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# Camera Image Interpolation using Directional Information

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**Abstract.** Currently, most digital cameras use color filter array (CFA) instead of RGB camera which has beam splitters to capture image information. This paper proposes a camera image interpolation algorithm which uses directional information. Experimental results indicate that the presented method outperforms conventional benchmark method.

**Keywords:** color image, image interpolation, upsampling quality assessment, image quality enhancement.

## 1 Introduction

Multi-channel full color images are usually composed of three color channels as human eyes have three difference cones (red, green and blue) to obtain three colors [1-2]. Three difference sensors are requested to obtain the intensity of each color [3]. To reduce cost for camera manufacture, most cameras use a single sensor with color filter array (CFA). To restore full color image, demosaicking process is inevitable [4]. There are several CFA patterns in literature. However, Bayer pattern CFA is mainly used [5-6].

The demosaicking methods can be categorized into heuristic or non-heuristic, and they are classified into spatial domain and frequency domain. The adaptive color plane interpolation (ACPI) is one of popular method which gives good performance with less complexity [7-9]. In general, conventional methods were based on heuristic approach. A method based on bilinear interpolation is assumed to be the straightforward method, where the missing channel information is restored on each color channel separately and high frequency information is not able to be well remain in the output result. By using inter-channel information (correlation), some methods were proposed to try to retain edge detail or restrict hue transitions to give better color interpolation result. The ECI method is presented to obtain a full color image by reconstructing the color differences between G and R/B channels [7]. Based on ECI, some methods were presented recently. For example, a PCSD method eliminates color channel artifacts by pledging the same demosaicking direction for each color channel of a pixel [8]. This paper presents a method which is based on ACPI, but edge direction calculation process is more advance.

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This paper is organized as follows. Section 2 explains the proposed method. Experimental results and conclusion remarks are provided in Sections 3 and 4.

## 2 Proposed Method

In ACPI method, the green channel is restored first and then the other channels (red and blue) are reconstructed. The reason green channel is restored first is that green channel has twice more information as its sampling rate is twice than that of other two colors. When red or blue channel is restored, one may use restored green channel information.

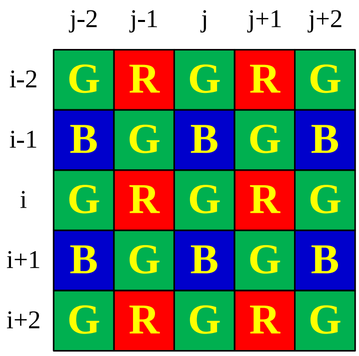



**Fig. 1.** 5-by-5 size Bayer pattern CFA.

Fig. 1 shows an example of 5-by-5 size Bayer pattern CFA. In this paper, horizontal and vertical gradients at (*i*,*j*) position, $H_{i,j}$ and $V_{i,j}$, are calculated as follows.

$$H_{i,j} = \left|G_{i,j-1} - G_{i,j+1}\right| + \lambda \left|R_{i,j-2} - 2R_{i,j} + R_{i,j+2}\right|. \tag{1}$$

$$V_{i,j} = \left|G_{i-1,j} - G_{i+1,j}\right| + \lambda \left|R_{i-2,j} - 2R_{i,j} + R_{i+2,j}\right|. \tag{2}$$

Where, $R_{i,j}$ and $G_{i,j}$ stand for the known red and green CFA information at location (*i*,*j*). Then, the missing green information, $mg_{i,j}$, is obtained as follows.

$$mg_{i,j}^{case1} = \frac{G_{i,j-1} + G_{i,j+1}}{2} - \gamma \frac{R_{i,j-2} - 2R_{i,j} + R_{i,j+2}}{4}. \tag{3}$$

$$mg_{i,j}^{case2} = \frac{G_{i-1,j} + G_{i+1,j}}{2} - \gamma \frac{R_{i-2,j} - 2R_{i,j} + R_{i+2,j}}{4}. \tag{4}$$

$$\begin{aligned} mg_{i,j}^{case3} = & \frac{G_{i,j-1} + G_{i,j+1}}{2} - \gamma \frac{R_{i,j-2} - 2R_{i,j} + R_{i,j+2}}{4} \\ & + \frac{G_{i-1,j} + G_{i+1,j}}{2} - \gamma \frac{R_{i-2,j} - 2R_{i,j} + R_{i+2,j}}{4} \end{aligned}. \tag{5}$$

There are three cases, *case*1, *case*2, and *case*3. Assume that the region is with *case*1 when $H_{i,j}$ is smaller than $V_{i,j}$. On the other hand, when $H_{i,j}$ is bigger than $V_{i,j}$, this region is determined as *case*2. Finally, a region is determined as *case*3 when $H_{i,j}$ and $V_{i,j}$ are identical. To improve correctness of the edge direction filter, parameters $\lambda$ and $\gamma$, which control the weights between color channels, are added. The red and blue pixels are restored as Eqs. (6-9),

$$R_{i,j} = G_{i,j} + \frac{R_{i,j-1} - G_{i,j-1} + R_{i,j+1} - G_{i,j+1}}{\mu} . \tag{6}$$

$$B_{i,j} = G_{i,j} + \frac{B_{i-1,j} - G_{i-1,j} + B_{i+1,j} - G_{i+1,j}}{\mu} . \tag{7}$$

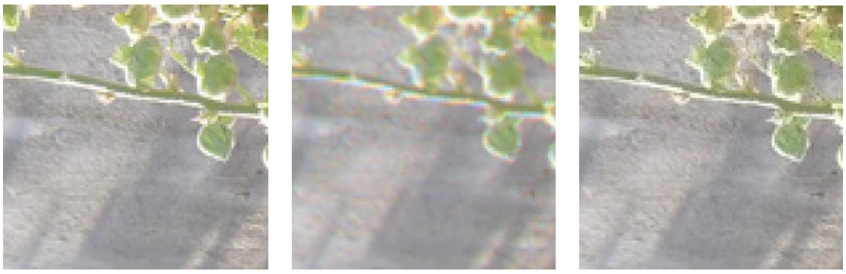
$$R_{i,j} = G_{i,j} + \frac{R_{i-1,j} - G_{i-1,j} + R_{i+1,j} - G_{i,+1j}}{\mu} . \tag{8}$$

$$B_{i,j} = G_{i,j} + \frac{B_{i,j-1} - G_{i,j-1} + B_{i,j+1} - G_{i,j+1}}{\mu} . \tag{9}$$

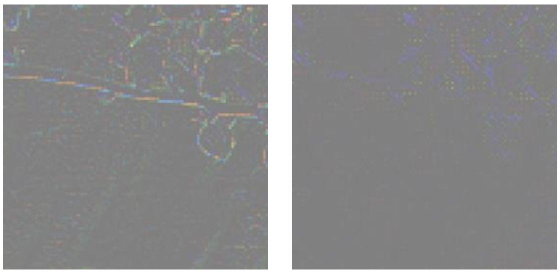
For red color interpolation at blue position (or blue color interpolation at red position), pixels located in diagonal direction may be good candidates of being populated. Where, μ is the denominator to control the weight of R and G differences.

## 3 Experimental Results

The proposed method is tested on LC dataset. All test images are primarily down-sampled in Bayer CFA pattern and then demosaicked back to three color channels using color interpolation methods. Parameters $\lambda$, $\gamma$, and $\mu$ are determined as 1.2, 0.8, and 3.0, which were obtained empirically. Fig. 2 and Fig. 3 show simulation results comparison using LC #122 and LC #116 images, respectively. Assume that the bilinear interpolation method as the benchmark, and compared with proposed method. As one can see, results from the proposed method well reconstructed image similar to the original one. However, the result of the bilinear interpolation shows unwanted color artifacts.



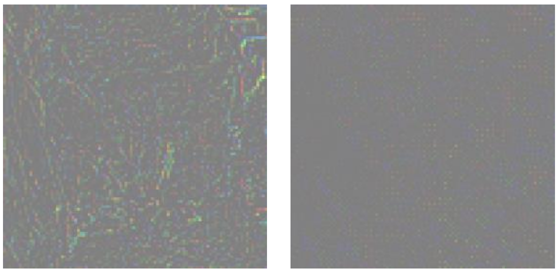
(a) (b) (c)



(d) (e)

**Fig. 2.** (a) Original image of LC #122 image, (b) bilinear interpolation, (c) proposed method, (d) difference between (a) and (b), and (e) difference between (a) and (c).

(a) (b) (c)



(d) (e)

**Fig. 3.** (a) Original image of LC #116 image, (b) bilinear interpolation, (c) proposed method, (d) difference between (a) and (b), and (e) difference between (a) and (c).

## 4 Conclusion

For economical reason, most digital cameras uses color filter array instead of RGB camera. Although RGB camera provides more natural images, but its beam splitters for each pixel may cause high costs. Therefore, usage of CFA is inevitable and its color interpolation is important topic. In this paper, an image interpolation method using directional information is proposed. This method is based on well-known ACPI. By proposing a new edge direction determination rule, good restoration performance is achieved.

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