A New Color Interpolation Algorithm for Bayer Pattern Digital Cameras Based on Green Components

Huaping Ma, Shuang Liu, Guanglu Wei, Zunlie Tang, Shangjian Zhang, and Yong Liu

1 Introduction

With the development of the digital technology, digital cameras are increasingly being applied to daily life. For the consideration of the size and cost, most digital cameras use a single-chip CCD image sensor with a color filter array (CFA) [1]. In order to restore full-color images, interpolation is required.

Because human eyes are more sensitive to luminance, the Green channel contributes the most to the luminance of an image. So, in the being widely used Bayer CFA pattern, the Green components are twice as much as Blue or Red. In view of this, the interpolation can be based on the Green channel [1].

In order to rebuild the Bayer image, a lot of color interpolation algorithms had been proposed. Such as Nearest Neighbor Replication [2], Bilinear Interpolation [3], Adapted color plane interpolation [4], and Edge sensing Interpolation [5].

Although Nearest Neighbor Replication and Bilinear interpolation are simple demosaicing method, and they can rebuild a good image in the smooth area, blur and many color artifacts are induced on the edge. Thus, gradient-based adaptation edge-directed interpolation was proposed in [6]; it can get a clear edge, but false color may appear on the whole image. Additionally, some advanced algorithms [7,8] can get a high image quality through simulation, but the realization of these algorithms is a big challenge for digital cameras.

For the consideration above, the new color interpolation algorithm based on Green component is introduced in the second section.

H. Ma • S. Liu (✉) • G. Wei • Z. Tang • S. Zhang • Y. Liu
University of Electronic Science and Technology of China, Chengdu,
Sichuan 610054, People's Republic of China
e-mail: shuangliu@uestc.edu.cn

S. Xing et al. (eds.), *Unifying Electrical Engineering and Electronics Engineering*, Lecture Notes in Electrical Engineering 238, DOI 10.1007/978-1-4614-4981-2_119,

2 Demosaicing Process

In view of the characteristic of the Bayer CFA Pattern (as shown in Fig. 1), the interpolation process can be divided into two main situations as discussed bellow.

2.1 The Reconstruction Process for the Central Component Is Red or Blue

In the Bayer CFA pattern, the overwhelming majority of the Red or Blue components are surrounded by Green component (as shown in Fig. 2a). So, the absolute difference value of Green channel will be used as the direction judgment for the interpolation. Firstly, horizontal gradient $\triangle H$ and vertical gradient $\triangle V$ and four complementary gradient H_L, H_R, V_U, V_D will be defined; T_R, T_G, T_B is the threshold of the Red, Green, Blue, respectively.

$$\begin{cases} \Delta V = abs(G_{12} - G_{32}) \\ \Delta H = abs(G_{21} - G_{23}) \\ H_L = abs(G_{22} - G_{21}) \\ H_R = abs(G_{22} - G_{23}) \\ V_U = abs(G_{22} - G_{12}) \\ V_D = abs(G_{22} - G_{32}) \end{cases} \tag{1}$$

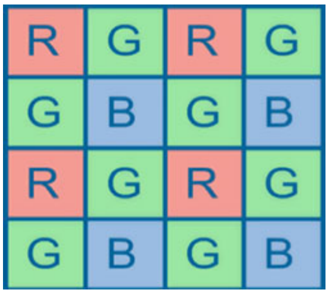

Fig. 1 Bayer color filter array pattern

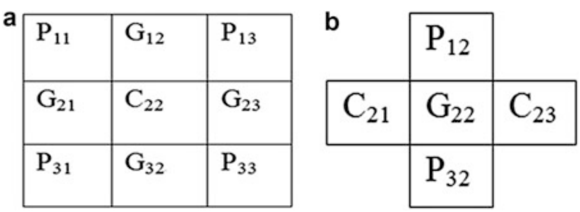

Fig. 2 (**a**) Green component surround the *Red* or *Blue*; (**b**) central component is *Green* component

When C_{22} is Blue component, the process of restoring Green component and Red component in C_{22} can be declared in detail below:

$$\begin{cases} \text{if } \Delta H - \Delta V > T_G, \text{then } G_{22} = \dfrac{G_{12}+G_{32}}{2} \begin{cases} \text{if } H_L - H_R > T_R, R_{22} = (R_{13}+R_{33})/2 \\ \text{if } H_R - H_L > T_R, R_{22} = (R_{11}+R_{31})/2 \\ \text{if } |H_R - H_L| \le T_R, R_{22} = (R_{11}+R_{13}+R_{31}+R_{33})/4 \end{cases} \\ \text{if } \Delta V - \Delta H > T_G, \text{then } G_{22} = \dfrac{G_{21}+G_{23}}{2} \begin{cases} \text{if } V_U - V_D > T_R, R_{22} = (R_{31}+R_{33})/2 \\ \text{if } V_D - V_U > T_R, R_{22} = (R_{11}+R_{13})/2 \\ \text{if } |V_D - V_U| \le T_R, R_{22} = (R_{11}+R_{13}+R_{31}+R_{33})/4 \end{cases} \\ \text{if } |\Delta V - \Delta H| \le T_G, G_{22} = \dfrac{G_{12}+G_{32}+G_{21}+G_{23}}{4}, R_{22} = (R_{11}+R_{13}+R_{31}+R_{33})/4 \end{cases} \tag{2}$$

When the component in the location C_{22} is Red, the process of reconstructing Green and Blue component can be completed through replacing R with B and T_R with T_B.

2.2 The Reconstruction Process When Central Component Is Green

The restoration of the Red and Blue components in the following situation (as shown in Fig. 2b) will be based on the restored Green component.

For example, if the C component is Red, the P component will be Blue. The defined four gradient H_L, H_R, V_U, V_D mentioned in Sect. 2.1 will be used as the judgment of the interpolation direction again. The procedure will be described in detail as follows:

$$\begin{cases} \begin{cases} \text{if } V_U - V_D > T_B, B_{22} = B_{32} \\ \text{if } V_D - V_U > T_B, B_{22} = B_{12} \\ \text{if } |V_D - V_U| \le T_B, B_{22} = (B_{32}+B_{12})/2 \end{cases} \\ \begin{cases} \text{if } H_L - H_R > T_R, R_{22} = R_{23} \\ \text{if } H_R - H_L > T_R, R_{22} = R_{21} \\ \text{if } |H_R - H_L| \le T_R, R_{22} = (R_{21}+R_{23})/2 \end{cases} \end{cases} \tag{3}$$

Similarly, when the C component is Blue and the P component is Red, the reconstruction process can be completed through exchanging B and R, T_B, and T_R.

After the two steps above, the restoration of the whole image except the border has been completed. Generally, the border of an image can be ignored, so, the reconstruction of the border adopts Nearest Neighbor Replication method. After the restoration of the whole image, the quality of the interpolation will be evaluated and verified by the MATLAB simulation.

3 Experimental and Results

In the experiments, the method will be tested firstly. Then, the contrast will be carried out among Nearest Neighbor Replication, Bilinear Interpolation, and Edge sensing Interpolation method through peak signal-to-noise ratio (PSNR) and percentage of false color (FC%) [9].

$$\begin{cases} \underset{k=\mathrm{R,G,B}}{\mathrm{MSE}_k} = \dfrac{1}{\mathrm{WH}} \sum_{i=1}^{W} \sum_{i=1}^{H} (O_{i,j,k} - N_{i,j,k})^2 \\ \underset{k=\mathrm{R,G,B}}{\mathrm{PSNR}_k} = 10 \log \left(\dfrac{255^{\ 2}}{\mathrm{MSE}_k} \right) \\ \mathrm{FC}\% = \dfrac{100}{\mathrm{WH}} \mathrm{card}\{P_{i,j} | \max_{k=\mathrm{R,G,B}} (|O_{i,j,k} - N_{i,j,k}|) > T\} \end{cases} \tag{4}$$

In the formulas, W and H are the width and height of the image in pixels, O represents the original image, N represents restored new image, and T is the threshold value.

The images-printed circuit board and peppers will be chosen as test pictures; and when choosing $T_G = 40$, $T_R = 30$, $T_B = 30$, the improved method has achieved a better result. Then, the improved method with these parameters is compared with Nearest Neighbor Replication, Bilinear Interpolation, and Edge sensing Interpolation methods. In the experiment, $T = 30$ is chosen as the threshold of each color difference. The experiments results are shown as below. In Table 1, $\mathrm{PSNR_R}$, $\mathrm{PSNR_G}$, and $\mathrm{PSNR_B}$ is the peak signal-to-noise ratio of the Red, Green, and Blue channel, respectively.

From the tables and images (Figs. 3, 4, 5, and 6), the conclusions can be elicited: the Nearest Neighbor Replication and Bilinear Interpolation method can acquire a better quality in the smooth area but will bring in blur and zipper effect on edge; although the edge sensing interpolation can get a better quality on the edge, obviously, the false color on the whole image is so conspicuous. Relatively, the improved interpolation method can get a better quality not only in the smooth area but also on the edge.

Table 1 Performance comparison of printed circuit board and peppers

Image	Method	$\mathrm{PSNR_R}$	$\mathrm{PSNR_G}$	$\mathrm{PSNR_B}$	FC%
Printed circuit board	Nearest neighbor replication	76.3459	81.1182	76.4368	16.4112
	Bilinear interpolation	75.5348	79.8773	75.9198	15.5542
	Edge sensing interpolation	70.9870	84.8412	71.6465	21.4341
	The improved method	79.9503	81.4731	80.6315	10.6099
Peppers	Nearest neighbor replication	87.4322	92.3345	86.0054	1.6479
	Bilinear interpolation	93.9723	102.3504	92.5245	0.2101
	Edge sensing interpolation	87.0944	105.6705	69.1482	20.2738
	The improved method	95.9903	102.7284	96.6649	0.2574

Fig. 3 Printed circuit board images: (A0) Original image; (A1) Nearest Neighbor Replication method; (A2) Bilinear Interpolation method; (A3) Edge sensing Interpolation method; (A4) improved Interpolation method

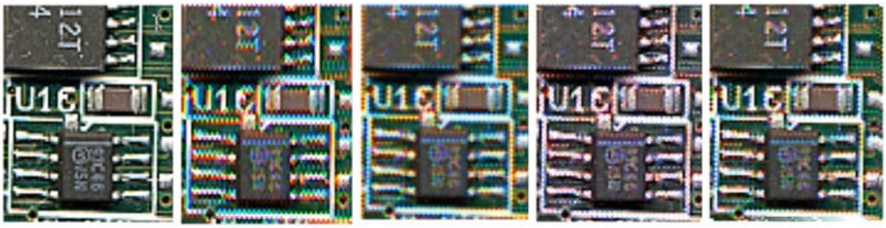

Fig. 4 The zoom in printed circuits board images of the left-up part: (a0) Original image; (a1) Nearest Neighbor Replication; (a2) Bilinear Interpolation; (a3) Edge sensing Interpolation; (a4) improved Interpolation method

Fig. 5 Peppers: (B0) Original image; (B1) Nearest Neighbor Replication method; (B2) Bilinear Interpolation method; (B3) Edge sensing Interpolation method; (B4) improved Interpolation method

Fig. 6 The zoom in peppers images of the *right*-up part: (B0) Original image; (B1) Nearest Neighbor Replication; (B2) Bilinear Interpolation; (B3) Edge sensing Interpolation; (B4) improved Interpolation method

4 Conclusion

The improved interpolation method is brought up based on the comprehensive consideration of the Nearest Neighbor Replication, Bilinear Interpolation, and Edge sensing Interpolation method. More attention is paid to the Green channel interpolation, as the Green channel is more important to human perception. The judgment of edge or smooth area is decided by the orientation gradient of Green channel. Additionally, in order to reduce the false color caused by the interpolation of different channel with different orientation judgments, the interpolation orientation of the Red and Blue will be based on the orientation gradient of Green channel.

Experimental results show that the proposed algorithm will not only reduce false color remarkably but also preserve the edge information better. Besides, the proposed algorithm does not involve complicated calculation; so it is easy to realize for digital cameras.

Acknowledgment This project was supported partly by the National Natural Science Foundation of China (61177035), Sichuan Provincial Science and Technology Support Project (2011GZ0003), CCD Research Center of China Electronics, and the Fundamental Research Funds for the Central Universities (ZYGX2009X010).

References

1. Rastislav L (2009) Single-sensor digital color imaging fundamentals. In: Single-sensor imaging methods and applications for digital cameras, 3rd edn. CRC, Boca Raton, FL
2. Adams JE (1995) Interactions between color plane interpolation and other image processing functions in electronic photography. Proc SPIE 2416:144–151
3. Parulski KA (1985) Color filters and processing alternatives for one-chip cameras. IEEE Transact Electron Dev 32:1381–1389
4. Lei H, Lei X, Huifang C (2010) A color Interpolation algorithm for Bayer pattern digital cameras based on green components and color difference space. IEEE Int Conf Prog Informat Comput 2:791–795
5. Xiaomeng W, Weisi L, Ping X (2005) Demosaicing with improved edge direction detection. IEEE Int Symp Circuits Syst 3:2048–2050
6. Orchard MT, Xi L (2001) New edge-directed interpolation. IEEE Transact Image Process 10:1521–1527
7. Alain H, Djemel Z (2011) An edge-sensing generic demosaicing algorithm with application to image resampling. IEEE Transact Image Process 20:3136–3150
8. Changxiong Z, Chunmei L, Yubo T, Chuanlin Z (2012) Image magnification method based on linear interpolation and wavelet and PDE. Lect Notes Comput Sci 6839:678–693
9. Yanqin Y, Olivier L, Luc D (2007) Quality evaluation of color demosaicing according to image resolution. IEEE Int Conf Single-Image Technol Internet-Based Syst 10:689–691