Analysis and Comparison of Three Classical Color Image Interpolation Algorithms

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Abstract. With the development of society, the progress of science and technology, the level of computer has been improved. Digital imaging technology has also achieved unprecedented development. The most commonly used digital cameras are Charge-coupled device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) image sensors. Bayer filters are often used to help sensors capture color information. However, only one component can be achieved per pixel. Full-color images must be obtained by color interpolation. Therefore, the color interpolation algorithm has attracted the attention of the academic community. In this paper, three classical color interpolation algorithms- Bilinear interpolation algorithm, COK Algorithm, Gradient Interpolation Algorithm- are compared and studied. The Optimal Algorithm is selected by comparing false color, noise and color moire fringe. After comparison, it is found that the three basic algorithms will have color moire fringes appear. But the gradient interpolation algorithm has the least moire fringe and noise. COK Algorithm, second of all. But the COK Algorithm has color overflows.

Keywords: Bilinear Interpolation Algorithm, COK Algorithm, Gradient Interpolation Algorithm, Color Interpolation, Digital Imaging.

1. Introduction
With the development of multimedia, science and technology, and the improvement of computer technology, digital imaging technology has attracted the attention of the academic community [1]. In modern Charge-coupled device (CCD) or Complementary Metal Oxide Semiconductor (CMOS), there is only one sensor unit per pixel. Therefore, only one color in Red, Green, Blue (RGB) can be recorded per pixel. Bayer filter array is usually used as the color filter array, which is one of the most widely used in the world today as an RGB filter. Because these RGB can be combined into almost any color in the world, therefore, it is also commonly known as the “three primary colors.” [2]. For colors that cannot be received, the other two-color components of a pixel are recovered from the pixels around the pixel; such process is called color interpolation [3]. Despite its wide uses, color interpolation can cause the image mosaic effect, as well as the boundary and zipper effect and a series of problems. In order to be able to solve this kind of problem, people improve the processing effect by constantly improving the Algorithm. The traditional interpolation algorithm model is simple and the computation is small. But the algorithm to get the pixels around the mapping point is different. Therefore, the quality of image processing is also different [4]. In the current paper, three classical interpolation algorithms are
analyzed and compared in this paper. We examine the practicality and subjective visual effect. The overall structure of the paper is as follows: the first section is the introduction, which mainly introduces the research background and significance of color interpolation algorithm; Section 2 mainly introduces the basic theory of three classical interpolation algorithms; Section 3 shows the implementation of the algorithm and the simulation process; In section 4, some classical interpolation algorithms are studied, and their advantages and disadvantages are analyzed through the comparison of experimental data; and finally a conclusion is drawn in Section 5.

2. Principle and significance of interpolation algorithm

2.1. Bilinear Interpolation

Bilinear interpolation is a single channel independent interpolation algorithm. It is one of the simplest, most basic, and most traditional interpolation algorithms. It is also the basis of understanding other advanced algorithms, and is also of great significance in evaluating other algorithms. Because bilinear method is independent interpolation between the single channel and ignore the correlation between the three-color channels, the interpolation effect is relatively poor. In particular, the processing of the edge will produce false color and also the formation of Moire stripes [5].

2.2. Constant Interpolation Algorithm

Constant Interpolation Algorithm’s (COK) color constancy based bilinear interpolation is one of the early algorithms used in digital camera systems, taking into account the correlation between different color channels. The quality of reconstructed image has been improved obviously. The MONDRIAAN image model is used here. In a smooth image interior, the image color is mostly uniform. So, their ratio is also close to a fixed value. At this point we can calculate this constant value to infer the color of the surrounding pixels. This is the color ratio constant law [5]. The images that go through the color ratio constancy algorithm have fewer image Moiré stripes than the images that go through the bilinear interpolation algorithm, and the resulting colors are more realistic. But there are still flaws in the edge processing and the color mutation. At the same time, when G is equal to 0, the equation of constant color ratio is meaningless. When G is close to 0, the color ratio is too high. It is easy to produce a great error.

2.3. Hibbard Interpolation (Gradient)

The human eye is very sensitive to the change of the edge color of the image. The gradient edge interpolation method reasonably solves the boundary interpolation problem. The interpolation is guaranteed to follow the boundary [6]. When G component is restored, the horizontal and vertical gradients are calculated and compared to find out the proper direction for interpolation. At the same time, the gradient edge algorithm also uses the idea of constant chromatic aberration to get the information. The false color at the edge of the result obtained by this interpolation algorithm is well suppressed. The problem of Color Moire fringe has also been solved to a certain extent [6]. The distortion effect is also much less than the other two algorithms.

Fig. 1. Bayer filter array
3. implementation and Simulation

3.1. How Bilinear Interpolation Works?
The R and B values on g pixels are obtained by averaging the two adjacent R and B values from the Horizontal Vertical Direction of the G Pixel. In Figure 1, for example, G43, the R and B values of that point can be expressed as:

\[ R_{43} = \frac{R_{33} + R_{53}}{2} \]  
\[ B_{43} = \frac{B_{42} + B_{44}}{2} \]

The G component on the R or B Pixel is averaged by the g component on the nearest four G pixels. As shown in Figure 1, the component G at B42 is

\[ G_{42} = \frac{G_{32} + G_{52} + G_{41} + G_{43}}{4} \]

And for R33

\[ G_{33} = \frac{G_{23} + G_{43} + G_{32} + G_{34}}{4} \]

For the R component on the B Pixel and the B component on the R Pixel, the R or B component of the four adjacent pixels on the diagonal is equal to the average value. As shown in Figure 1, the R component at B42 is

\[ R_{42} = \frac{R_{31} + R_{33} + R_{51} + R_{53}}{4} \]

At R33, the B component is

\[ B_{33} = \frac{B_{22} + B_{24} + B_{42} + B_{44}}{4} \]

Because bilinear method is to interpolate data independently between single channels by taking the average value of 3x3 filter, it ignores the details and boundaries of the image and the correlation of the three-color channels of the image; therefore, it is difficult to get satisfactory interpolation effect in most of the pictures, easy to produce false color at the edge and cause Moire effect [7].

3.2. How Cok Algorithm Works?
For Cok Algorithm, all Green component values are restored using the bilinear interpolation algorithm. And other colors can be calculated by the green component. First, this method uses the basic bilinear algorithm to restore all the green channel points, the value. And the rest of the color component is then calculated based on the Green Component. It can be seen that the R and B components on the g pixel can be obtained from the horizontal and vertical two R and B components. Then the R component at Gxy can be written as:

\[ R_{xy} = G_{xy}(R_{ab}/G_{ab}) \]

Multiple adjacent points can be averaged, for example:

\[ R_{43} = \frac{(R_{32} + R_{34} + R_{52} + R_{54})/4 \cdot G_{43}}{4} \]

At the same time, if g is too small, the calculation error may be too large. So, an improved logarithmic-based algorithm is proposed.
\[ \log_{x,y} = \log_{R_{a,b}} / \log_{G_{a,b}} + \log_{G_{x}} \]  

(9)

3.3. How the Hibbard-Laroche Algorithm Works?

The HIBBARD method is as follows:

\[ \alpha = |G_{32} - G_{34}| \]  
\[ \beta = |G_{23} - G_{43}| \]  

(10) (11)

Laroche’s theory

\[ \alpha = |2R_{33} - R_{31} - R_{35}| \]  
\[ \beta = |2R_{33} - R_{13} - R_{53}| \]  

(12) (13)

If \( \alpha < \beta \), it is more likely to interpolate along the vertical direction

\[ G_{33} = (G_{32} + G_{34}) / 2 \]  

(14)

If \( \alpha > \beta \), then it is more likely to interpolate horizontally

\[ G_{33} = (G_{23} + G_{43}) / 2 \]  

(15)

In the interpolation of any Pixel R or B component value, the use of color difference constant as the basic algorithm.

\[ R_{ab} - G_{ab} = R_{cd} - G_{cd} \]  
\[ B_{ef} - G_{ef} = B_{gh} - G_{gh} \]  

(16) (17)

When inserting the value of the R or B component over a g pixel

\[ R_{x-1, y} = G_{x-1, y} + (R_{x-2, y} - G_{x-2, y} + R_{x,y} - G_{x,y}) / 2 \]  

(18)

4. Results
Fig. 1(b). Bilinear interpolation algorithm

Fig. 1(c). Cok algorithm

Fig. 1(d). Hibbard-Laroche algorithm

Fig. 2(a). Original image

Fig. 2(b). Bilinear interpolation algorithm
Fig. 2(c). Cok algorithm

Fig. 2(d). Hibbard-Laroche algorithm

Fig. 3(a). Original image

Fig. 3(b). Bilinear interpolation algorithm
4.1. Bilinear Interpolation Algorithm
Bilinear interpolation is the most basic algorithm, but because the correlation of the color channels is not considered, the effect is very poor. For pictures with obvious boundaries, false colors and blurred boundaries will appear, but pictures with unobvious boundaries can be better restored. However, after zooming in, you can find obvious distortion and a lot of noise, and moiré fringes inevitably appear on the edges.

4.2. Cok Interpolation Algorithm
Compared with the bilinear interpolation algorithm, the COK algorithm has fewer moiré fringes and fewer false colors on the edges, but there is still a large amount of color overflow in the shadow part. It has a good effect on images with unobvious edges; but when the colors are darker, there are problems with distortion and color overflow, which are somewhat different from the original image. For images with obvious edges, compared with bilinear interpolation, it demonstrates better results, nevertheless, there is still a certain degree of distortion and blurred edges.

4.3. Hibbard Interpolation Algorithm
The final Hibbard algorithm significantly reduces noise and color moiré fringes are well suppressed. At the same time, the color overflow phenomenon in the Cok algorithm is also well suppressed. For pictures with unobvious edges, the restoration degree is very good, and the color overflow phenomenon in the Cok algorithm is also well suppressed. As for pictures with obvious edges, the restoration degree is good, and the overall performance is better than the Cok algorithm and bilinear interpolation algorithm. But there is still distortion in the edge area with slope and angle [8].

In the last set of images (Figure 3), there are only a few colors. At this point, the three algorithms are not too far apart. But relatively speaking, the bilinear interpolation algorithm still has a lot of noise.

Overall, it can be observed that the Hibbard interpolation algorithm is the best method, which has better performance than the other two classic algorithms in most images. It has less noise and moiré. There is almost no color bleeding.

4.1. Cok algorithm
4.2. Hibbard-Laroche algorithm
5. Conclusions
In this paper, Bayer color filter array is used to remove the distortion and Moire fringes in interpolation algorithm. At the same time, the theory of three basic algorithms is introduced. We provide a detailed analysis and comparison, through the experimental. However, limited by time and resources, we didn’t seek to fundamentally address the shortcomings of the classical algorithm and defects. In the future, we hope to combine different algorithms to achieve better results.

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