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An improved demosaicing method based on Hibbard algorithm

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Abstract. As computer vision become more widespread and deeper, the requirements for accuracy and clarity of an image gradually increase, and more accurate image reconstruction algorithms urgently need to be developed and researched. Existing image reconstruction algorithms mainly use the conversion of images into RGB or use the difference to predict certain regions to build mathematical models and then revert to images. The existing bilinear interpolation algorithm may reduce the resolution and damage the high frequency part, thus blurring the edges and making it difficult to achieve the expected results. The colorimetric constant method is greatly affected by noise, and the boundary problem is still unsolved. The gradient edge interpolation method only considers the horizontal and vertical directions, which is a single idea and does not meet the needs of oblique edges, and there will be problems such as color overflow. And based on some features near the oblique boundary, this paper focus on the case of large or small edge slope, and select the horizontal difference and vertical difference for algorithm improvement respectively by comparing the color difference along all four directions. Experimental results show that the PSNR value increases slightly—by 0.0013. It effectively optimizes the image and lays the foundation for feature perception in the image.

Keywords: image reconstruction, edge detection, Hibbard algorithm

1. Introduction

Edge detection has been an indispensable research content in image reconstruction, especially the demosaicing algorithms. The correctness and reliability of the results will have a direct impact on the understanding of the objective world towards human being and the machine vision system. The increasing demands on image accuracy and clarity have created an urgent need to develop and research more accurate image reconstruction algorithms.

The image is described by a 3D matrix, and each pixel of the image is described by RGB（Red，Green and Blue), which can determine the color of individual pixels. When the image needs to be reconstructed, the key is to reconstruct the RGB value and try to find the RGB value similar to the original image.

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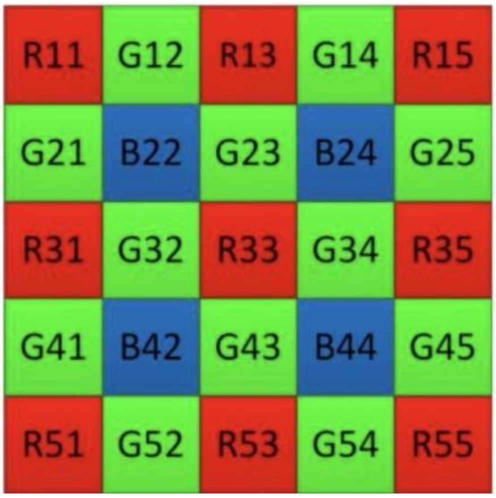

Figure 1. color filter array pattern.

At present, the mainstream algorithms are divided into augmentation-based and recovery-based interpolation algorithms. Bilinear interpolation method refers to the two dimensions of X and Y, and the principle of this algorithm is to find the average value of several nearby pixels. However, this method has a significant error, especially for some images with sharp edges, which will produce sawtooth stripes at the edge. Compared with the Bilinear algorithm. The improved color ratio rule of cok algorithm is as follows.

$$\frac{R_{ij}}{G_{ij}} = \frac{R_{mn}}{G_{mn}}$$
$$\frac{B_{ij}}{G_{ij}} = \frac{B_{mn}}{G_{mn}} \tag{1}$$

where R_{ij},G_{ij}andB_{ij}represent the composition of red, green and blue respectively on the pixel which is located at the position(i,j), in which i indicates the row and j indicates the column. Similarly, R_{mn},$G_{mn}$and B_{mn} represent the same things but at the position(m,n).

The ratio Red/Green is locally constant within a given "object" (the same is true for Blue/Green)[1]. This first step is to reconstruct the green on all red and blue pixels using Bilinear algorithm. Then the simple rule could be used to calculate the red and green, which is followed by calculating the average. Although the color ratio rule is contained in this method, the edge problem still can not be addressed.

Traditional augmentation-based interpolation algorithms usually need to preprocess the image to extract the edges or regions of the image for locating the labeled lines. These interpolation methods tend to produce jagged artifacts at the edges, blurring the details in the texture. This method can produce speckle noise or distortion around the image while preserving the edge structure of the image. The image effect is enhanced by improving image contrast to meet visual requirements, but the essence of image quality degradation is ignored, resulting in blurred image edges. The method has poor ability to maintain image edges, and it will produce phenomena such as zipper effect and color overflow in areas with obvious boundaries[2][3].This makes traditional image preprocessing and defect detection algorithms ineffective. As shown in Figure 2, the resolution target image is used to test the bilinear interpolation method, the COK algorithm and the partially adaptive threshold method. As can be seen, the results of these methods make it difficult to distinguish between lines without lines and bubbles.

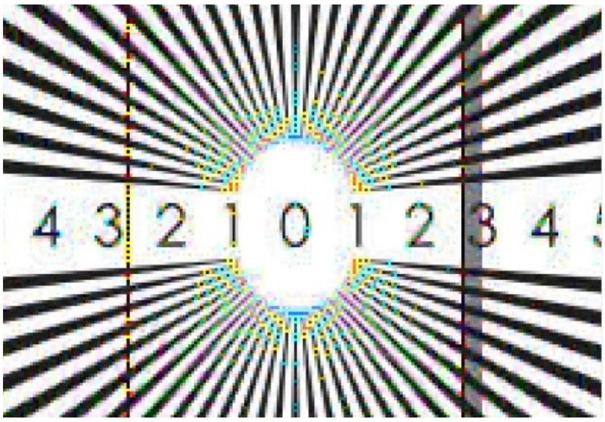

Figure 2. traditional image preprocessing result.

In recent years, classical image edge detection algorithms such as Prewitt [4], Kirsch [5] and Canny[6] have been constantly proposed. Faced with the problems existing in the traditional image edge detection methods, this paper should establish an algorithm that can more accurately predict the position and RGB value of the edge, or can eliminate some serious problems, such as zipper effect and Mohr fringe, so as to make the edge clearer, improve the image quality and avoid the reduction of resolution.

Compared to the two algorithms introduced above, the Hibbard algorithm, which is a gradient-based interpolation, could provide a better result on the color edge and be useful to enhance the sharpness of an image. There are two main steps in this algorithm. The first step is to interpolate the missing green values by considering the horizontal gradient, the vertical gradient and a threshold value. Hibbard divided the situations into four classes. The interpolation should be along the vertical if vertical gradient $<\text{threshold and horizontal gradient}>\text{threshold}$ .And the interpolation should be along the vertical if horizontal gradient$<\text{threshold and vertical gradient}>\text{threshold}$, Otherwise, four neighbors should be averaged for the interpolation[7]. The second step is to reconstruct red and blue using the rule of constant color difference, which is that $K_R = G - R$ and $K_B = G - B$ are constant[8]. However, the "edge problem" still exists in Hibbard algorithm and this method is quite simplified. And the Hibbard algorithm has already been improved by many scientists. For example, red in the proximity of target are taken into account when reconstructing the green instead of considering green independently[9]. But there are still many ways to improve Hibbard method such as considering the other two direction and using weighted average instead of the arithmetical average.

After analyzing the existing methods of demosaicing and determining their advantages and drawbacks, this paper proposes a practical algorithm based on Hibbard algorithm and provides some possible ways, which could be useful in theoretical terms, to deal with the noise appearing in the reconstruction.

2. Advanced Hibbard algorithm

2.1. Analysis of edge gradient feature perception

In Hibbard algorithm, the interpolation of green values is along either the vertical orientation or the horizontal orientation by comparing the difference of green values along these two directions. It is true that this method would provide a desirable result when dealing with the horizontal and vertical edges, however, it fails to take account into the oblique edges, which are along other directions except these two. The situations are quite complicated for the oblique edges with different edges. This proposed algorithm would focus on two kinds of edges—straight edges with quite small gradients and that with quite large gradients. In the former case, which is shown in figure3. It is noticed that, for a chosen pixel on the edge, the difference between the color composition on the nearby pixel which is below the target one and that of the right-hand side pixel is small. This could be used as the conditions to determine which points are along such edges. Apart from that, this figure also reveals that, for the boundary with small gradients, there are several horizontal adjacent pixels with similar values before a jump occurs on the diagonal, which occurs repeatedly on the boundary. The analysis for edges with large gradients is similar: the diagonal difference could be used to determine the position of the boundary and the pattern for this situation is that a few similar adjacent pixels on the vertical followed by a jump on diagonal.

Figure 3. The situation on an oblique boundary after zooming.

2.2. Improved Interpolation algorithm

Reference to the two features of the edges with very small and large gradients discussed above, the method of interpolating green values could be improved. For the small gradient parts, horizontal interpolation would be used after determining the edge by comparing differences along all of four directions—vertical, horizontal, and diagonal. To be specific, before the beginning of the interpolating process, the area where there are edges with small gradients should be chosen. After that, considering the absolute value of the difference along the diagonal.

$$\left|G_{i,j+1} - G_{i+1,j}\right| \tag{2}$$

where $G_{i,j+1}$ is the green value on the single pixel at $(i, j + 1)$, which is on the right of pixel at (i, j) and $G_{i+1,j}$ is the green value on the single pixel at $(i + 1, j)$ located below the nearby pixel at (i, j), if this difference is the smallest, and also smaller than a threshold value, such as 50, this pixel could be considered as one on the boundary. The horizontal interpolation is as follows:

$$G_{i,j} = \frac{G_{i,j-1} + G_{i,j+1}}{2} \tag{3}$$

Where$G_{i,j-1}$is the green value on the single pixel at$(i, j - 1)$that is on the left of pixel at (i, j). Analogously, when dealing with the parts with large-gradient edges, the interpolation along the vertical direction should be chosen after determining the positions of the boundary.

$$G_{ij} = \frac{G_{i-1,j} + G_{i+1,j}}{2} \tag{4}$$

where$G_{i-1,j}$ is the green value on the single pixel at $(i - 1, j)$ that is positioned above the target pixel at (i, j). Besides, for the other positions in the image, the original method of Hibbard algorithm is still used: compare the horizontal and vertical difference and then interpolate along the direction with smaller difference. After finishing the reconstruction of green values, the rest of the algorithm would be the same as Hibbard algorithm: using the constant color difference to reconstruct red and blue values. The constant color difference leads to$R_{ij} - G_{ij} = R_{mn} - G_{mn}$ and $B_{ij} - G_{ij} = B_{mn} - G_{mn}$ and then the red value is reconstructed.

$$R_{i-1,j} = G_{i-1,j} + \frac{\left(R_{i-2,j} - G_{i-2,j} + R_{i,j} - G_{i,j}\right)}{2} \tag{5}$$

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where $R_{i-1,j}$ represents the red value at (i-1, j) -the coordinate indicates the position of a pixel- which is above the proximity pixel located at (i, j) and $R_{i-2,j}$ represents the red value at (i-2, j) which is above the proximity pixel located at (i-1, j). Similarly, $G_{i-2,j}$ represents the green value on the pixel (i-2, j) which is above the proximity pixel located at (i-1, j).The blue values are calculated by the same way.

3. Results of experiments and analysis

In order to test this proposed method, there are two ways to show that this interpolation is reasonable and improved to some extent. Firstly, if performing the horizontal interpolation on an image containing straight boundaries with both small and large gradients, the outcome would show that the edges with quite small gradients are clear, while there is serious color overflow near the large-gradient edges, as shown in figure 4 Comparably, if using the vertical interpolation, it would lead to the opposite result, which is figure 5 Secondly, in order to test the result more precisely, there are two common quantitative measurements that are peak signal to noise ratio[10] and mean square error(MSE). The former one is used here. An image with some small-gradient edges is chosen and PSNR is calculated for the result of the original Hibbard algorithm and the improved one. The PSNR value increases slightly—by 0.0013.

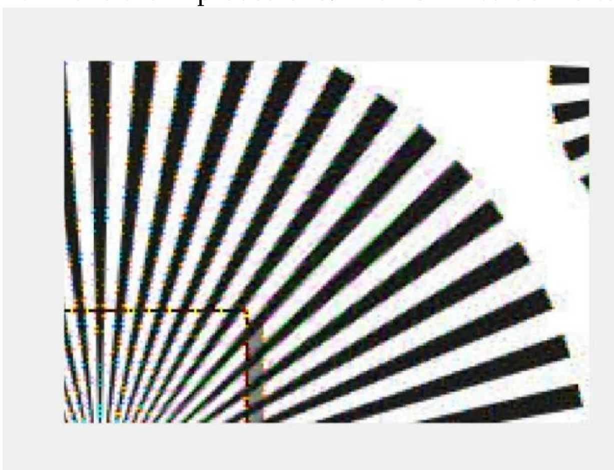

Figure 4. Results of interpolation for the small-gradient edges.

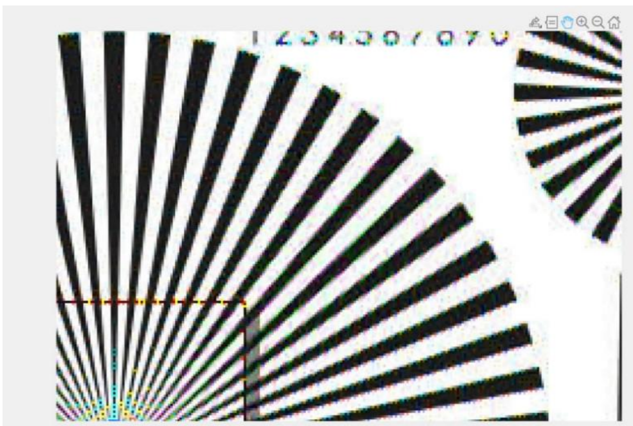

Figure 5. Results of interpolation for the large-gradient edges.

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4. Conclusion

This paper focus on the case of large or small edge slope based on some features near the oblique boundary and select the horizontal difference and vertical difference for algorithm improvement respectively by comparing the color difference along all four directions.

In addition to the methods proposed in this paper, some other ways also could be used to improve Hibbard algorithm theoretically. For instance, the arithmetic average could be replaced by the weighted average, but a suitable "weight" is really hard to determine. Or the horizontal and vertical interpolation could be replaced by the diagonal interpolation. But the result of this method is not desirable. Maybe this is because the diagonal interpolation could only fit under limited conditions.

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