**Paper Title**

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**Abstract:** The paper presents a new fast interpolation method based on edge extraction. Our method extracts image edge by improved canny operator which has two specified thresholds first. Then for different areas, it chooses different methods. It can keep edge details while doing quick interpolation. The experimental results show that the effect of this method can hold the edge details very well, and it is obviously superior to the traditional ways. The method provides a better initial image for the super resolution reconstruction.

**Keywords:** Fast interpolation; Edge extraction; Canny operator; Gradient interpolation

**1 Introduction**

Image super resolution reconstruction [1] can obtain a high resolution image from a group of low resolution images. Image interpolation [2] gives it an initial image for the next steps. And the quality of given initial image can affect the reconstruction result directly in the image quality and the speed of iterative. Quick access to high resolution images is very important for getting the precise position, speed, posture and other information of spacecraft. And the high resolution images can relocate the moving target exactly.

There are lots of image interpolation methods such as nearest, bilinear [3], bicubic spline [4], etc. Nearest interpolation is the most simple method, but it is also the worst. Bilinear interpolation has over smoothing effects and edge blur. Bicubic interpolation can prevent the over smoothing effects and edge problems of nearest interpolation and bilinear interpolation, but it also leads to high computational-complexity. Some methods like improved PDE (partial differential equations) [5] and NEDI (new edge directed interpolation) [6] have a better result, but they also need too much time to do complex iterative interpolation. Those methods are not applicable to the super resolution reconstruction. The super resolution reconstruction of space motion images needs both entire quality and clear edge. And it should be simple enough to reducing the algorithm’s iteration times.

This paper proposes a new fast edge preserving interpolation method based on edge extraction [7] to hold image’s quality and edge details while reducing computational complexity. We do independent processing on the extracted edge obtained by improved canny operator [8], and then put it back to the image which is interpolated by the bilinear to ensure the quality and speed. The experimental results show that the proposed method has a better subjective outcome and better objective results like PSNR (peak signal to noise ratio) [9], gradient [10] and MSE (mean square error) [11] compared with the traditional methods. And the results have some improvement compared to the NEDI. Plus, the computation time substantially decreased compared to other new method such as NEDI.

**2 Traditional bilinear interpolation**

Bilinear interpolation is one of the most common interpolation algorithms. Its result has a well quality and smoothing pixel distribution. But the zoomed image’s edge is blurry. The method is linear expansion of an interpolation function with two variables. It does interpolation in two directions by linear interpolation. The main processes are as follow.

First, do linear interpolation on the X direction, finding the gray value of R1 and R2 as shown in Figure 1.



**Figure 1** Bilinear Interpolation

$$f\left(R\_{1}\right)≈\frac{x\_{2}-x}{x\_{2}-x\_{1}}f\left(Q\_{11}\right)+\frac{x-x\_{1}}{x\_{2}-x\_{1}}f\left(Q\_{21}\right) $$

$ where R\_{1}=(x,y\_{1})$ (1)

$$f\left(R\_{2}\right)≈\frac{x\_{2}-x}{x\_{2}-x\_{1}}f\left(Q\_{12}\right)+\frac{x-x\_{1}}{x\_{2}-x\_{1}}f\left(Q\_{22}\right) $$

$ where R\_{2}=(x,y\_{2})$ (2)

We do interpolation on the Y direction based on R1 and R2 to get the gray value of P.

$f\left(P\right)≈\frac{y\_{2}-y}{y-y\_{1}}f\left(R\_{1}\right)+\frac{y-y\_{1}}{y\_{2}-y\_{1}}f\left(R\_{2}\right)$ (3)

The paper uses bilinear linear interpolation to do the whole image interpolation. Then, expand edge in a 3\*3 window on the edge image, and interpolate the expanded edge image individually.

**3 Proposed fast interpolation method based on edge extraction**

We do interpolation on the whole image using bilinear interpolation to ensure the quick speed and superiority in flat areas of bilinear interpolation. Then we obtain the image edge by improved edge extraction method, and do independent edge interpolation based on gradient. After those steps, put the interpolated edge back to the bilinear interpolation image.

**3.1 Improved edge extraction method based on canny operator**

Firstly, we extract image edge using canny operator with two specified thresholds. Image edge is the local area which has significant changes in brightness. And the area’s grayscale changes severely. There are many edge detection operators like Sobel, Prewitt, Canny, etc. Canny operator has a better result than others. But the image edge extracted by original canny operator has too much detail noise and useless information. We present a new canny operator with two specified thresholds in doing non-maximal inhibition by studying the original. By doing a lot of experiments, we get the most appropriate values to obtain the best image edge for most images.

Canny operator is composed of four steps. First, do image de-noising by gaussian filter. Second, calculate original image’s three gradient images which including vertical, horizontal and diagonal. Third, do non-maximal inhibition with the three gradient images in the second step. Fourth, connect edge on the image. The major factors of the quality of image detection are the third and fourth steps. The traditional process of non-maximal inhibition is simply detecting the pixel points which have bigger gradient amplitude value than other points adjacent to it along the gradient direction as the edge points. The comparison points are uncertain by this method, and the results would have some mistakes. We set two thresholds named T1 and T2 during the non-maximal inhibition. We can find out that the image edge is extracted more accurately by improved canny operator. And lots of noises and useless information are removed. The result is beneficial to the edge interpolation.

  

**(a) (b) (c)**

**Figure 2 (a)** original image **(b)** edge image of original canny operator **(c)** edge image of improved canny operator

**3.2 Proposed edge interpolation method**

While doing the bilinear interpolation, the edge of original image will be amplified to the enlarged image. We know that the edge pixels are mainly associated with the pixels which are closed to the edge. We can obtain the original gray values of the image edge. By knowing this, the edge pixels’ values of the amplified image can be calculated with the 3\*3 window of the expanded edge image. The expanded edge image is formed by the edge points and some points in the 3\*3 window around the edge. We do the edge interpolation individually on the expanded edge image.

There are many indices for objective evaluation of the results. We choose four indices include PSNR, gradient, MSE and interpolation time which are mostly used. The original low resolution images are generated by down sampling the higher images. Then we use the bilinear interpolation and our method handling the lower images to obtain the results. The bigger values of PSNR and gradient indicate a better result. And, the lower values of MSE and interpolation time mean the better. The objective evaluation is shown in Table I and Table II.

**Table I** The objective evaluation of different methods

|  |  |
| --- | --- |
|  | Peppers |
|  | PSNR | gradient | MSE |
| Nearest | 26.9362 | 4.9314 | 0.0084 |
| Bilinear | 28.8247 | 3.9053 | 0.0083 |
| NEDI | 29.5631 | 4.4024 | 0.0069 |
| Our method | 31.3169 | 4.1645 | 0.0071 |
|  | Lena |
|  | PSNR | gradient | MSE |
| Nearest | 28.2662 | 4.9323 | 0.0083 |
| Bilinear | 30.1697 | 3.6345 | 0.0082 |
| NEDI | 32.3551 | 4.2602 | 0.0064 |
| Our method | 32.3660 | 3.8869 | 0.0061 |

**Table II** Different interpolation time of different methods

|  |  |
| --- | --- |
|  | Interpolation time |
|  | Lena | Peppers |
| Nearest | 0.0150s | 0.0029s |
| Bilinear | 0.1595s | 0.0192s |
| NEDI | 39.4495s | 39.3594s |
| Our method | 1.5591s | 1.5392s |

According to the objective indicators contrast of the images, the PSNR and MSE of our method have improved significantly compared with the traditional methods. The gradient has manifest improvement compared with bilinear. But it is worse than nearest. This is because the nearest just considering the pixels very closed to the interpolation points. And the whole interpolation image of nearest is very poor. Our result image has some improvement compared with the NEDI in PSNR and MSE. This means that the whole image’s quality is better. But the gradient is worse than NEDI because of that NEDI has done a lot of iterations on the edge. It is more closed to the accurate interpolation edge. However, our method has obviously lower time complexity than the NEDI, and the image’s quality has some improved.

The data shows that our method has a better effect than the traditional ways in both subjective feeling and objective evaluation. Our results have some elevation compared with NEDI, and the gradient effects are worse than NEDI. But we need far less time than it. It’s very suitable for obtaining the initial image of super resolution reconstruction or other image interpolation fields.

**5 Conclusions**

We have present a new fast interpolation method based on edge extraction. The method makes full use of the well effect and speed of bilinear interpolation to handle the flat area. And, expand the edge image which is extracted by improved canny operator. Our edge extraction method can obtain clear edges and reduce the edge noises. Then, do interpolation on the expanded edge image independently by our method. The edge interpolation method handles the edges on cross direction and diamond direction independently based on gradient. Then put the independent interpolation part back to the front image which is interpolated by the bilinear. We want the best interpolation results, and minimize the quantity of pixels that need independent interpolation as well. Our method has a much better effect than the traditional methods and maximum the details of edge and veins compared to the traditional methods. It obtains a good result which has some improvement compared with NEDI. But, it reduces the computational significantly. The result shows that we propose a simple, efficient method to amplify images.

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