pixels because the human eye is more sensitive to green than two other two colors. It gives information about the intensity of light. Recently,

[1]Corresponding author

a new demosaicing approach is proposed, called the residual interpolation (RI) [Kiku et.al., 2013].

Instead of conducting interpolation on the CD fields, the RI-based algorithm performs interpolation on the so-called residual fields, whereas residual is defined as the difference yielded between the initially-acquired color-component value (i.e., the ground truth) and its estimated value obtained by applying the guided filter [He et.al., 2013]. A single image sensor with a color filter array (CFA) is widely used in current color digital cameras, where only one pixel value among RGB values is recorded at each pixel [Lukac, 2008]. The other two missing pixel values must be generated by an interpolation process, which is typically called a demosaicking process [Bayer, 1976 and Li et.al., 2008]. The demosaicking process plays a crucial role in acquiring high-quality color images. The most popular and widely used CFA is the Bayer CFA [Menon and Calvagno, 2011]

The rest of this paper is organized as follows. Section II presents our basic observation for the minimized residual interpolation accuracy with respect to the Laplacian energy. Section III explains the experimental results of our algorithm of our proposed Residual Interpolation. Finally, Section IV concludes the paper.

PROPOSED MINIMIZED-LAPLACIAN RESIDUAL INTERPOLATION

Outline

We first introduce the basic processing pipeline of the proposed MLRI by using the interpolation of the R pixel values as an example, we compare the proposed MLRI with the standard color difference interpolation. The interpolation process of the R pixel values by using the proposed MLRI is shown in the Fig. 2. The G image is interpolated First, which is same as the color difference interpolation. After that, the tentative estimate of the R image is generated by using the guided filter and this paper this techniqueis called as guided upsampling. Then, we find the residuals between the observed and the tentatively estimated R pixel values at the R pixel locations. The tentative estimate of the R image is generated by minimizing the Laplacian energies of the residuals. After that, we interpolate the residuals instead of the color differences. Finally, the tentative estimate of the R image is added to the interpolated residual image to acquire the interpolated R image. We generate the tentative estimate of the R image by upsampling the observed R pixel values by using the guided Filter. The guided filter can exactly upsample input data by using a given guide image. This image is used as a reference to exploit image structures. The GBTF algorithm consists of three steps for interpolation process of the G pixel values:(i) In the horizontal and vertical directions the Hamilton and Adams' interpolation formula is used in order to estimate the G pixel values at the R and B pixels and the R or B pixel values at the G pixels. With the help of this, the horizontally and vertically estimated R, G, and B pixel values are generated. (ii) At each pixel, the horizontal and vertical color differences (G-R or G-B) are estimated. Then, the horizontal and vertical color differences are smoothed and combined into the final color difference estimate. (iii) Adding the observed R or B pixel values to the final color estimate the G pixel values at the R and B pixels are calculated.

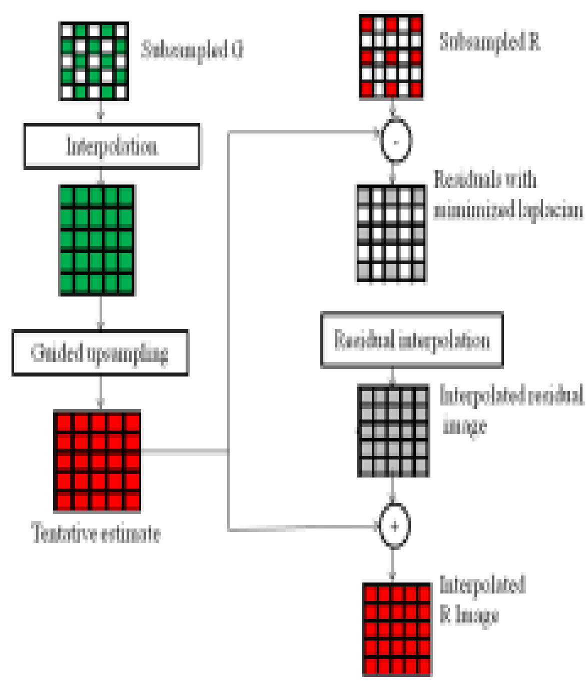


Figure 2: Overview of interpolation process of R pixel values

The horizontal and vertical color differences (G-R or G-B) are calculated at each pixel. The horizontal and vertical color differences are smoothed and combined into the final color difference estimate. The G pixel values at the R and B pixels are interpolated by adding the observed R or B pixel values to the final color estimate. The Hamilton and Adams interpolation formula for the R pixel value in the horizontal direction can be expressed as:

$$\check{R}^{H}_{i,j}=(R_{i,j-1}\ R_{i,j+1}+R_{i,j-1})/2+(2*G_{i,j}-G_{i,j+2}-G_{i,j-2})/4, \quad (1)$$

where the suffix i; j represents the target pixel, $\check{R}^{H}_{i,j}$

is the horizontally estimated R pixel value at the G pixel.

This interpolation formula can be interpreted as the linear color difference interpolation as:

$$\check{R}^{H}_{i,j}-G_{i,j}=(R_{i,j+1}-G^{H}_{i,j+1})+(R_{i,j-1}-G^{H}_{i,j-1})/2/2 \quad (2)$$

Where G^H is the horizontally estimated G pixel value at the R pixel calculated as:

$$G^{H}_{i,j-1}=(G_{i,j}+G_{i,j-2})/2$$

$$G^{H}_{i,j+1}=(G_{i,j+2}+G_{i,j})/2 \quad (3)$$

EXPERIMENTAL RESULTS

The proposed work is tested using the 24 Kodak images and are used to test performance quality of the proposed demosaicing algorithm. The proposed algorithm is compared with some of the existing algorithm. Three existing algorithm such as Adaptive homogeneity-directed demosaicing algorithm [Hirakawa and Parks, 2005], Color demosaicking via directional linear minimum mean square-error estimation [Zhang and Wu, 2005], Gradient based threshold free CFA interpolation [Pekkucuksen and Altunbasak, 2010], are used to compare the performance of the proposed algorithm. The performance is compared with their CPSNR values. The comparison table of the 24 Kodak image with different algorithm is shown in table I. The performance of the proposed algorithm is compared to the existing algorithms.

In demosaicing the quality of the image is measured using Color Mean Squared Error (CMSE), Color Peak Signal-to- Noise Ratio (CPSNR). Color mean square error value is calculated to determine the CPSNR value. It takes the squared difference between the original image and the reconstructed image. CMSE and CPSNR are very simple techniques. CMSE involves first calculating the squared difference between the reference image and demosaiced image at each pixel and for each color channel. These are then summed and divided by three times the area of the image.”

CPSNR is calculated using the CMSE (color mean square error)and the equation are shown below:

$$\mathrm{CMSE}=\frac{\sum_{i=R,G,B}\sum_{J=1}^{W}\sum_{k=1}^{H}(I_{i,j,k}-\bar{I}_{i,j,k})2}{3WH} \quad (4)$$

$$\mathrm{CPSNR}=10\log\left(\frac{255^2}{\mathrm{CMSE}}\right) \quad (5)$$

Where I is the reference Image and W and H represents width and height of the Image.

Figure 3: Kodak and IMAX data sets

Table 1: PSNR and CPSNR performances of Kodak data sets

Kodak Data sets	Red	Green	Blue	CPSNR
1	43.20	46.73	43.40	44.17
2	39.72	41.63	39.09	39.09
3	43.21	45.66	42.40	43.53
4	34.93	37.47	34.84	35.59
5	43.03	45.05	41.92	43.15
6	39.14	41.34	39.35	39.84
7	43.30	45.07	42.49	43.49
8	40.28	42.11	39.46	40.48
9	41.91	43.25	40.16	41.58
10	38.69	40.48	37.94	38.91
11	39.21	41.31	38.56	39.55
12	36.15	37.51	34.48	35.87
AVERAGE	**40.23**	**42.30**	**39.51**	**40.44**

Table 2: PSNR and CPSNR performance of CDM datasets

MCM Data Sets	R	G	B	CPSNR
1	29.58	32.78	27.42	29.41
2	34.97	39.63	33.48	35.35
3	34.35	36.91	32.14	34.04
4	38.66	41.84	35.62	38.00
5	37.49	38.36	31.21	34.43
6	39.68	42.59	36.36	38.82
7	37.15	38.73	35.74	37.04
8	34.86	41.25	38.05	37.30
9	34.63	41.92	36.72	36.84
10	38.30	42.64	37.81	39.11
11	39.30	42.26	39.61	40.20
12	40.54	42.37	37.82	39.84
13	42.77	45.33	37.56	40.66
14	39.64	43.27	36.71	39.10
15	37.20	42.91	39.39	39.25
16	34.76	35.54	36.06	35.42
17	31.87	37.97	32.00	33.18
18	35.14	37.70	36.77	36.41
Average	**36.71**	**40.22**	**35.58**	**36.91**

Table 3: The average PSNRs and CPSNRs of IMAX 18 images

	PSNR			CPSNR
	R	G	B	
AHD	33.00	36.98	32.16	33.49
DLMMSE	34.03	37.99	33.04	34.47
GBTF	33.48	36.59	32.71	33.89
LPA	34.36	37.88	33.30	34..72
LDI-NAT	36.28	39.76	34.39	36.20
PROPOSED	**36.71**	**40.22**	**35.58**	**36.91**

Table 4: The average PSNRs and CPSNRs of KODAK 12 images

	PSNR			CPSNR
	R	G	B	
AHD	38.81	40.84	38.42	39.22
DLMMSE	41.17	43.94	40.51	41.62
GBTF	**41.71**	**44.85**	**41.01**	**42.21**
LPA	41.66	44.46	41.00	42.12
LDI-NAT	38.30	40.49	37.94	38.77
PROPOSED	40.23	42.30	39.51	40.44

Table 5: The total average PSNRs and CPSNRs of IMAX and Kodak images

	PSNR			CPSNR
	R	G	B	
AHD	35.32	38.52	34.66	35.78
DLMMSE	36.89	40.37	36.02	37.33
GBTF	36.77	39.89	36.03	37.22
LPA	37.28	40.51	36.38	37.68
LDI-NAT	37.09	40.05	35.81	37.23
PROPOSED	**38.12**	**41.05**	**37.15**	**38.32**

The PSNR and CPSNR performances of Kodak datasets are shown in Table1. The PSNR and CPSNR performances of IMAX datasets are shown in Table 2. The average CPSNR of the proposed algorithm on the Kodak dataset is lower than the GBTF, LPA and DLMMSE algorithms. It is remarkable that several algorithms only work well for one dataset, but do not for another dataset. For example, the LDI-NAT algorithm only works well for the IMAX dataset, in contrast, the GBTF algorithm only works well for the Kodak dataset. The table 3and 5 shows that the CPSNR and PSNR value of Existing interpolation is less when compare to proposed method The alternative projection method used transform only for red and blue channel, so the CPSNR and PSNR value is less when compare to proposed method. The proposed method give better image quality when compare to above mentioned algorithm, because directional color difference and gradient based method is used for green channel interpolation and the estimated green plane is used for red and blue plane interpolation. The proposed algorithm outperforms all the state-of-the-art algorithms in terms of the total average PSNRs and CPSNR

CONCLUSION

The proposed algorithm is an alternative to widely used color difference interpolation for color image demosaicking. The interpolation accuracy is improved by reducing the Laplacian energy of the image to be interpolated. Based on this observation, the proposed Minimized Laplacian Residual Interpolation (MLRI) performs interpolation in the residual domain with minimized Laplacian energy, where the residuals are differences between the observed and the tentatively estimated pixel values. The tentative pixel value is estimated by minimizing the Laplacian energy of the residuals by guided upsampling. Experimental results reveal that our proposed demosaicking algorithm using MLRI provides results with reduced color artifacts and increased color peak to signal noise ratio (CPSNR) values for IMAX datasets and Kodak datasets.

In future, the proposed demosaicking algorithm and the super resolution algorithm are combined to make a high resolution image with high degree of accuracy.

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