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Abstract

This paper presents a color interpolation algorithm for a single sensor color camera. The proposed algorithm is especially designed to solve the problem of pixel crosstalk among the pixels of different color channels. Interchannel cross-talk gives rise to blocking effects on the interpolated green plane, and also spreading of false colors into detailed structures. The proposed algorithm separates the green channel into two planes, one highly correlated with the red channel and the other with the blue channel. These separate planes are used for red and blue channel interpolation. Experiments conducted on McBeth color chart and natural images have shown that the proposed algorithm can eliminate or suppress blocking and color artifacts to produce better quality images.

Keywords

channel, green, camera, separation, sensor, method, single, interpolation, color

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METHOD OF COLOR INTERPOLATION IN A SINGLE SENSOR COLOR CAMERA USING GREEN CHANNEL SEPARATION

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ABSTRACT

This paper presents a color interpolation algorithm for a single sensor color camera. The proposed algorithm is especially designed to solve the problem of pixel cross-talk among the pixels of different color channels. Inter-channel cross-talk gives rise to blocking effects on the interpolated green plane, and also spreading of false colors into detailed structures. The proposed algorithm separates the green channel into two planes, one highly correlated with the red channel and the other with the blue channel. These separate planes are used for red and blue channel interpolation. Experiments conducted on McBeth color chart and natural images have shown that the proposed algorithm can eliminate or suppress blocking and color artifacts to produce better quality images.

1. INTRODUCTION

In single sensor electronic imaging systems, scene color is acquired by sub-sampling in three-color planes to capture color image data simultaneously for red, green and blue color components. Usually this is accomplished by placing a mosaic of red, green and blue filters over a 2D single sensor array. One way of arranging red, green and blue pixels to form a mosaic pattern (e.g. Bayer pattern) [1] is shown below:

R	Gr	R	Gr	R
Gb	B	Gb	B	Gb
R	Gr	R	Gr	R
Gb	B	Gb	B	Gb
R	Gr	R	Gr	R
Gb	B	Gb	B	Gb

Figure 1. RGB color filter array with Bayer pattern

One significant characteristic of this type of sensors is horizontally adjacent pixels appear to contribute significantly to the response of their neighbors. Some colors exhibit a large variation between Gb and Gr values depending on the dominance of B and R channel values. This discrepancy gives rise to a blocking effect on the color interpolated (and zoomed) image, and also spreading of false colors into detailed structures, due to R and B channel induced errors. Therefore, it is important to consider Gr/Gb discrepancy in subsequent processing.

Existing methods suggest modification of the captured green pixel values based on the adjacent pixel gradient classification [2]. However, this method can seriously alter the captured scene information by way of excessive smoothing. It is also undesirable to discard the captured green pixel information, which cannot be recovered at a later stage in processing. Another method proposed in literature comprise of applying a linear low pass filter on 5x5 pixel neighborhoods to eliminate the artifacts caused by the Gr/Gb difference [3]. However, this can excessively smooth the edges and thin image structures will be removed from the scene. In order to sharpen the image, a matching high pass filter will have to be used. However, this can adversely affect the noise performance of the system.

This paper presents a color interpolation algorithm that is specially designed to solve the problem of pixel cross-talk among the pixels of different color channels. Section 2 describes a method of constructing two different green planes without modifying or destroying the captured raw data. In Section 3, an interpolation scheme is described which uses highly correlated color planes to reconstruct the missing color and structure information. Experimental results on both standard and natural images are presented in Section 4, followed by some concluding remarks in Section 5.

2. GREEN CHANNEL SEPARATION

The proposed method employs a simple median filter among the 4 Gr values and the single Gb value (see Figure 2) to replace the existing Gb value. This creates a GR plane which favours the R channel. However, B channel favored image details can be lost in this process. It is important to preserve the captured pixel values, and also avoid unnecessary smoothing of image structures.Therefore, the process needs to be repeated with the roles of Gr and Gb swapped, creating separate GR and GB planes. It should be noted that in this process, the captured green pixel values will always be preserved in either GR plane or in the GB plane.
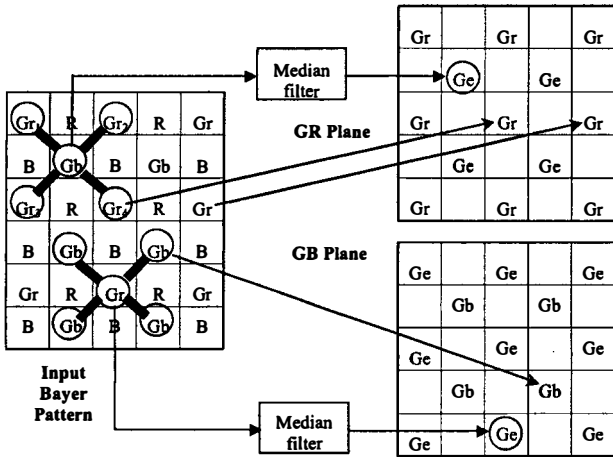

Figure 2. Separation of green channel into the GR and GB planes

3. INTERPOLATION ALGORITHM

There are two stages to the interpolation. Firstly, the missing green pixel values for the GR and GB planes are interpolated separately using a suitable interpolation algorithm, such as bilinear interpolation with second order Laplacian correction terms [4][5]. Secondly, the R and B pixels are interpolated. High correlation between R-GR and B-GB planes can be exploited to interpolate R and B channels to gain better noise suppression. Hence R is interpolated using the edges of GR and, B using GB. The color interpolated image is composed using the R, B and average values of GR and GB planes. Complete block diagram of the proposed interpolation scheme is shown in Figure 3.

Four green pixels are used to decide whether to interpolate in the horizontal direction or the vertical direction. It is undesirable to interpolate across an edge because this

would have an effect of smoothing the edge and losing image sharpness. Therefore, the gradient is checked between two vertical green pixels (Δv) and two horizontal green pixels (Δh) and the direction of the lowest gradient is selected.
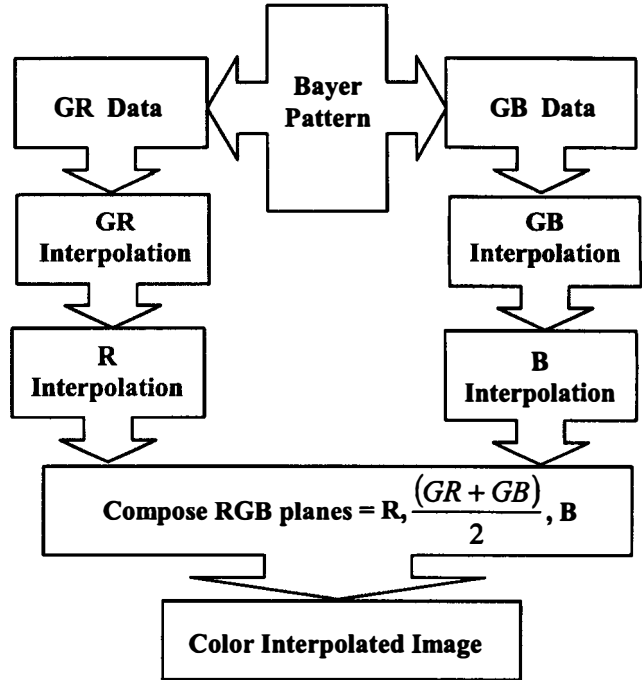

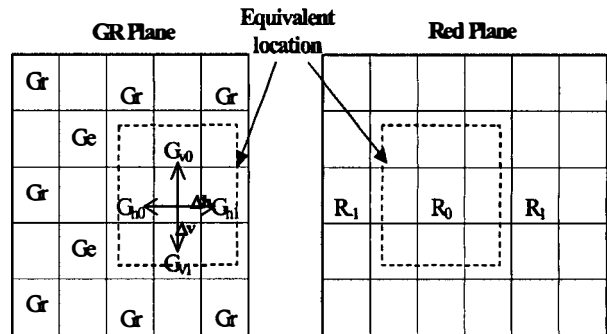Figure 3. Block diagram of the proposed color interpolation method

Figure 4. Calculation of the gradients for correlated planes

Figure 4 illustrates the process involved where $\Delta h < \Delta v$ so the horizontal direction has been chosen for interpolation. The average between the two selected green pixels is then calculated. However, the rate of change of the red channel can then be used to adjust the estimated Gr value. Then the three adjacent R values are used to calculate the

second Laplacian change. For example, if the horizontal direction is that of the least gradient, then the calculations are as follows:

$$G_{avg} = \frac{G_{ho} + G_{h1}}{2}$$

2nd order Laplacian gradient:

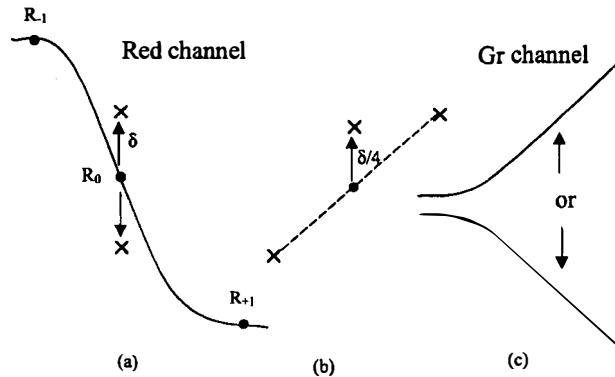$$\delta = (2R_0 - R_{-1} - R_{+1})\frac{1}{4}$$

Figure 5. Adjustment of GR-channel using red channel's second Laplacian gradient

Note that this gradient is weighted by a quarter to get the same relative shift when added to the Gr channel. However, before the correction can be made to the Gr channel, the direction of the change in gradient must be checked because, when the R channel gradient changes in one direction, the Gr channel can change in one of two directions (see Figure 5). The gradients of the red and green channels are multiplied together. If the sign is negative, then it means that the R and Gr gradients are changing in the opposite direction. If this is the case, then the second order Laplacian change is subtracted from the Gr average, otherwise it is added. This means that the interpolated value is improved in that it is not just the average between two Gr values, but takes into account the movement of the R values in this region.

It should be noted that if the row in the GR plane being examined is the equivalent of the blue channel row, these are the rows with the Ge values in them (see Figure 2). Then it is not possible to use a second order Laplacian gradient for a correction because there are no R values available (only B values), and these are less correlated with the Gr channel. In this case, although it is still important to calculate which is the direction of the lowest gradient, the interpolated Gr value is just taken to be the average between the chosen two Gr values.

This process is repeated for the GB plane using the blue pixels to calculate the adjustment to the average. The result of this process is two complete separate green planes – GR and GB. The interpolated GR and GB planes are then used to interpolate the R and B pixels respectively.

4. EXPERIMENTAL RESULTS

The following results are included to illustrate the capability of the proposed algorithm in terms of false color suppression, blocking artifact reduction and visible noise suppression, compared to the interpolation methods currently available. It should be noted that results are produced for the specific case of images captured via CMOS single sensor array with Bayer color filter array (CFA) [1]. No gamma correction or color correction has been applied to the processed images to illustrate the performance of the interpolation scheme only.

4.1 False Color Suppression

Two aspects of false color suppression were examined.
1. False colors appearing in smooth regions.
2. False colors appearing at thin and sharp edges of the structures.

Figure 6 illustrates a comparison between images processed using conventional and proposed color interpolation methods. The images zoomed x 2 for better visual comparison.
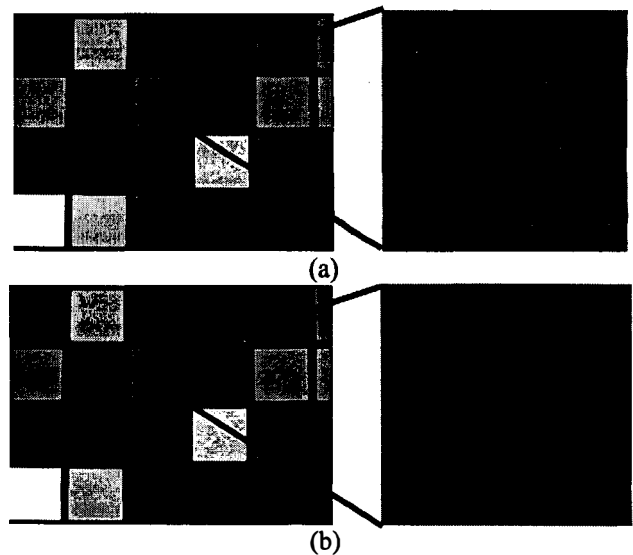

Figure 6. Visual comparison on false colors in a typical smooth region: (a) processed using bilinear interpolation with edge detection [5]; (b) processed using the proposed method.

Table 1 presents the standard deviation values for R, G, and B channels after interpolation, for the zoomed blocks indicated in Figure 6.

Color	(a)	(b)
R	6.06	4.80
G	8.97	4.50
B	5.72	5.46

Table 1. Standard deviation , for the zoomed blocks indicated in Figure 6, where (a) represents bilinear interpolation with edge detection and (b) is the proposed algorithm.

It was observed that on average there is **54%** reduction of false color values specially related to the green channel. This is a significant improvement since the human eyes are more sensitive to the green channel. The processed images of the McBeth color chart were used to derive the above conclusion. The false colors are detected using the deviation of each pixel value from the specified value in terms of separate red, green and blue channels. However, the false color reduction is not only limited to smooth regions. As shown in Figure 7, image areas with thin edges also benefit from the false color reduction by the proposed algorithm. Images are zoomed x 4 to clearly show the relevant regions indicated by red arrows.
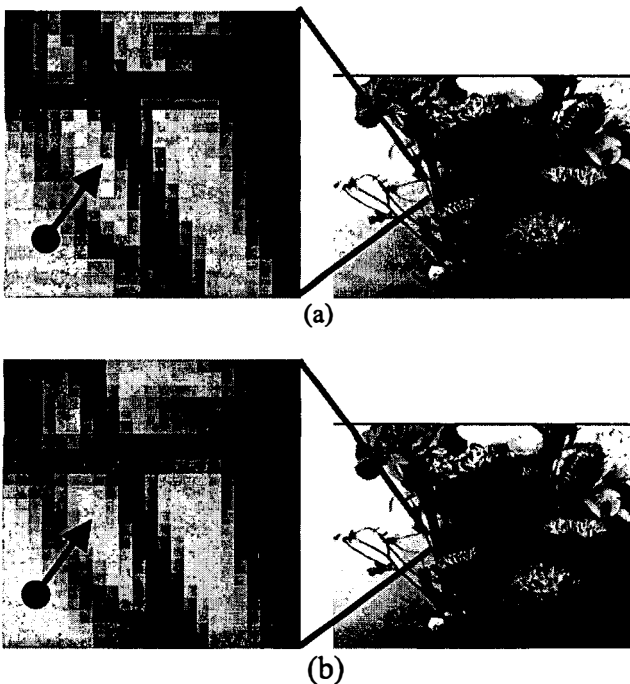

(a)

(b)

Figure 7. Visual comparison on false colors in a typical edge region with thin lines (zoom x 4): (a) processed using bilinear interpolation with edge detection [5]; (b) processed using the proposed method.

4.2 Blocking artifact reduction

Blocking artifacts due to Gr/Gb difference are clearly seen on a color where there is a significant difference in red and blue channel values. Figure 6 shows a typical example of this effect using a region extracted and zoomed (x 2) from the McBeth color chart.

4.3 Visible noise suppression

A quantitative comparison on SNR is performed using the McBeth color chart and the results are shown in Table 2. It is important to note that the images are not gamma corrected. It is observed from the results, that edges of the image structures are unaffected while the visual noise is significantly reduced.

Color	Noise reduction
R	0.7% - 3.78%
G	42.1% - 64.8%
B	1.75% - 3.17%

Table 2. Noise reduction of the proposed algorithm, compared to bilinear interpolation with edge detection.

5. CONCLUSIONS

A method of color interpolation in a single sensor color camera using green channel separation was presented. The proposed method of green channel separation can be implemented with any interpolation scheme utilizing edge sensing, pattern recognition or green plane correction terms to minimize blocking artifacts, false colors and visible noise, and for general improvement on the image quality.

6. REFERENCES

[1] U.S. Patent No. 3,971,065, Bayer, Eastman Kodak Company.
[2] U.S. Patent No. 5,596,367, Hamilton et al., Eastman Kodak Company.
[3] U.S. Patent No. 5,652,621, Adams et al., Eastman Kodak Company.
[4] Adams J.E. (jnr.), "Interactions between color plane interpolation and other image processing functions in electronic photography", SPIE Vol. 2416, pp. 144-151, 1995.
[5] Chang et al., "Color filter array recovery using a threshold-based variable number of gradients", SPIE Vol. 3650, pp. 36 – 43, 1999.