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Fusing Soft-Decision-Adaptive and Bicubic methods for Image Interpolation

Xudong Kang, Shutao Li and Jianwen Hu
College of Electrical and Information Engineering, Hunan University
Changsha 410082, China
xudong_kang@163.com, shutao_li@yahoo.com.cn, hujianwen1@163.com

Abstract

In this paper, a novel image fusion based interpolation method is proposed. Soft-decision-adaptive interpolation (SAI) is one of the state of the art image interpolation algorithms. However, SAI may produce serious artifacts in small-scale edge areas. Bicubic interpolation performs better in preserving the fidelity of small-scale edges. But, bicubic interpolation may cause zigzag and blurring artifacts around strong edges. The proposed method combines the advantages of SAI and Bicubic together through image fusion. The artifacts in the SAI interpolated image are first detected and then removed by fusing the SAI interpolated image with the bicubic interpolated image. Experiments demonstrate the effectiveness of the proposed method.

1. Introduction

Magnifying an image to a higher resolution is a prime technique in image processing and has been used in many applications such as digital photography. To construct high resolution (HR) images, image interpolation such as bilinear and bicubic have been widely used. However, these methods tend to produce jagging and blurring edges [see Fig. 1(a)].

To solve this problem, various edge-directed interpolation methods [1-3] have been proposed to improve the quality of the up-sampled images. These methods explicitly [1] or implicitly [2, 3] estimate the edge information that plays an important role in the interpolation. The method of [1] first creates a high resolution edge map and uses it to correct the interpolation process. The method of [2] tunes interpolation coefficients according to local edge structures estimated by statistic method. Among these methods, soft-decision-adaptive interpolation [3] shows the state of the art performance in terms of peak signal-to-noise ratio (PSNR) and structural similarity (SSIM). However, SAI relies on the consistency of geometric structures across resolutions so that low-resolution samples can be used to estimate high-resolution parameters. This assumption may fail for small-scale edges [3]. As a result, SAI method may produce serious distortions in small-scale edge areas [see Fig. 1(b)].

In this paper, in order to remove these artifacts caused by SAI and bicubic interpolation, an image fusion [4] based interpolation method is proposed. Image fusion can make full use of the complementarity of different methods with a little computing cost. As show in Fig. 1(c), our method can effectively remove artifacts produced by SAI and bicubic methods.

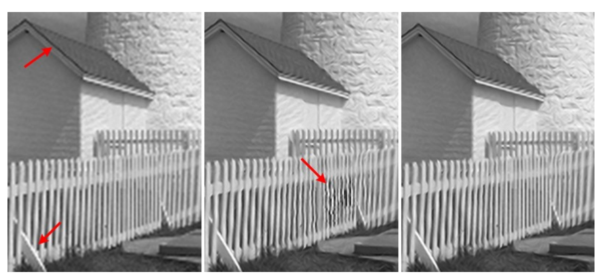


Figure 1. Portions of results of image "Lighthouse". Interpolated images using SAI (a), bicubic interpolation (b) and the proposed method (c).

In section 2, we describe the proposed image fusion based interpolation method in detail. Results are presented and compared in section 3. Finally, section 4 gives the conclusion.

2. The proposed interpolation method based on image fusion

Fig. 2 illustrates the proposed method consisting of three steps: SAI and Bicubic interpolation, weight estimation and weighted sum based image fusion.

2.1. SAI and bicubic interpolation

As shown in Eqs. (1) and (2), the LR image is first magnified by using SAI and bicubic interpolation respectively.

$$I_{SAI}^{H} = \mathrm{SAI}(I^{L}) \tag{1}$$

$$I_{BIC}^{H} = \mathrm{Bicubic}(I^{L}) \tag{2}$$

where SAI means soft-decision-adaptive interpolation, Bicubic refers to bicubic interpolation and I^{L} is the input low resolution (LR) image.

2.2. Weight estimation and weighted sum based image fusion

The second step of the proposed method aims at constructing weight maps for image fusion. The major motivation is to detect the artifacts in the SAI interpolated image so that these artificial pixels can be substituted by those from the bicubic interpolated image. Since the bicubic interpolated image performs well in preserving fidelity. A straightforward way to detect the artifacts caused by SAI interpolation is calculating the difference image between I_{SAI}^{H} and I_{BIC}^{H} as follows:

$$M_{1}(x,y) = | I_{SAI}^{H}(x,y) - I_{BIC}^{H}(x,y) | \tag{3}$$

When $M_{1}(x,y)$ is very large, the pixel (x,y) of I_{SAI}^{H} tends to be the artifacts. However, calculating the pixel difference cannot guarantee the detection of all visible artifacts. The human visual system is more sensitive to structural difference than to pixel values [5]. So, besides the measure of equation (3), we measure the structural difference of I_{SAI}^{H} and I_{BIC}^{H} as follows:

$$M_{2}(x,y) = SSIM(I_{SAI}^{H}(x,y), I_{BIC}^{H}(x,y)) \tag{4}$$

where SSIM refers to the classic image quality metric named as structural similarity index. The detailed description of the SSIM index can be found in [5].
As shown in Eq. (5), the two different quality metrics are combined together to detect the artifacts of I_{SAI}^{H}.

$$M(x,y) = M_{1}(x,y) \times M_{2}(x,y) \tag{5}$$

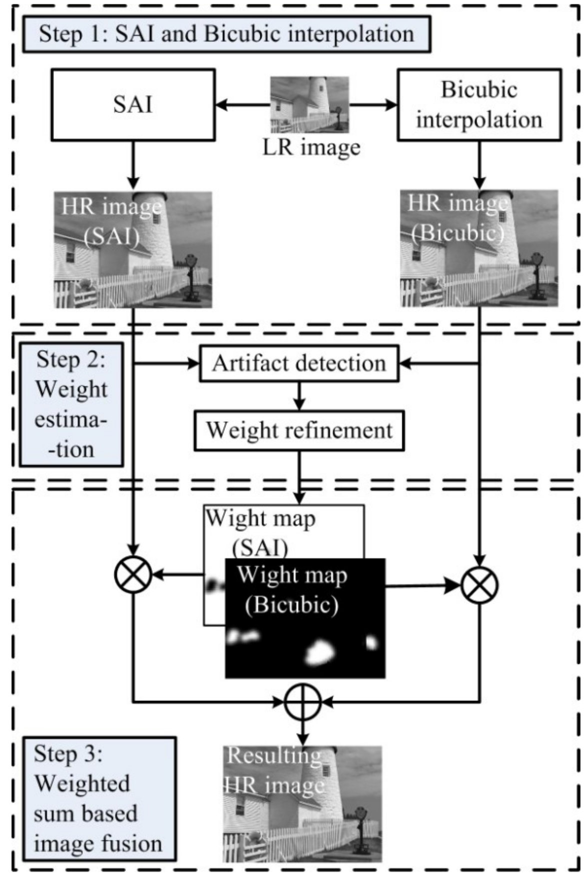


Figure 2. Schematic diagram of the proposed interpolation method.

The blurring and zigzag edges of the bicubic interpolated HR image may be also detected. To remove the influence of these pixels which usually appear as points or thin lines, a Gaussian blurring filter is first performed on M to decrease the influence of noisy pixels and then a threshold $\boldsymbol{TH}$ is adopted to detect those salient distortions caused by SAI.

$$W_{SAI}(x,y) = \begin{cases} 0 & \text{if } M(x,y) < \boldsymbol{TH} \\ 1 & \text{otherwise} \end{cases} \tag{6}$$

where $\boldsymbol{TH}$ is set to 0.9 since it can generate good detection results for most images and $W_{SAI}(x,y)$ =0 means the pixel (x, y) of H_{SAI} is artifact. Since a hard weight map may cause seam artifacts, W_{SAI} is refined by cross-bilateral filtering [7] with the HR image I_{SAI}^{H} serving as the joint image:

$$\hat{W}_{SAI} = BF(W_{SAI}, I_{SAI}^{H}) \tag{7}$$

Figure 3. Test images: (left to right and top to bottom) House, Computer, Flower, Aula, Park, Building, Wall, Square, Barbara, Entrance, Lighthouse, and Woods.

where BF is the bilateral filter. Once the weighting map W_{SAI} is obtained, the resulting HR image can be easily obtained by weighed sum of the two HR images:

$$I^H = \hat{W}_{SAI} \times I^H_{SAI} + (1 - \hat{W}_{SAI}) \times I^H_{BIC} \quad (8)$$

3. Results and evaluation

For all examples, the standard deviations of the space and range Gaussians of the bilateral filter are set to 7 in the experiments. The up-scale factor is 2. Three representative algorithms, bicubic interpolation, SAI [3] and new edge-directed interpolation (NEDI) [2], are used for comparison. The implementations of SAI and NEDI are available on the authors' homepages[1,2]. Experiments are performed on 12 test images presented in Fig. 3.

Fig. 4 presents a comparison of the HR images obtained by different algorithms. From Fig. 4 (a), it can be seen that bicubic interpolation produces blurring or zigzag artifacts along object boundaries. By contrast, the HR images shown in Fig. 4 (b) and (c) show better visual quality in these areas while presenting serious distortions in small-scale edge areas. By contrast, our fused images [see Fig. 4 (d)] show the best visual performance since it can effectively remove all distortions caused by SAI and bicubic methods.

To verify the effectiveness of the proposed method, we present the PSNR and SSIM results in Table 1 and 2 respectively. Obviously, the proposed method shows the best performance in terms of PSNR and SSIM, except ranking as second in the PSNR of Barbara. Furthermore, the average PSNR and SSIM (25.876 and 0.857) of the proposed method is the biggest. Thus, it can be concluded that the proposed method is effective in improving both the subjective and objective performance of the SAI and bicubic interpolation methods.

Table 1. PSNR of twelve test images using different algorithms.

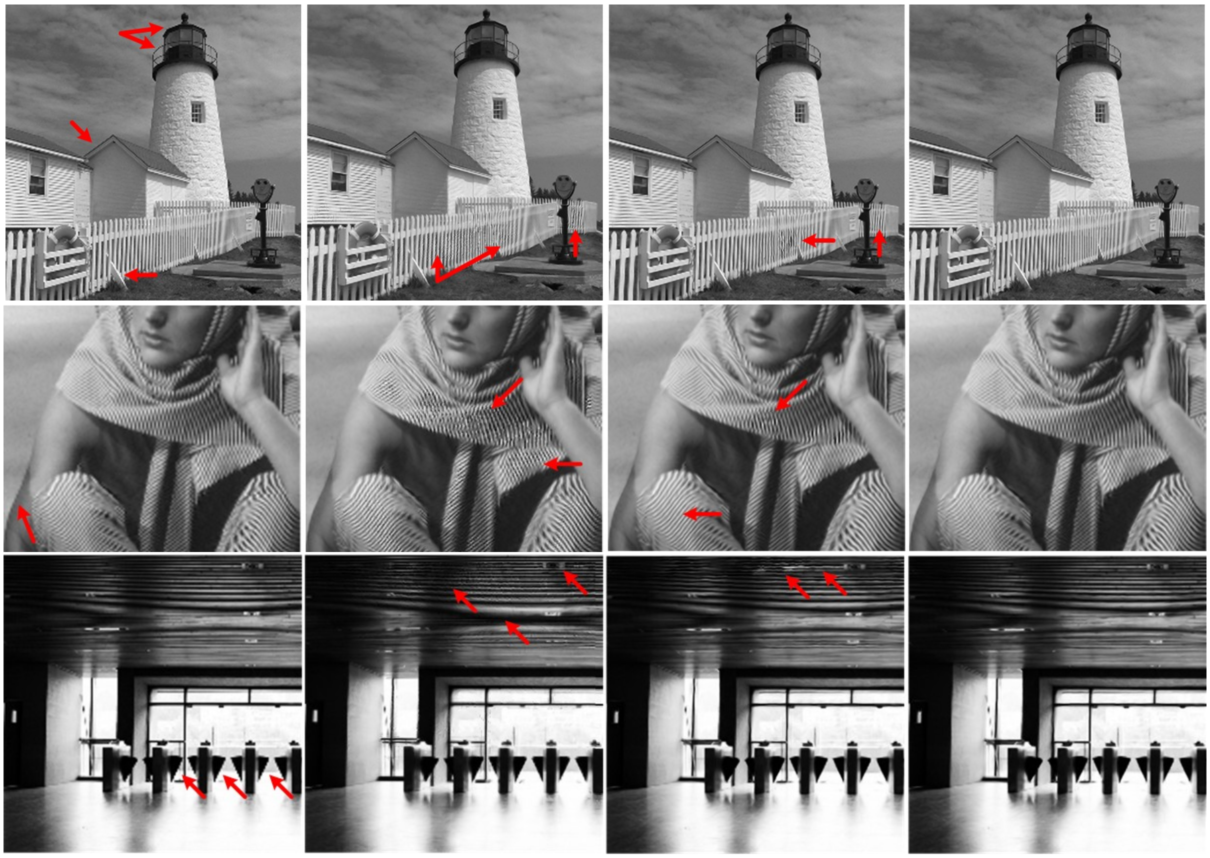
Images	BIC	NEDI	SAI	Proposed
House	22.213	21.776	22.312	**22.336**
Computer	30.372	30.314	31.655	**31.795**
Flower	28.090	27.343	**28.620**	**28.620**
Aula	24.405	24.037	24.504	**24.508**
Park	30.264	29.587	30.470	**30.694**
Building	22.800	22.492	22.882	**22.937**
Wall	26.345	26.261	26.272	**26.405**
Square	25.962	25.691	26.160	**26.169**
Barbara	**24.653**	22.047	23.589	24.374
Entrance	19.823	19.831	19.758	**19.905**
Lighthouse	27.048	26.432	26.784	**27.291**
Woods	25.303	25.108	25.454	**25.481**
Average	25.607	25.077	25.705	**25.876**

Table 2. SSIM of twelve test images using different algorithms.

Images	BIC	NEDI	SAI	Proposed
House	0.777	0.757	0.780	**0.782**
Computer	0.951	0.946	0.957	**0.960**
Flower	0.944	0.931	0.949	**0.950**
Aula	0.847	0.835	**0.849**	**0.849**
Park	0.963	0.956	0.965	**0.966**
Building	0.776	0.762	0.776	**0.778**
Wall	0.902	0.895	0.902	**0.906**
Square	0.846	0.840	0.852	**0.853**
Barbara	0.817	0.777	0.806	**0.822**
Entrance	0.755	0.754	0.749	**0.761**
Lighthouse	0.845	0.839	0.847	**0.851**
Woods	0.827	0.816	0.828	**0.832**
Average	0.854	0.842	0.854	**0.857**

[1] www.csee.wvu.edu/~xinl/demo/interpolation.html

[2] http://www.ece.mcmaster.ca/~xwu/



(a) (b) (c) (d)

Figure 4. From left to right: Interpolated images using bicubic interpolation, NEDI [2], SAI [3] and the proposed method.

4. Conclusion

In this paper, we presented a novel interpolation method which is based on image fusion. Considering the pixel value difference and structural difference of HR images, artifacts caused by different interpolation methods were detected and removed based on image fusion. Experiments demonstrated that the proposed method is simple yet effective in removing artifacts caused by different interpolation methods. However, for images without small-scale features, the proposed method may reduce to the SAI interpolation method. How to solve this problem can be further researched. Furthermore, we would like to investigate whether the proposed method can be applied to improve other interpolation methods.

Acknowledgements

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