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Low Complexity Demosaicing Directly Producing YCbCr 4:1:1 Output

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Abstract: Demosaicing is a process of obtaining a full color image by interpolating the missing colors of an image captured from a digital still and video camera that use a single-sensor array. To compress the demosaiced images, conversion from RGB to YCbCr format is required. This is a method in which a non adaptive interpolation is used to reduce the complexity of the technique which directly produces YCbCr format from mosaic image, i.e., raw single sensor array digital camera image. During computation of chrominance samples, the green channel is omitted to reduce the complexity because the green channel has minimal impact on the quality of chrominance channels. This technique saves considerable computational complexity by avoiding the need for performing demosaicing in RGB space and then converting from RGB to YCbCr 4:1:1. As compared with the recent demosaicing algorithms, the proposed algorithm produces the best demosaicing performance in YCbCr format with respect to mean square error. This approach outperforms other methods in-terms of no of operations per pixel.

INTRODUCTION

Digital cameras represent one of the most popular segments of consumer electronics product market and it has benefited immensely from digitization of consumer electronics products. The resolutions of digital cameras are becoming higher and higher but the principle is still the same. These cameras are based on a Charge Coupled Device (CCD) array and each sensor on the CCD captures only one sample of the color spectrum. By breaking up the sensor into a variety of red, blue and green pixels, it is possible to get enough information in the general vicinity of each sensor to make very accurate guesses about the true color at that location. This process of looking at the other pixels in the neighborhood of a sensor and making an educated guess is called demosaicing (Newlin and Monie, 2013).

The advantages of this method are that only one sensor is required for each pixel and all the color information (red, green and blue) is recorded at the same moment. That means the camera can be smaller, cheaper and useful in a wider variety of situations. The raw output from a sensor with a Bayer filter is a mosaic of red, green and blue pixels of different intensity.

Usually, demosaicing process is used to reconstruct the RGB color image from mosaic image which resulted from single-sensor color camera. Further to compress the demosaiced images, conversion from RGB to YCbCr format is required. Still image compression standards such as JPEG, JPEG2000 and video compression standards such as MPEG (Richardson, 2003), H.26x use the YCbCr format for compression.

This low complexity demosaicing directly producing YCbCr 4:1:1output technique saves considerable computational complexity by avoiding the need for performing demosaicing in RGB space and then converting from RGB to YCbCr 4:1:1. In this method, to reduce the complexity, a non-adaptive green channel interpolation is used. Computation of directional gradients and identification of edge direction by comparing directional gradients are avoided in this non-adaptive interpolation. So, the complexity of algorithm is heavily reduced by the non-adaptive algorithm. The complexity of this algorithm is reduced again by avoiding the role of green channel during low pass filtering and down sampling of chrominance, since, the green channel has minimal impact on chrominance.

MATERIALS AND METHODS

Luminance is more sensitive than chrominance for the human visual system. So, the chrominance Cb and Cr channels can be down-sampled by a factor of two in both the horizontal and vertical directions without loss of perceived image quality. In YCbCr 4:1:1 format, for every 2x2 mosaiced sensor image, there is one Cb, one Cr and four Y samples.

In this method, the low pass filtered green channel is omitted during down-sampling of chrominance samples to reduce the complexity in operation because the green channel has minimal impact on the quality of chrominance channels. The flow diagram of the proposed demosaicing directly producing YCbCr 4:1:1output is shown in Fig. 1.

Interpolation of green plane: To reconstruct a full-color image from CFA samples, the two missed color values at each pixel are to be estimated from neighboring CFA samples. The green plane is estimated first and the other color planes are estimated based on the interpolated value of the green plane. A non-adaptive green channel interpolation exploiting spatial correlation is used in this method to reduce the complexity of the algorithm. The green component at red pixel position is estimated using the bilinear interpolation of green plane and the difference in chrominance component at the pixel position (red) with the neighborhood chrominance pixels as in Eq. 1:

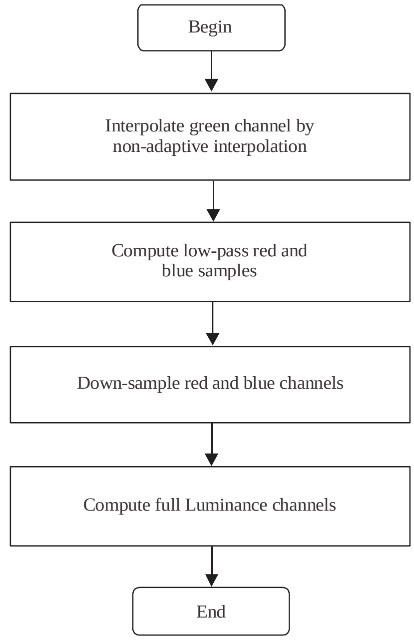

Fig. 1: Flow diagram of the proposed method

$$G_{i,j} = \left(G_{i,j-1}+G_{i,j+1}+G_{i-1,j}+G_{i+1,j}\right)/4+\left(R_{i,j}-R_{i-2,j}\right)/8+ \left(R_{i,j}-R_{i+2,j}\right)/8+\left(R_{i,j}-R_{i,j-2}\right)/8+\left(R_{i,j-}R_{i,j+2}\right)/8 \tag{1}$$

Similarly, the green component at blue pixel is estimated using the bilinear interpolation of green plane and the difference in blue component at the pixel position with the neighborhood blue pixels.

Low-pass filtering red and blue samples: If the green channel is fully populated at once, then the chrominance channels are interpolated in the demosaicing techniques that produce RGB image. The low-pass filtering can be performed in the YCbCr color space as in RGB color space since the conversion from RGB to YCbCr is a linear process. To deliver the demosaiced image in YCbCr space model, the interpolation on the color differences (G-R) and (G-B) is performed. The interpolation on the color differences (G-R) and (G-B) is more suitable than the interpolation on red and blue because the color differences are much smoother than individual red and blue planes.

To directly compute down-sampled chrominance components, the low-pass red and blue samples are estimated as in Eq. 2:

$$Rlp_{i,j} = \left(\left(R_{i,j-1}+R_{i,j+1}\right)-\left(G_{i,j-1}+G_{i,j+1}\right)\right)/4+\left(R_{i-2,j-1}-G_{i-2,j-1}+ R_{i-2,j+1}-G_{i-2,j+1}+R_{i+2,j-1}-G_{i+2,j-1}+R_{i+2,j+1}-G_{i+2,j+1}\right)/8\, Blp_{i,j} = \left(\left(B_{i-1,j}+B_{i+1,j}\right)-\left(G_{i-1,j+}G_{i+1,j}\right)\right)/4+\left(B_{i-1,j-2}-G_{i-1,j-2}+B_{i-1,j+2}- G_{i-1,j+2}+B_{i+1,j-2}-G_{i+1,j-2}+B_{i+1,j+2}-G_{i+1,j+2}\right)/8 \tag{2}$$

Down-sampling of chrominance channels: While calculating the chrominance samples, green channel should also be considered for low pass filtering along with red and blue planes. Since, the green channel has minimal impact on the quality of chrominance channels, green channel is omitted during low pass filtering of chrominance samples to reduce the complexity in operation. Chrominance channels can be calculated using low-pass, down-sampled red and blue channels as in Eq. 3:

$$\begin{aligned} Cb_{i,j} &= -0.1687\ Rlp_{i,j} + 0.5\ Blp_{i,j} \\ Cr_{i,j} &= 0.5\ Rlp_{i,j} - 0.0813\ Blp_{i,j} \\ Cr_{i+1,j} &= \left(Cr_{i,j} + Cr_{i+2,j}\right)/2 \end{aligned} \quad (3)$$

Calculation of full luminance channels: To generate the full luminance channel, both the green plane and down sampled chrominance values are used. The luminance value at green location having both red and blue samples is directly calculated as in Eq. 4:

$$Y_{i,j} = 0.299\ Rlp_{i,j} + G_{i,j} + 0.114\ Blp_{i,j} \quad (4)$$

At red sample location, blue sample value can be determined using bilinear interpolation. The luminance value at red sample location is calculated as in Eq. 5:

$$Y_{i,j+1} = 0.3375R_{i,j+1} + 0.6625G_{i,j+1} + 0.228Cb_{i,j+1} \quad (5)$$

where, $Cb_{i,j+1} = (Cb_{i,j} + Cb_{i,j+2})/2$. At blue sample location, red sample value can be determined using bilinear interpolation. The luminance value at blue sample location is calculated as in Eq. 6:

$$Y_{i+1,j} = 0.1626B_{i+1,j} + 0.8374G_{i+1,j} + 0.598Cr_{i+1,j} \quad (6)$$

where $Cr_{i+1,\ j} = (Cr_{I,\ j} + Cr_{\ i+2,\ j})/2$. At the pixel location having only green samples, the luminance value is calculated as in Eq. 7:

$$Y_{i+1,j+1} = 0.1785\left(Cr_{i,j} + Cr_{i+2,j} + Cr_{i,j+2} + Cr_{i+2,j+2}\right) + G_{i+1,j+1} + 0.086\ (Cb_{i,j} + Cb_{i+2,j} + Cb_{i,j+2} + Cb_{i+2,j+2}) \quad (7)$$

Thus, this algorithm presents a cost effective method that directly produces YCbCr 4:1:1 output. This method saves considerable computational complexity by avoiding the need for performing demosaicing in RGB space and then converting from RGB to YCbCr 4:1:1. Both the non adaptive interpolation on green channel and the computation of chrominance by avoiding role of green component reduced the complexity of this algorithm.

RESULTS AND DISCUSSION

The performance in terms of mean squared error can be seen in Table 1-3 for proposed and various

Table 1: MSE performance comparison of different demosaicing techniques with proposed for luminance Y

Image/method	Sakamoto *et al*. (1998)	Hamilton and Adams (1997)	Pei and Tam (2003)	Doutre *et al*. (2007)	Proposed
1	71.63	16.37	16.45	11.75	**10.64**
2	15.21	4.42	4.84	**3.91**	3.97
3	11.70	2.95	2.97	2.41	**2.36**
4	13.52	4.39	3.80	3.64	**3.62**
5	71.30	11.59	12.71	9.49	**8.85**
6	51.18	11.64	11.89	8.44	**7.62**
7	14.26	2.84	3.73	2.64	**2.47**
8	127.38	21.73	31.78	16.91	**15.64**
9	17.62	3.45	4.55	2.70	**2.45**
10	18.04	3.55	3.78	2.85	**2.49**
11	38.03	9.04	9.31	7.05	**6.25**
12	13.52	3.03	3.68	2.63	**2.32**
13	132.77	39.37	28.98	28.58	25.77
14	38.92	9.19	9.93	**8.02**	8.22
15	16.41	6.04	**4.68**	4.87	4.82
16	22.45	5.24	5.90	3.88	**3.46**
17	19.78	5.12	4.60	4.00	**3.66**
18	50.95	14.53	11.62	11.02	**10.72**
19	46.14	6.89	11.89	5.24	**4.94**
20	21.63	4.90	5.14	3.74	**3.61**
21	44.07	10.79	10.31	7.85	**7.31**
22	27.93	7.75	7.59	6.00	**5.96**
23	9.82	2.27	2.74	**2.12**	2.14
24	66.55	20.42	**15.04**	16.79	15.89
Average	40.03	9.48	9.50	7.36	**6.88**

Bold values are significant

Table 2: MSE performance comparison of different demosaicing techniques with proposed for Cb chrominance

Image/method	Sakamoto *et al*. (1998)	Hamilton and Adams (1997)	Pei and Tam (2003)	Doutre *et al*. (2007)	Proposed
1	20.42	6.46	7.52	3.51	**3.05**
2	4.37	2.05	2.44	1.84	**1.55**
3	3.44	1.85	1.89	**1.66**	1.87
4	2.94	1.75	1.61	1.14	**0.83**
5	12.33	5.32	5.50	4.51	**4.01**
6	15.71	4.82	5.63	3.01	**2.76**
7	3.35	1.79	2.22	1.88	**1.52**
8	40.56	9.31	17.38	6.00	**5.50**
9	4.94	1.95	2.55	1.88	**1.42**
10	4.57	1.79	1.96	1.57	**1.02**
11	10.64	3.63	4.26	2.38	**1.86**
12	4.13	1.51	1.99	1.42	**1.04**
13	34.29	15.67	12.74	8.38	**7.21**
14	10.92	5.66	6.46	6.00	**5.30**
15	4.09	2.83	2.09	1.71	**1.41**
16	8.00	2.41	3.15	1.76	**1.36**
17	4.32	2.34	2.21	1.93	**1.25**
18	12.71	6.08	5.46	**4.35**	4.96
19	13.65	3.26	5.97	2.68	**2.09**
20	5.61	2.64	2.94	2.37	**2.17**
21	12.62	4.78	5.02	3.07	**2.58**
22	7.96	3.95	4.30	3.60	**3.07**
23	2.22	**1.36**	1.68	1.85	3.18
24	19.50	10.21	8.28	7.25	6.27
Average	10.97	4.31	4.80	3.16	**2.80**

Table 3: MSE performance comparison of different demosaicing techniques with proposed for Cr

Image/method	Sakamoto *et al*. (1998)	Hamilton and Adams (1997)	Pei and Tam (2003)	Doutre *et al*. (2007)	Proposed
1	16.45	4.75	7.59	3.78	**3.37**
2	6.69	4.07	5.64	**4.57**	4.61
3	2.39	**1.50**	2.45	1.63	1.72
4	4.96	3.78	4.71	4.20	**3.11**
5	13.78	4.08	8.07	**3.94**	4.19
6	8.32	3.44	5.45	2.74	**2.34**
7	3.65	**1.55**	2.81	1.68	1.60
8	61.39	7.66	19.68	6.46	**5.37**
9	5.31	1.51	2.80	1.41	**0.99**
10	4.08	1.52	2.46	1.47	**1.00**
11	10.26	3.56	5.69	3.40	**2.93**
12	3.49	1.60	2.43	1.62	**1.27**
13	21.63	9.04	9.87	6.10	**5.38**
14	10.50	**6.08**	9.38	7.18	7.02
15	6.86	5.13	5.55	5.11	**3.56**
16	3.01	1.66	2.64	1.40	**1.04**
17	4.63	1.60	2.28	1.34	**0.88**
18	11.35	4.71	6.15	4.06	**3.67**
19	15.04	2.45	6.81	2.32	**1.83**
20	5.76	1.69	3.24	1.49	**1.18**
21	8.46	3.15	4.91	2.48	**2.29**
22	9.69	3.89	5.17	3.78	**3.08**
23	2.64	**1.64**	2.87	1.93	2.20
24	12.62	6.04	6.94	5.52	4.60
Average	10.54	3.59	5.65	3.32	**2.88**

Bold values are significant

other demosaicing algorithms such as demosaicing in YUV color space, bilinear interpolation (Sakamoto *et al*., 1998), effective color interpolation (Pei and Tam, 2003), adaptive color plane interpolation (Hamilton and Adams, 1997) and fast demosaicing directly producing YCbCr output (Doutre *et al*., 2007).

From Table 4 it is clear that the complexity of our algorithm is much better than the other algorithm in terms of the number of operation done on each pixels this is because there is nooperation for red and blue interpolation and YCbCr conversion.

Table 4: Complexity analysis of different demosaicing techniques with proposed (in operations per pixels)

Methods	Operation	Green interpolation	Red and blue interpolation	RGB to YCbCr conversion	Filtering and down sampling Cr	Filtering and down sampling Cb	Generation of full lumina-nce	Total
Sakamoto *et al*.	add	1.5	2	6	2	1	-	12.5
(1998)	shift	0.5	1	-	2	1	-	4.5
	abs	-	-	-	-	-	-	-
	com	-	-	-	-	-	-	-
	mul	-	-	9	-	-	-	9
Pei and Tam	add	4	8	6	2	1	-	21
(2003)	shift	1.5	1.5	-	2	1	-	6
	abs	-	-	-	-	-	-	-
	com	-	-	-	-	-	-	-
	mul	-	-	9	-	-	-	9
Hamilton and	add	8	8	6	2	1	-	25
Adams (1997)	shift	2.5	2	-	2	1	-	7.5
	abs	2	2	-	-	-	-	4
	com	1	1	-	-	-	-	2
	mul	-	-	9	-	-	-	9
Doutre *et al*.	add	4	8	-	4.25	4.25	3.5	24
(2007)	shift	1.5	1.5	-	0.75	0.75	-	4.5
	abs	-	-	-	-	-	-	-
	com	-	-	-	-	-	-	-
	mul	-	-	-	0.5	0.5	2.5	**3.5**
Proposed	add	4	-	-	4.25	4.25	3.5	**16**
	shift	1	-	-	0.75	0.75	-	**2.5**
	abs	-	-	-	-	-	-	-
	com	-	-	-	-	-	-	-
	mul	-	-	-	0.5	0.5	2.5	**3.5**

Bold values are significant

CONCLUSION

While comparing with any directly producing YCbCr format or fast demosaicing techniques through RGB color space, this cost effective demosaicing directly producing YCbCr 4:1:1 output technique produces considerable quality output on least computational complexity. Experimental results demonstrate that this low complexity demosaicing directly producing YCbCr 4:2:0 output technique can achieve considerable quality output at least computational complexity.

REFERENCES

Doutre, C., P. Nasiopoulos and K.N. Plataniotis, 2007. A fast demosaicking method directly producing YCbCr 4:2:0 output. IEEE Trans. Consumer Elect., 53: 499-505.

Hamilton, Jr. J.F. and J.E. Adams, 1997. Adaptive color plan interpolation in single sensor color electronic camera. United States Patent 5,629,734, May 13, 1997.

Newlin, D.R. and E.C. Monie, 2013. Edge sensing demosaicing using adaptive weighted interpolation. Am. J. Applied Sci., 10: 418-425.

Pei, S.C. and I.K. Tam, 2003. Effective color interpolation in CCD color filter arrays using signal correlation. IEEE Trans. Circuits Syst. Video Technol., 13: 503-513.

Richardson, I.E.G., 2003. H.264 and MPEG-4 Video Compression. John Wiley and Sons, New York, ISBN: 0-470-84837-5.

Sakamoto, T., C. Nakanishi and T. Hase, 1998. Software pixel interpolation for digital still cameras suitable for a 32-bit MCU. IEEE Trans. Consumer Elect., 44: 1342-1352.