# A Novel Image Super-resolution Method Combined with Edge Focusing

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**Abstract.** There are some problems existing in traditional image interpolation algorithms such as blockiness, blurring, etc. To overcome these problems, a novel image super-resolution algorithm based on edge detection and different filters was proposed. The algorithm firstly calculates an initial super-resolution image by Bicubic interpolation method. Then edge focusing is used to determine whether the interpolated point is on the edges. Finally, the intensity value of super-resolution image is achieved by calculating the weighting values of filters for the neighboring region. Experimental results demonstrate that the proposed algorithm makes full use of the edge information and local features to obtain better performance.

## Introduction

Super-resolution image reconstruction has become research hotspot recently and it is used widely in military reconnaissance, medical imaging, public security etc. Super-resolution image reconstruction technique is that in the condition of intrinsical imaging devices getting no update, adopting digital signals processing technique and taking advantage of low resolution of aliasing, obscure and included noise-including to observe images to get high-resolution images.

Image Interpolation is the easiest and most visualized method in super-resolution image reconstruction methods. In order to increase the visual effect of marginal area in reconstructed image, scholars put forward many interpolation algorithm [4-10] based on edge detection and the main idea of these methods is try to take the interpolation along but not getting through the direction of edge. Li ect [4] put forward NEDI (New Edge-Directed Interpolation). NEDI method improves the interpolation result of marginal area pixel, but its operation speed is slow. Zhou etc. put forward taking colorful images interpolation in YCbCr color zone, by testing whether there is strong edge in diagonal direction to determine pixel value of ready interpolation. Sajjad etc.[11] put forward one self-adaptive image interpolation method based on marginal multi-kernel. Wang etc. [12] put forward one adaptive gradient interpolation method based on edge orientation.

Protter etc.[13] use Non-local Means method [14] in vedio's super-resolution reconstruction. But the main defect is high operation complexity and it also needs many images with low-resolution as input. Bilateral Filter is one nonlinear filtering method [15], and its desine philosophy takes the spatial information and luminance similarity of image into consideration. Bilateral Filter can retain marginal information more effectively and its operation speed is faster. So this paper proposed a novel super-resolution image reconstruction algorithm with better edge preservation effect and better noise proof ability.

## Our Method

The specific algorithm flowchart is shown in Fig. 1, firslty by taking the method of Bicubic interpolation to enlarge input image by N times to get initial high-resolution image, on which taking marginal testing to ensure whether the pixel ready for correction is in marginal area, secondly, take

 

Bilateral Filter on marginal pixel and take Nonlocal-Means on others, finally, get pixel gray value by weighing.

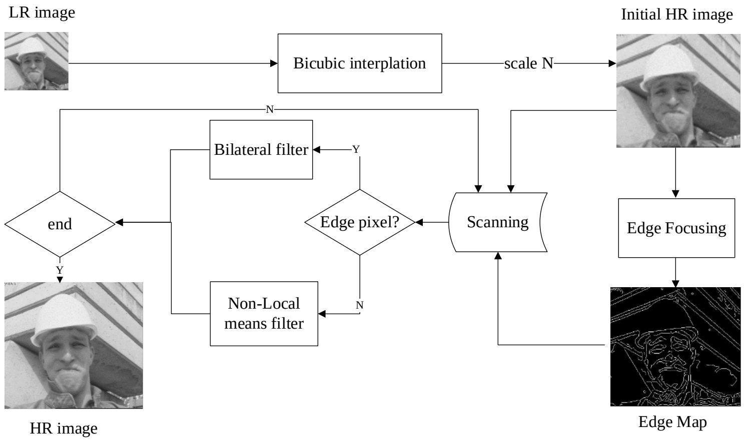


Fig. 1 The Flowchart of our method

Assume that, the value of low-resolution image $L_{x,y}$ is $M \times N$, the space coordinates of pixel $i$ is $(x, y)$, the amplification factor is 2, so the value of high-resolution image ready for interpolation $H_{2x,2y}$ is $2M \times 2N$, that is $H_{2x,2y} = L_{x,y}$. By making use of known information $H_{2x,2y} = L_{x,y}$ to take interpolation for $H_j \neq L_i$, the space coordinates of $j$ is $(2x + 1, 2y + 1)$ , and the specific counting process, please refer to Eq.1:

$$H_j = \sum_{2i \in s(j)} \alpha_{i,j} L_i \qquad (1)$$

The computation for the weight of $\alpha_{i,j}$ , please refer to Eq.2

$$\alpha_{i,j} = \begin{cases} w_{BL}(i,j), & j \notin edge(H_I) \\ w_{NL}(i,j), & j \in edge(H_I) \end{cases} \qquad (2)$$

$H_I$ is the initial high-resolution image got by Bicubic interpolation method, $s(j)$ is the search window with pixel $j$ as the center and size of $S \times S$, then for $2i \in s(j)$, $2i$ is the neighborhood pixels of $j$. $j \in edge(H_I)$ means that $j$ is the marginal pixel, which takes Bilateral Filter to calculate the weight $w_{BL}(i,j)$, conversely, takes Non-local Means to calculate the weight $w_{NL}(i,j)$ , finally weighted average to get the gray value $H_j$ of pixel $j$ ,

$$BL[n](i) = \sum_{j \in N(i)} w_{BL}(i,j)\, n(j) \qquad (3)$$

$N(i)$, taking $i$ as the center, with a size of $S \times S$ , is a image block, for $j \in N(i)$ , $j$ is the neighbor pixel of $i$, and the value of weight $w_{BL}(i,j)$is made up with two parts, whic can be calculated by Eq.4 :

$$w_{BL}(i,j) = \frac{1}{z(i)} \exp\left\{-\frac{||L(i)-L(j)||_2^2}{h_1^2}\right\} \exp\{-\frac{||n(i)-n(j)||_2^2}{h_2^2}\} \qquad (4)$$

$L(i)$ is the spatial position information of pixel $i$, $||L(i) - L(j)||_2^2$ is the spatial Euclidean distance between $i$ and $j$, $||n(i) - n(j)||_2^2$ is the spatial Euclidean distance of grey value between $i$ and $j$, $h_1$ and $h_2$ is the filter width, $z(i)$ is normalization parameter.

For the given noise image $n = \{n(i)|i \in I\}$, the grey value $NL[n](i)$ of pixel $i$ ready for valuation can be calculated by Eq.5:

$$NL[n](i) = \sum_{j \neq i} w_{NL}(i,j)\, n(j) \qquad (5)$$

The value of weight $w_{NL}(i,j)$depends on the level of similarity of $N(i)$ and $N(j)$, which can be calculated by Eq.6:

$$w_{NL}(i,j) = \frac{1}{z(i)} \exp\left\{-\frac{||R(i)-R(j)||_2^2}{h^2}\right\} \quad (6)$$

$R(i) = [r_1 \dots r_k \dots r_{s^2}]^T$ is the vector made up with all pixels in $N(i)$ , and $r_k$ is the pixel value at the K place. $||R(i) - R(j)||_2^2$ is the Euclidean distance between $R(i)$ and $R(j)$, that is the similarity of $N(i)$ and $N(j)$, and $h$ is the filter length.

**Edge Focusing.** [16] have made conclusion after comparing that gauss operator is the best measurement operator to keep edge consistency in orthogonal transformation, and Canny operator is the measurement operator based on gaussian kernel function. Please refer to Eq. 7:

$$g(x,y) = \frac{1}{2\pi h^2} \exp\left\{-\frac{x^2+y^2}{h^2}\right\} \quad (7)$$

Among the about Eq. 7, $x$ and $y$ are the coordinate and $h$ is the length of gaussian filter. In order to detect edge exactly, this paper introduces Edge Focusing technology into Canny edge detecting. The core concept of Edge Focusing is that firstly using the detection result when the value of $h$ is higher, later decrease the value gradually and continuously observe and correct the detection result until the value decreases less than 1, for the specific process please refer to Fig. 2.

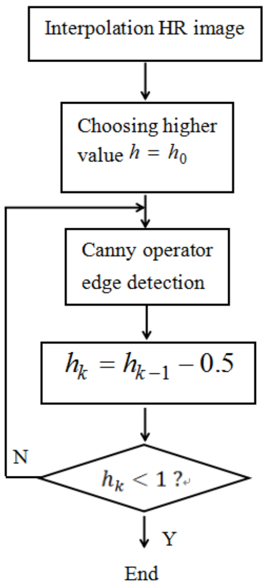


Fig. 2 Edge Focusing

## Experiment Result and Analysis

In our experiment images, as Fig. 3 shows. The parameter setting of bilateral filter: piece radius of 5, $h_1$ of 3, $h_2$ of 0.1. The parameter setting of nonlocal filter are: research radius of 20, $h$ of 3.5, piece radius of 3. This paper takes compare of methods and present 4 representative interpolation algorithm:Bilinear interpolation, BI, CC, ICBI [18]（Iterative curvature based interpolation）and NEDI[4]（New Edge-Directed Interpolation）.

From the datas in table 1, we can get the PSNR comparison of all the methods picked in this paper. Fig. 4 shows the result of comparison between reconstructed high-resolution image Forman and partial section of initial image by taking different methods. The experiment data proves that, the methods in this paper not only reserve the image edge information very well, but also correct the pixel in image flat area and has better robustness for image noise, which has certain improvement than traditional methods no matter from subjective visual effect or PSNR comparison.

## Conclusion

This paper show our novel super-resolution image reconstruction method, firstly use traditional image interpolation method to obtain initial high-resolution image, secondly take correction on image different regions by taking different filtering methods to obtain final high-resolution image. The experiment result proves that, the methods in this paper not only take full advantage of filtering effect of different filters on image specific regions and keep the edge information and local features better, but also they have good noise proof ability and have better reconstruction effect comparing to other interpolation methods, so it is one practical super-resolution image reconstruction method.

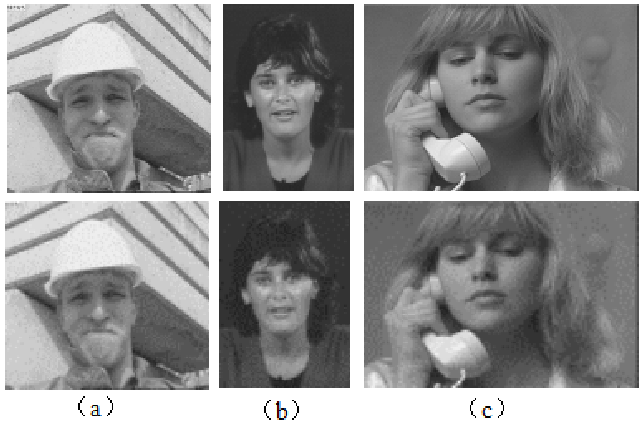


Fig. 3 Experiment image. Top: initial high-resolution image Bottom: low-resolution image
(a)Foreman (b) Miss America (c) Suzie

Table 1 Comparison of PSNR（dB）with different methods

| Image | BI | CC | ICBI | NEDI | Proposed Method |
|---|---|---|---|---|---|
| Foreman | 28.5081 | 29.0793 | 29.1844 | 28.8135 | 29.5603 |
| Miss America | 34.2415 | 34.8554 | 34.6785 | 34.1284 | 35.2111 |
| Suzie | 29.6711 | 30.0323 | 29.8561 | 29.2720 | 30.2199 |
| Average | 30.8069 | 31.3223 | 31.2397 | 30.7380 | 31.6638 |

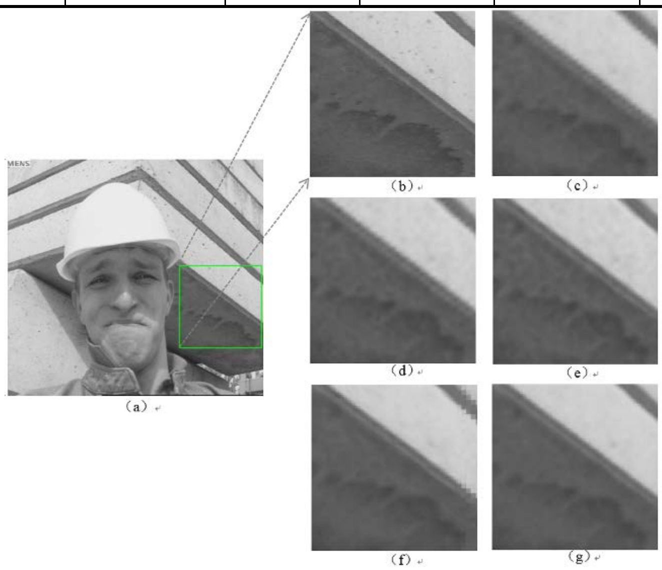


Fig. 4 Result Comparison of Amplifying Partial Region of Foreman Image
(a)Original Image (b) part of Original Image (c)BI (d)CC (e) ICBI (f) NEDI (g)our method

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