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The modified gradient edge detection method for the color filter array image of the CMOS image sensor

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ABSTRACT

The modified gradient edge detection method applied in demosaicing the color filter array image is proposed in this paper. Firstly, the adjacent pixels are ranged from large to small. Then, the absolute differences of sorted pixels are calculated to analyze the distribution of the possible edge. Finally, the arithmetic operators being along the possible edge and that being across the possible edge are designed to estimate the accurate edge information. The experimental results verify that the proposed method gives better performance than the traditional gradient edge detection methods, and can discriminate the accurate edge, even where the gradients in different direction are close.

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1. Introduction

CMOS image sensor is one kind of optoelectronic device. In order to reduce the cost, many CMOS image sensors only use photodiode diode covered with color filter array (CFA) to capture one of the three-primary colors at every pixel location. The process of restoring the CFA image to the full color image is called CFA interpolation or demosaicing. It will generate the color artifacts to interpolate the missing color values across edges.

Gradient edge detection is one of the most common methods to distinguish the boundaries of different objects in one CFA image. Due to the mosaic structure of the CFA image, the gradient edge detection methods used in the full color image cannot be used directly in detecting the edges of the CFA image. The existing gradient edge detection methods used in the edge-sensitive demosaicing algorithm can be classified into two categories. The first category of methods directly or indirectly employed the vertical, horizontal or diagonal gradients to orientate the direction of the edge [1–4], or adaptively fused the vertical and horizontal demosaicing values to acquire the missing color values [5,6]. The second category of methods designed the filters or arithmetic operator masks to estimate the direction of the missing color channel [7–10].

All the above gradient edge detection methods have made a contribution to reduce the generation of the color artifacts. However, these methods only pay attention to the relative difference values of the same color channel or the same color difference. And they are liable to cause the mistake that considers the edges with the same gradient values as the same edge. In order to overcome this drawback, the proposed method focuses more on analyzing the value distribution of the adjacent pixels, instead of only focusing on their relative difference values. This method firstly ranges the values of the adjacent pixels with the same color from small to large. Then, it calculates the absolute differences between every two sorted pixels to ascertain the possible edge of the current pixel. Finally, the more accurate edge is determined by designing the adaptive arithmetic operators.

The rest of the paper is organized as follows: Section 2 presents the proposed method. The experimental results and the performance comparisons with other state-of-the-art gradient edge detection approaches are reported in Section 3. The conclusions are given in Section 4.

2. The proposed algorithm

Although there exist many CFA patterns, the Bayer pattern in Fig. 1 is the most widely used pattern in digital devices [1]. Let us take B_{23} in Fig. 1 as the current pixel for example. The supporting theory of many gradient edge detection methods to acquire the edge information of adjacent green pixels is the intra-channel

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correction theory, namely the same channel values of the pixels being along the same edge vary less [1–10]. However, according to these edge detection methods, the following mistakes are often made, as shown in Fig. 2. Fig. 2 is extracted from the test image in Fig. 3(b). The images in Fig. 3 are the standard testing images in the RGB pattern, which are supplied by Kodak company. The vertical and horizontal gradients are respectively $gradient\_v = |99-49| = 50$, and $gradient\_h = |40-90| = 50$. With the mean value principle, the missing green value of the current blue pixel is calculated by $green\_current = |99+90+49+40|/4 = 69.5$, while the raw green value of the current blue pixel is 40. Thus, the wrong edge detection and the wrong demosaicing value appear.

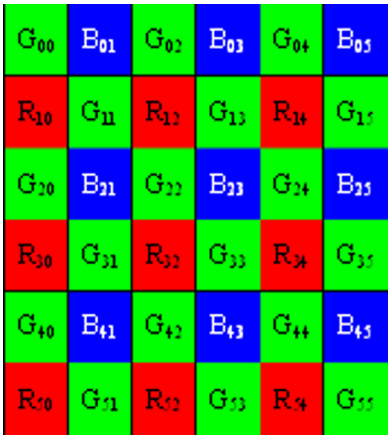

Fig. 1. Bayer pattern.

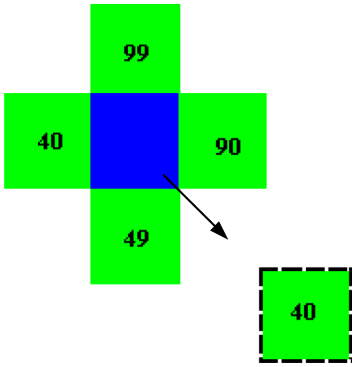

Fig. 2. The data distribution is liable to make wrong edge detection.

The similar mistake will occur in detecting the edge information of color difference. The reason why the wrong edge detection appears is that the vertical and horizontal gradients are close, and the traditional gradient edge detection method cannot distinguish the accurate edge information. In order to overcome this kind of mistakes, this paper proposed the modified gradient edge detection method applied in demosaicing the color filter array image. The structure of the proposed method is shown in Fig. 4.

The supporting theory of the proposed method is still the intra-channel correction theory. In order to distinguish the accurate edge information of the missing pixel with close gradient values, the proposed method adapts three steps. Firstly, the adjacent pixels of the current pixel in CFA image are ranged from large to small. Then, the absolute differences of sorted pixels are calculated to analyze the distribution of the possible edge. Finally, the arithmetic operators being along the possible edge and that being across the possible edge are designed to estimate the accurate edge information. Thus, the accurate edge information of the CFA image is obtained.

Since the green channel contributes mostly to the illumination of the image, and the good green demosaicing will benefit the interpolation of red and blue channels, this paper starts with the edge detection in demosaicing the missing green value at blue/red pixel in Bayer pattern. The edge detection in demosaicing the missing blue/red values at red/blue pixels, and in demosaicing the missing blue/red channel values at green pixels, can use the similar method.

2.1. The edge detection in demosaicing the missing green channel values at blue/red pixels

Firstly, the values of adjacent pixels are sorted from large to small. Since the number of the adjacent pixels is only 4, no matter what kind of sorting algorithm does not significantly change the complexity of

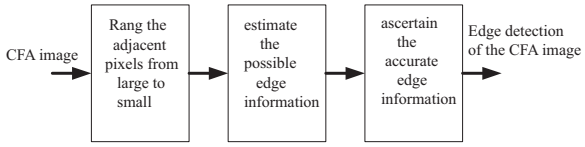

Fig. 4. The structure of the proposed method.

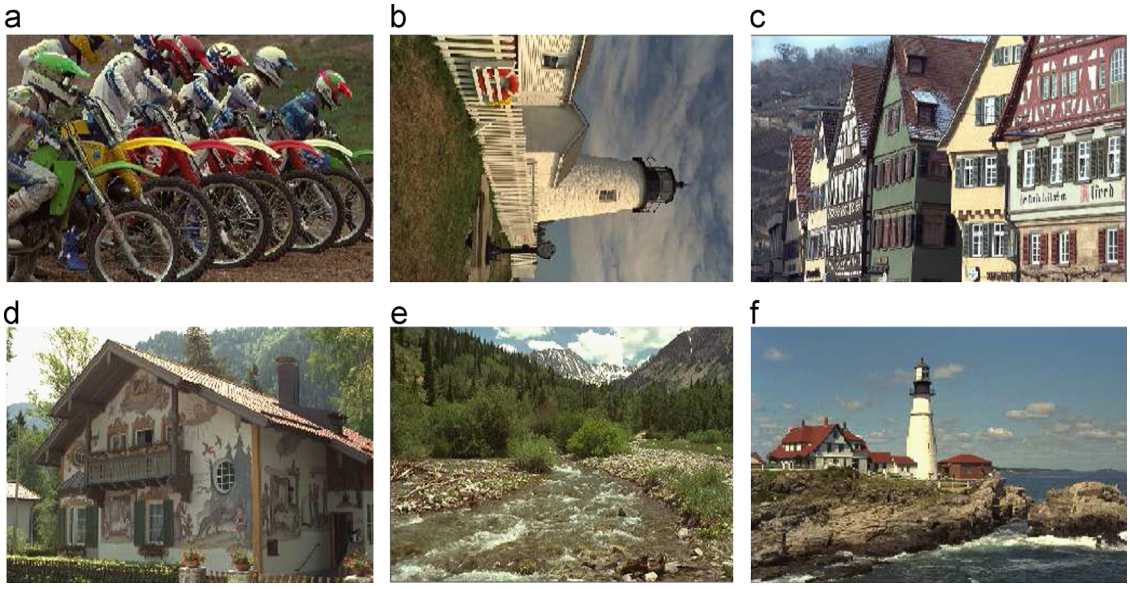

Fig. 3. The testing images.

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