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A new interpolation algorithm based on Hibbard-Laroche algorithm and its superiority

Yuxuan Huang[1, †],Yiming Ren[2, 3, †]
[1]Shaoguan University, Shaoguan, Guangdong Province, China, 512005
[2]University of Shanghai for Science and Technology, Shanghai, China, 200093

[3]Corresponding author: 1912140119@st.usst.edu.cn
[†]These authors contributed equally.

Abstract. In order to optimize the possible problems and improvements in the existing color image restoration interpolation algorithms, we conduct research based on the existing bilinear interpolation method, cok algorithm and Hibbard-Laroche algorithm. Our method is to use our own comparison method to compare different types of images through three algorithms to find the advantages and disadvantages and to some extent combine the advantages of bilinear interpolation and Hibbard-Laroche algorithm to try to innovate a new algorithm to compare with the existing three algorithms. The results show that the existing three algorithms have their own advantages in different scenarios, and the new algorithm is superior to the existing algorithms in terms of clarity and color restoration accuracy in most scenarios. However, due to the large computational complexity, the operation speed is slow.

Keywords: algorithm comparison, Hibbard-Laroche algorithm, a new algorithm, algorithm improvement.

1. Introduction

In daily life, it is not difficult to find that when our mobile phone is facing the computer screen, obvious stripes will appear. The photos we take are enlarged to see some details are distorted. These are all problems in color image restoration [1].

In order to solve the problem of color image restoration, scientists have proposed several famous interpolation algorithms, including bilinear interpolation method, color ratio constant method, and gradient edge interpolation method [2]. These algorithms cleverly use the average value, ratio, difference and so on of adjacent pixels in bayercfa for interpolation calculation.

However, there are some color interpolation distortion phenomena such as zipper effect and moire fringe effect [3]. When the image jumps from low frequency to high frequency, the interpolation is not along the boundary but through the boundary, and the boundary part will produce blur and color overflow. After interpolation, there are some regular interval distribution of pixels in the horizontal or vertical direction, which is called zipper effect. When the optical image frequency is close to the CCD pixel frequency, the frequency aliasing is generated, and the Moiré fringe is generated. In the processing of black and white high-frequency edge images, we found that the images restored by bilinear interpolation method and color ratio constant method have obvious edge jagged stripe grids, and the laroche method can be perfectly restored. This is because this algorithm considers the edge situation in

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the horizontal and vertical directions, but in fact, the laroche method does not perfectly eliminate the distortion phenomenon. When the image has uneven black and white stripes, it also has a certain degree of distortion. This is because the mechanism of judging the boundary is still flawed [4].

Based on the discovery that the Hibbard-Laroche algorithm is good for this edge, we began to consider that different algorithms may have different advantages for different images [5]. The selection of interpolation algorithms directly affects the final effect of the image.For different application fields, it is necessary to comprehensively consider the complexity and recovery effect of the interpolation algorithm and select the appropriate algorithm [6]. In order to deeply understand the principle of color image interpolation algorithm, this paper firstly introduces several commonly used image interpolation algorithms for digital image sensors based on Bayer format color filter array, then we improves the Hibbard interpolation algorithm and forms a new algorithm [7]. The simulation results of different styles of images are compared with the other three difference algorithms. Finally, the corresponding conclusions are given.

2. Related Works

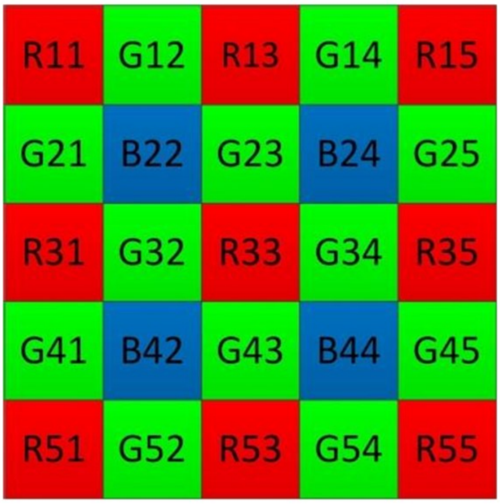

Figure 1. RGB filter.

2.1. Bilinear algorithm

As Figure 1 shows, in such a Bayer CFA, we take the average of the component values around each pixel as the value of the channel[5]. On the r_{53} pixel, take the picture as an example, find b_{53}, g_{53}.

$$b_{53} = \frac{(b_{42} + b_{44} + b_{62} + b_{64})}{4} \tag{1}$$

$$g_{53} = \frac{(g_{43} + g_{52} + g_{54} + g_{63})}{4} \tag{2}$$

Similarly on the B pixel. On the G pixel point, r_{54} and b_{54} are calculated as g_{54}.

$$r_{54} = \frac{(r_{53} + r_{55})}{2} \tag{3}$$

$$b_{54} = \frac{(b_{44} + b_{64})}{2} \tag{4}$$

By analogy, this is a bilinear interpolation method.

2.2. Cok algorithm

Because from the perspective of physical optics, in a small smooth neighborhood of the same object,the proportion of light intensity of the three color channels will not mutate, so there is the following law :

$$\frac{R_{ij}}{G_{ij}}=\frac{R_{mn}}{G_{mn}} \tag{5}$$

$$\frac{B_{ij}}{G_{ij}}=\frac{B_{mn}}{G_{mn}} \tag{6}$$

Therefore, we first use the bilinear interpolation method to calculate all the G components in the picture, and use the adjacent pixel R and B components to calculate the pixel R and B components to be solved [5].

$$R_{mn}=G_{mn}\left(\frac{R_{ij}}{G_{ij}}\right) \tag{7}$$

Multiple adjacent points were averaged as r_{53} cases:

$$b_{53}=g_{53}\times\frac{\frac{B_{42}}{G_{42}}+\frac{B_{44}}{G_{44}}+\frac{B_{62}}{G_{62}}+\frac{B_{64}}{G_{64}}}{4} \tag{8}$$

2.3. Hibbard-Laroche algorithm

2.3.1. According to the gradient to determine the possibility of the existence of the horizontal direction.

Hibbard method : take the green component as an example, if $\alpha=|G_{43}-G_{63}|$, $\beta=|G_{52}-G_{54}|$, $\alpha<\beta$, The possibility of boundary in the vertical direction is small, and the interpolation is carried out along the vertical direction[5].

$$g_{53}=\frac{(g_{43}+g_{63})}{2} \tag{9}$$

Contrarily,

$$g_{53}=\frac{(g_{52}+g_{54})}{2} \tag{10}$$

Laroche method: taking red component as an example, if $\alpha=|2\times R_{53}-R_{51}-R_{55}|$, $\beta=|2\times R_{53}-R_{33}-R_{73}|$, $\alpha<\beta$, The possibility of boundary in the vertical direction is small, and the interpolation is carried out along the vertical direction, and the formula is the same as above.

2.3.2. Using the idea of constant color difference to restore the red and blue channel. Constant chromatic aberration is considered constant in a small smooth region of an image [5].

$$R_{ij}-G_{ij}=R_{mn}-G_{mn} \tag{11}$$

$$B_{ij} - G_{ij} = B_{mn} - G_{mn} \tag{12}$$

Therefore,

$$R_{i-1,j} = G_{i-1,j} + \frac{R_{i-2,j} - G_{i-2,j} + R_{i,j} - G_{i,j}}{2} \tag{13}$$

3. Simulation of three algorithms

3.1. Bilinear algorithm

Bilinear algorithm is also known as bilinear interpolation method. Firstly, select the material photo and read its rows and columns and the value of the channel and then define a zero matrix named bayer, only rows and columns, traverse the matrix, and assign the channel value of the selected material photo to bayer[8]. If the odd row even sequence is assigned to blue, the even row odd sequence is assigned to red, and the other is assigned to green. The bayer is expanded to form a new matrix, and then a zero matrix with rows and columns and channels is defined. Four loops and judgment statements are used to traverse each pixel point and interpolate it with bilinear interpolation formula. After transforming the data type, the new image is output[9].

3.2. Cok algorithm

Cok algorithm is also known as color ratio constant method. Firstly, the original bayer image is extracted and expanded as the bilinear interpolation method. The for loop and the judgment statement are used to traverse each pixel point after the bayer expansion and the bilinear interpolation method is used to calculate all the green components. The for loop and the judgment statement traverse all the pixels once by judging the odd and even rows and columns, and use the color ratio constant method formula to interpolate the red and blue, and output the new image after transforming the data type[10].

3.3. Hibbard-Laroche algorithm

Hibbard-Laroche algorithm is also known as gradient edge interpolation method. Get the image information and list the three channels RGB respectively, forming three matrices with only rows and columns. The three matrices are filled in the corresponding components in the original image, and then the green component is recovered first. The values of the horizontal gradient a and the vertical gradient b are calculated and compared. At the B and R components, the G component is obtained by comparing the a and b values. Then, the R and B components are calculated at the G component by using the formula of color difference constant method. At the B component, find the R component; at the R component, find the B component. After transforming the data type, a new image is output[4].

3.4. A new algorithm based on Hibbard-Laroche algorithm

3.4.1. Firstly, the image information is obtained, and then the values of the R, G and B components of the three channels on the bayer template are color restored according to the image information. By using the method of line-by-line traversal, the value of the red channel component in the original image is assigned to the odd column of the odd row, the value of the green channel component in the original image is assigned to the even column of the odd row and the even column of the even row, and the value of the blue channel component is assigned to the even column of the even row. Then write a simple function to compare the size of three numbers and get the maximum value.

The bayer template obtained above is divided into nine grids, and the average of each part of R, G and B components is calculated to obtain R1, G1 and B1 respectively.

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```
for i=2:m/3
    for j=int32((n-1)*(2/3)):(n-1)
        if
            sum1=sum1+G(i,j);
            a1=a1+1;
        elseif
            sum2=sum2+R(i,j);
            a2=a2+1;
        else
           sum3=sum3+B(i,j);
            a3=a3+1;
        end
  end
end
G1=sum1/a1;
R1=sum2/a2;
B1=sum3/a3;
```

3.4.2. Next, according to the average value of G1, R1 and B1, we compare the size of the three numbers and get the maximum value function to judge which color channel in each region has the most components and calculate all the component values of the channel color in the region. The G value is calculated by the gradient calculation method mentioned in the Hibbard-Laroche algorithm, and the R and B values are calculated by bilinear interpolation method.

3.4.3. Finally, the idea of constant color difference is used to restore the color components of other channels in each pixel, such as when G is the background color in a block: $R_{ij} - G_{ij} = R_{mn} - G_{mn}$, $B_{ij} - G_{ij} = B_{mn} - G_{mn}$,When R is the background color: $G_{ij} - R_{ij} = G_{mn} - R_{mn}$, $B_{ij} - R_{ij} = B_{mn} - R_{mn}$, When B is the background color: $G_{ij} - B_{ij} = G_{mn} - B_{mn}$, $R_{ij} - B_{ij} = R_{mn} - B_{mn}$, Convert data types and output new images.

4. Experimental evaluation

In this chapter, we use three methods to quantitatively analyze the image processing results of the new algorithm and the other three old algorithms. First, we select five different types of images for algorithm simulation and scoring. Secondly, we compare the time required for the operation of the four algorithms and rank them, and add and subtract points according to the different rankings. Third, we adapted the image clarity scoring software to score the processing results of the four algorithms. Finally, we add the total scores of the three parts to intuitively reflect the advantages of the new algorithm.

4.1. Flow chart

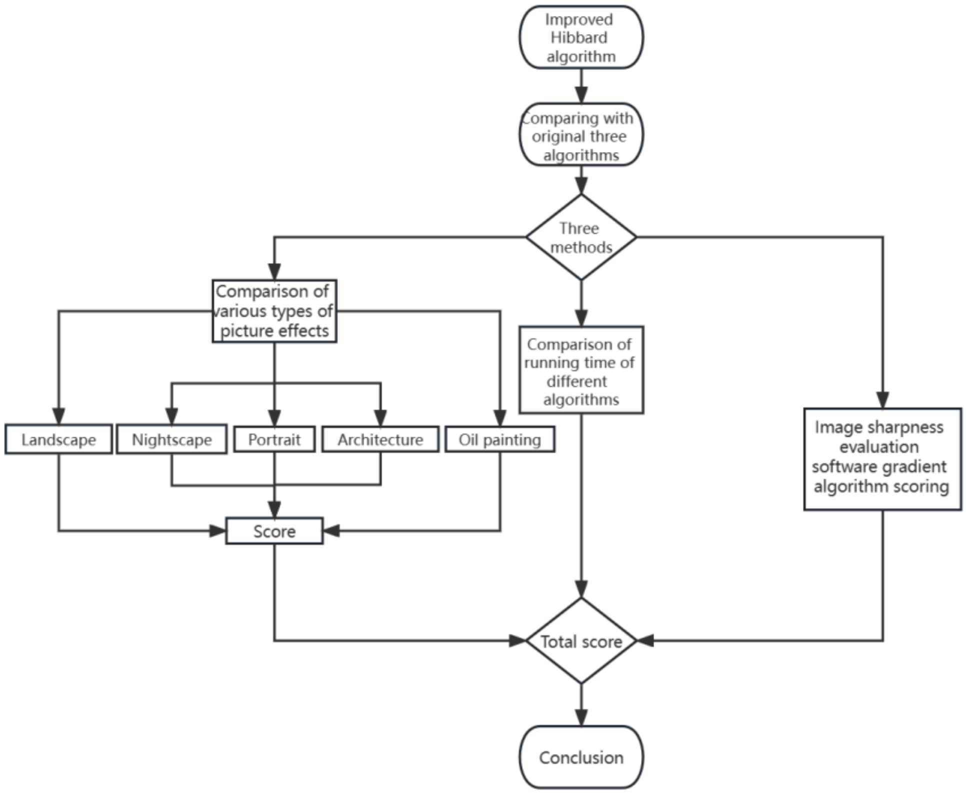

Figure 2. Flow chart.

4.2. Comparison of effects of various types of pictures

In order to compare the new algorithm with the other three old algorithms more comprehensively, we decided to select different kinds of pictures for simulation comparison. As the Figure 2. shows, we selected five types of pictures: landscape photos, buildings, night scenes, portraits and oil paintings for comparison. There are five evaluation criteria, four of which are fixed, and the remaining one will be adjusted according to the type of picture. The full score of each standard is 3 points, and the minimum is 1 point. The simulation results of each type of picture are 15 points, and the total score of the five types is 75 points. After the comparison, we will make a table to compare the total score and average score of the simulation results of each algorithm.

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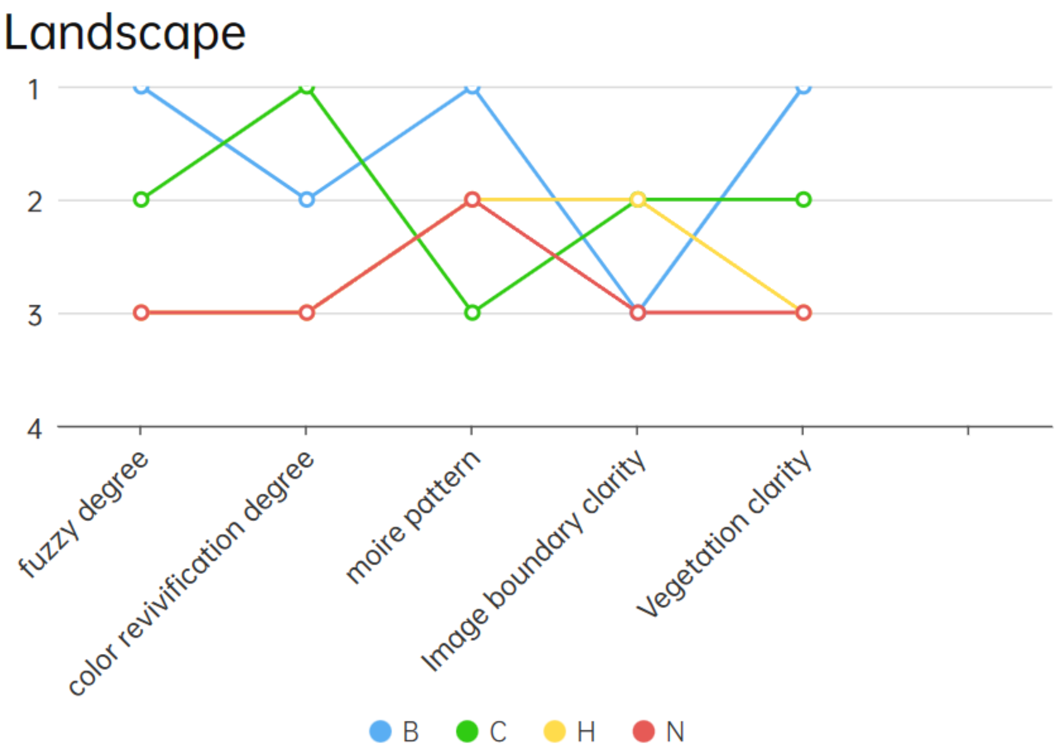
4.2.1. Landscape photos

Figure 3. Different landscape photos.



Effects:

Figure 4. Scores of various algorithms for landscape simulation.

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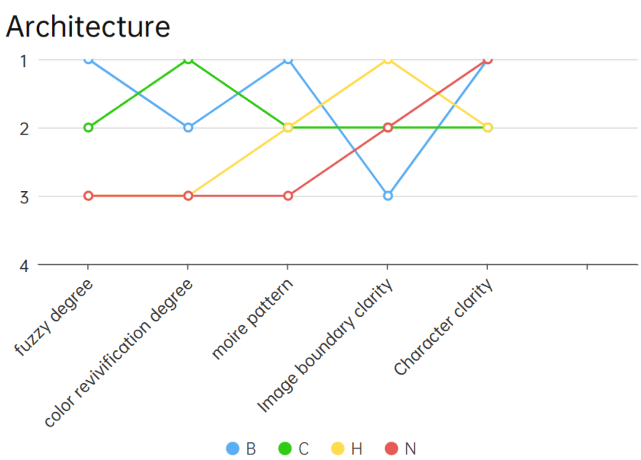
4.2.2. Architectures

Figure 5. Different architecture photos.



Effects:

Figure 6. Scores of various algorithms for architecture simulation.

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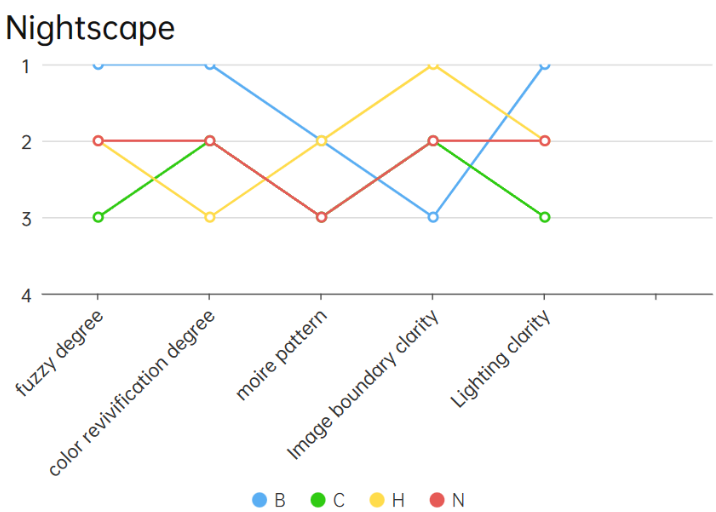
4.2.3. Nightscape photos

Figure 7. Different nightscape Photos.



Effects:

Figure 8. Scores of various algorithms for nightscape simulation.

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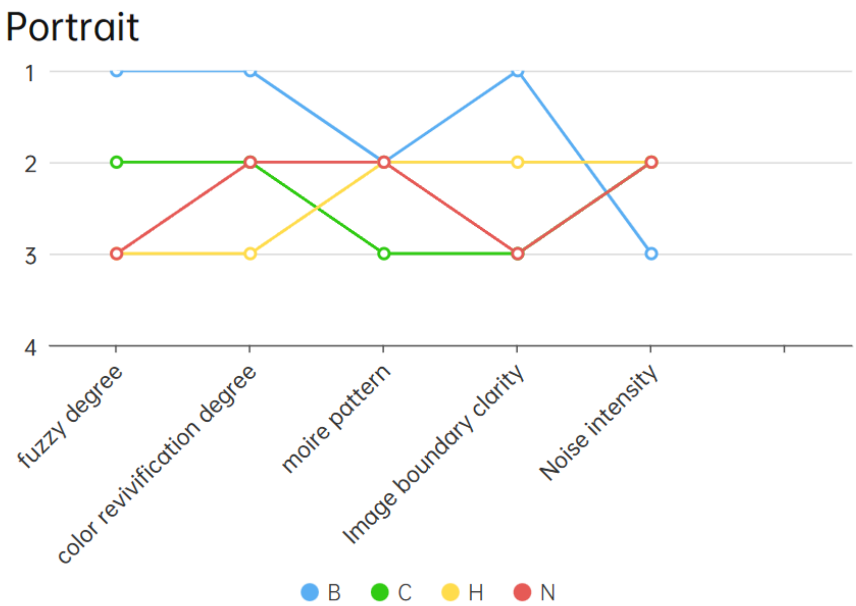
4.2.4. Portrait

Figure 9. Different Portraits.



Effects:

Figure 10. Scores of various algorithms for portrait simulation.

4.2.5. Oil paintings

Figure 11. Different oil paintings.

Effects:

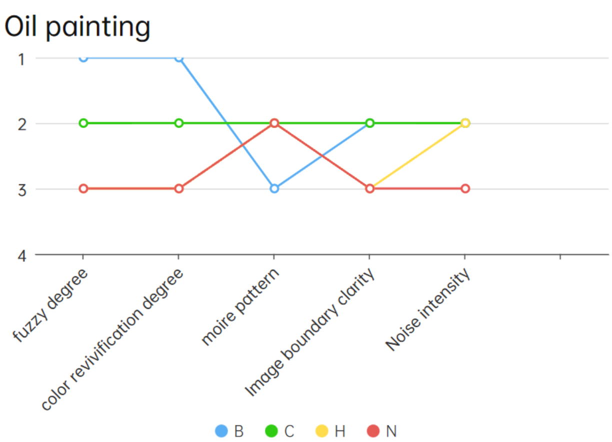


Figure 12. Scores of various algorithms for oil painting simulation.

4.2.6. Data summary

According to Figure 4,6,8,10 and 12, by adding the simulation results of five different types of pictures, we get the data of the following table.

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Table 1. The scores of 4 algorithms for 5 different types of picture simulation.

Algorithm	Landscape	Architecture	Nightscape	Portrait	Oil painting	Overall	Average
Billinear	8	8	8	8	10	42	8.4
Cok	10	9	13	12	9	53	10.6
Hibbard	13	11	10	12	13	59	11.8
New algorithm	14	12	11	12	14	63	12.6

Note: The higher the score, the better thr effect.

*4.3. Comparison of the time required for various interpolation algorithms to run.*In Table 2, we get the data according to the running time of the four algorithms.

Table 2. The running time comparison of 4 algorithms.

Unit: second

Average running time	Billnear	Cok	Hibbard	New algorithm
Landscape	1.48	1.54	1.64	1.70
Architecture	1.69	1.64	1.58	1.68
Nightscape	2.13	2.21	2.50	2.80
Portrait	1.71	1.81	1.71	1.92
Oil painting	1.61	2.10	2.15	2.40
Average of all the types	1.72	1.86	1.92	2.10

It can be seen that the Cok algorithm is close to the Hibbard-Laroche algorithm, the Bilinear algorithm has the shortest running time, and the new algorithm takes the longest time. According to the ranking, the shortest algorithm adds 10 points, the second adds 5 points, the third adds 2 points, and the longest algorithm does not add points.

*4.4. Gradient algorithm scoring using image sharpness evaluation software.*The functions of the software used are as follows :

*4.4.1. Brenner function.*The gradient filter method, also known as the gradient filter method, only needs to calculate the difference between two pixels in the x direction, that is, to calculate the second-order gradient, with less calculation.

$$F=\sum_{x}\sum_{y}\{[f(x+2,y)-f(x,y)]^{2}\} \tag{14}$$

4.4.2. Tenengrad function. The Sobel operator is used to extract the gradient values of the horizontal and vertical directions of the pixel points. The Tenengrad function is defined as the sum of squares of the pixel gradient, and a threshold T is set for the gradient to adjust the sensitivity of the function.

Set Sobel convolution kernel to Gx,Gy, then the gradient of the image at the I point:

$$S(x,y) = \sqrt{G_x * I(x,y) + G_y * I(x,y)} \quad (15)$$

The Tenengrad value of the image is defined as : (where n is the total number of pixels in the image)

$$Ten = \frac{1}{n} * \sum_x \sum_y S\,(x,y)^2 \quad (16)$$

Or not average: Evaluation function F (k):

$$\text{F(k)} = \sum_{\text{x}} \sum_{\text{y}} [\text{G(x,y)}]^2 (\text{G(x,y)} > \text{T}) \quad (17)$$

And T is the given edge detection threshold.

$$g_x = \frac{1}{4}\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad , \quad g_y = \frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad (18)$$

The weight of the two is 50 %, and the original image is 100 points.

4.4.3. Effects of Software Assessment

Table 3. Software scoring of image clarity after 4 algorithms processing.

Types	Billnear	Cok	Hibbard	New algorithm
Landscape	39.6818	58.3340	76.9311	82.4084
Architecture	43.1878	67.7712	80.3566	86.2876
Nightscape	60.1294	86.9294	97.4237	96.5636
Portrait	44.5932	74.1739	90.3777	94.7440
Oil painting	39.4804	84.8219	89.7351	87.8616
Average score	45.4145	74.4061	86.9648	89.5730

Note: The weight of the two functions is 50% respectively, and the original image is 100 points.

It can be seen that the new algorithm has the highest clarity of the image, the Hibbard-Laroche algorithm is in the second place, the Cok algorithm gets the third hightest score, and the Billinear algorithm has the lowest score.

4.5. Total score

In Figure 13, by summarizing the data of the above three different algorithms for the processing results of the pictures, we obtain the scores of the following table.

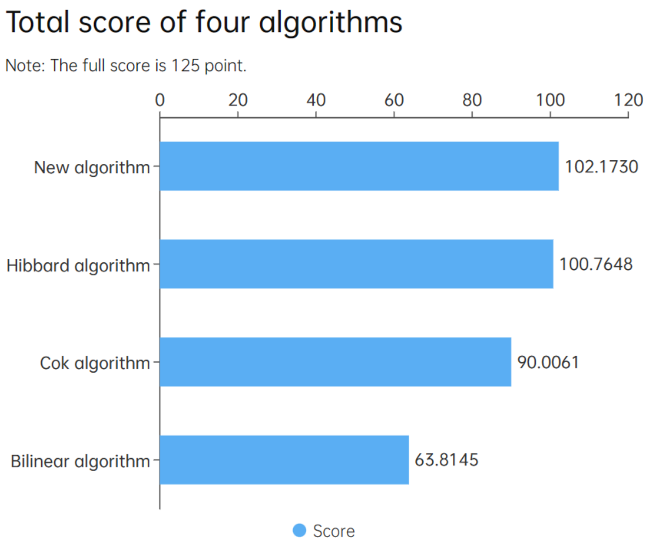

Figure 13. Total score of 4 algorithms.

5. Conclusion

As shown in the figure, the three evaluation methods are combined to obtain the highest score of the new algorithm. The Hibbard-Laroche algorithm has the second highest score, the Cok algorithm is the second, and the Bilinear algorithm has the lowest score. It can be seen that the new algorithm is the most restoration of image clarity and has obvious advantages. However, the three algorithms are also different in different types of images. In general, different interpolation algorithms for different images have different recovery effects. For example, Cok algorithm can be selected when night scene images need to be processed, but the effect is better than Hibbard-Laroche algorithm and new algorithm. However, in general, the image restored by the adaptive color layer interpolation algorithm has the best effect and the bilinear interpolation has the lowest computational complexity. This also leads to the calculation speed of the bilinear difference algorithm is the fastest of the three algorithms. In summary, although the new algorithm is not as fast as the original three algorithms, the new algorithm is the best choice if both the image effect and the computational complexity are taken into account.

Appendixes

The code of 3.4.2:

```
if max(G1,R1,B1)==G1
    if
        if a>b

        elseif a<b

        else

        end
    end
elseif max(G1,R1,B1)==R1
    if

    elseif

    elseif
```

```
                end
            else
                if

                elseif

                elseif

                end
            end
        end
end
```

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