

Wavelet Transform Based Image Interpolation Using PBP Cubic and Hybrid Filter

Su Young Han

*Dept. of Computer Science, Anyang University, 102 Samsungli, Buleunmyun,
Ganghwagun, Incheon, Korea, 417-833
syhan@anyang.ac.kr*

Abstract

In this paper, a new wavelet based image interpolation algorithm using pixel-by-pixel (PBP) cubic image interpolation and hybrid filter is proposed for images which include many mid and high frequency elements. There is much important information in frequency bands. Because conventional interpolation techniques have blurring or blocking effects, the quality of interpolated remote sensing images is not good over that of standard test images. The proposed interpolation technique uses PBP, DWT and hybrid filter to address these problems preserving thin lines and edges information. Simulation result shows that the proposed technique outperforms the conventional techniques in terms of PSNR.

Keywords: *interpolation, wavelet transform, hybrid filter, PBP cubic interpolation*

1. Introduction

Wavelets are playing a significant role in many image processing applicants. Image interpolation using wavelet transform is a relatively new subject and can enhance the high frequency information effectively [1-2].

Image interpolation algorithms obtain a high-resolution image from the available low-resolution image. It is applied when the image need to be resized or remapped from one pixel grid to another. A good interpolation method can improve the quality of the image. However conventional linear interpolation techniques cannot enhance the contrast and smooth edges simultaneously, including nearest neighbor interpolation [3], bilinear interpolation [4] and bicubic interpolation [5]. The resulting image may be inevitably blurred, and sometimes have block effects. Therefore in the case of remote sensing images that the edges or high frequency elements have importance, the quality of the interpolated images is noticeably poor over the standard images.

In this paper, we propose an interpolation technique using pixel-by-pixel (PBP) cubic interpolated DWT high-frequency subband images and input low-resolution image. The PBP cubic interpolation is based on optimizing the standard cubic image interpolation formula at each estimated pixel [6]. Thus the mean square error (MSE) in the entire image is minimized. Inverse DWT has been applied to combine all these images. In order to achieve a sharper image, we use hybrid-filter.

The remainder of this paper is organized as follows. Section 2 introduces the proposed waved based interpolation technique. Section 3 discusses the quantitative results of the proposed method with the conventional interpolation techniques. Conclusions are given in Section 4.

2. Proposed Image Interpolation

2.1. Proposed Algorithm

The schematic diagram of our proposed algorithm can be seen in Figure 1. After pixel-by-pixel cubic interpolation is carried out on original image, the result image is wavelet decomposed. While the three high frequency component images are maintained, a low frequency component image is substituted with interpolated image. Inverse DWT is carried out on these subband images.

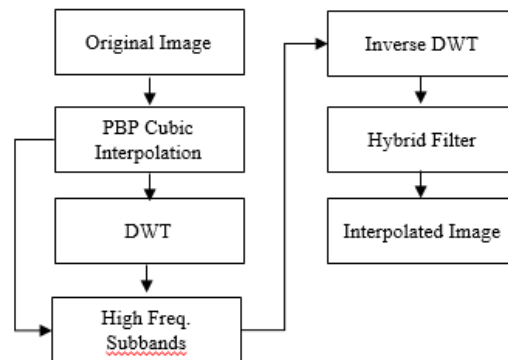


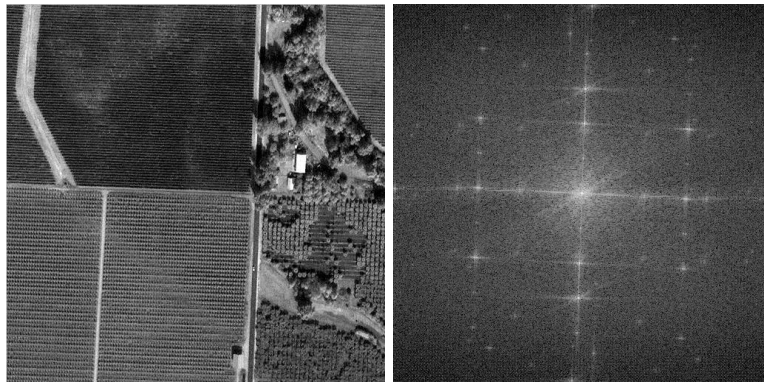
Figure 1. Block Diagram of the Proposed Algorithm

2.2. Characteristic of Remote Sensing Images

Figure 1 shows the results after 2D FFT of standard test images and remote sensing images. In the result of 2D FFT, the center of the figure is the origin of the frequency coordinate system. The u-axis runs center to right and represents the horizontal component of frequency. The v-axis runs center to top and represents the vertical component of frequency. In both cases there is a dot at the center that represents the (0, 0) frequency term or average value of the image. Images usually have a large average value and lots of low frequency information so FFT images usually have a bright blob of components near the center. But because of many high frequency components such as lines, remote sensing images have bright dots away from center in the vertical direction and horizontal direction [7-8]. The characteristic of high frequency of remote sensing images can easily be found by comparison with standard images.



(a) Barbara Image and the Result of 2D FFT



(b) Fresno Image and the Result of 2D FFT

Figure 2. Comparison of Standard Images and Remote Sensing Images

2.3. Space Varying PBP Cubic Image Interpolation

The pixel by pixel (PBP) cubic interpolation algorithm has been proposed in [6]. The previous cubic image interpolation formula is as follows [9].

$$l(x_{k+1}) = g(x_{n-1})[as^3 - 2as^2 + as] + g(x_n)[(a+2)s^3 - (3+a)s^2 + 1] + g(x_{n+1})[-(a+2)s^3 + (2a+3)s^2 - as] + g(x_{n+2})[-as^3 + as^2] \quad (1)$$

where $l(x_{k+1})$ is the value of the sample to be estimated and $g(x_n)$ is the equally spaced data and a is a parameter that controls the rate of decay of the cubic interpolation basis function and s is the distances between x_{k+1}, x_n and x_{n+1} as :

$$s = x_{k+1} - x_n, 1 - s = x_{n+1} - x_{k+1} \quad (2)$$

Equation (1) has two main controlling parameters s and a which can be optimized to give the best interpolation results.

2.4. 2D Discrete Wavelet Transform

Wavelet transform is an excellent tool for digital image processing and analyzing. 2D wavelet decomposition of an image is performed by applying the 1D DWT along the rows of the image first, and then along the column of the image. This 2D wavelet decomposition will make four decomposed subband images referred to LL, LH, HL, and HH. All those four subbands cover the full frequency band of the original image [10-12].

Figure 3 shows the 3-level wavelet decomposed Barbara image. In Figure 3, the image in low frequency subband is quite similar to original image because it is approximation of original image. The images in high frequency subbands are edges in vertical, horizontal, diagonal direction and similar Figures.



Figure 3. Wavelet Decomposition of Barbara Image

Wavelets interpolation is based on pixel-by-pixel cubic interpolation. Suppose that the required magnification factor is 2. Wavelet decomposition is carried out on a result amplified with the pixel-by-pixel cubic interpolation method, thus the low frequency component image LL and three high frequency component images: horizontal direction HL, vertical direction LH and diagonal direction HH.

Suppose that $I_{bicubic}$ is the pixel-by-pixel cubic interpolated image of the original image, I . Wavelet transform is carried out on the result. It is denoted as.

$$[LL, HL, LH, HH] = DWT2D(I_{bicubic}) \quad (3)$$

Where LL denotes the low frequency band, HL, LH, HH, respectively, denoted the high frequency bands along the horizon, vertical and diagonal direction.

$$I_{output} = IDWT2D(I_{bicubic}, HL, LH, HH) \quad (4)$$

Where I_{output} is the result of wavelet interpolation.

Compared to other existing interpolation methods, our proposed method seems to enhance the high frequency information and to reduce the undesirable artifacts, such as blurring, ringing, block effects and edge distortion.

2.5. Hybrid Filtering

We use hybrid filter to extract the noise distortion that was added to the image. This hybrid filter consists of the median filter and the wiener filter to reduce white Gaussian noise and impulse noise respectively. It efficiently removes Gaussian and impulse noise from digital images while preserving thin lines and edges in the original image [13-15].

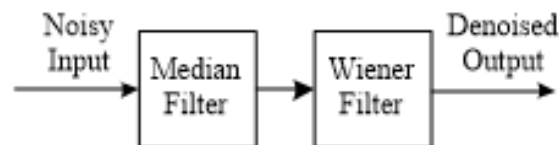


Figure 4. Structure of Hybrid Filter

3. Experimental Results

In this section, experimental results for 512 x 512 images, Fresno (Figure 5), Barbara (Figure 6), Boats (Figure 7) and Airfield (Figure 8) are summarized in Table 1 for comparing other result. Aerial photograph images (Figure 5 and Figure 8) are usually composed simplified and recursive geometrical structures such as rectangular, circles,

lines and groups of points by high altitude view. Two-dimensional 9/7 tab biorthogonal wavelet filter is used for wavelet decomposition.

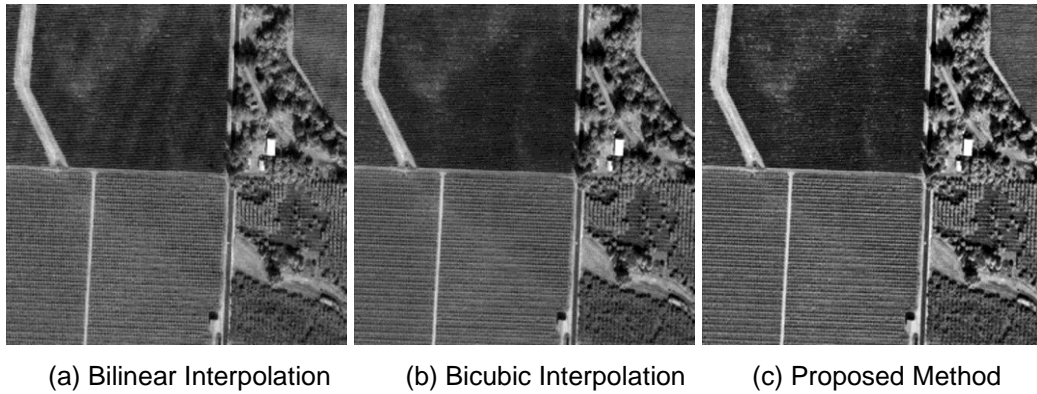


Figure 5. The Results of Fresno Image

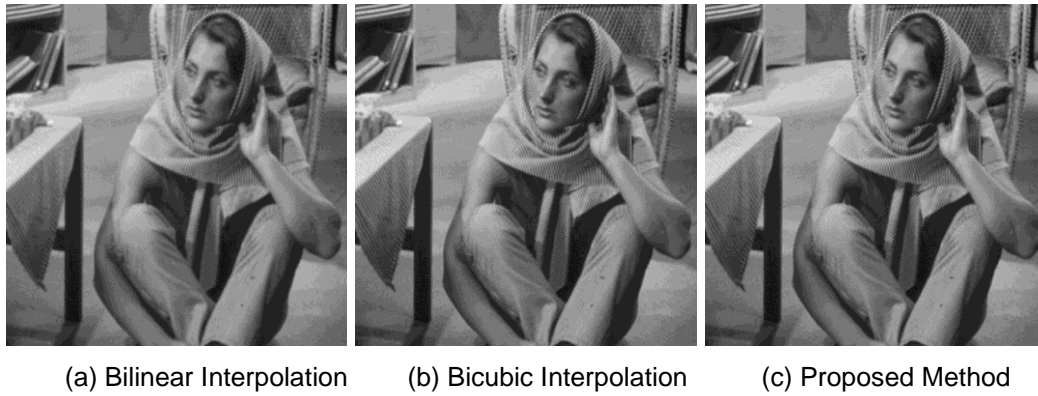


Figure 6. The Results of Barbara Image

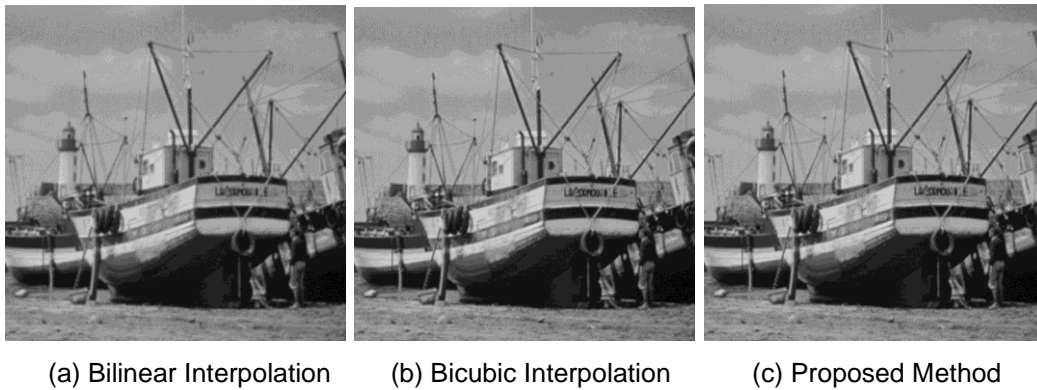


Figure 7. The Results of Boats Image

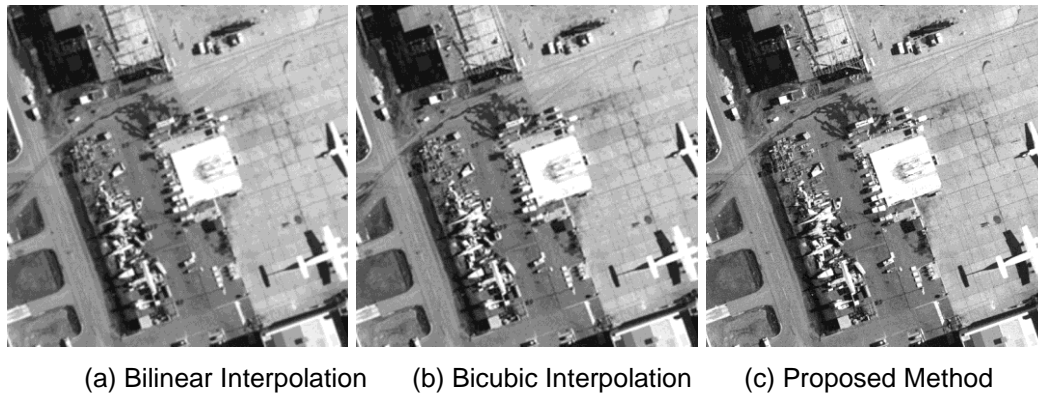


Figure 8. The Results of Airfield Image

In Figure 5 ~ Figure 8, a comparison of the suggested algorithm performance with other different interpolation techniques including bilinear interpolation and bicubic interpolation. Experimental results show that bilinear interpolation often causes block effects, while bicubic interpolation suffers from the blurring problem in edge regions. The result from the proposed algorithm exhibits a better performance. This method can eliminate zigzagging artifact efficiently and smooth the inside of a region.

Table 1 represents the measured PSNR in all the algorithms, these results shows the superiority of the proposed model compared to the other algorithms. We use Peak Signal-to-Noise Ratio (PSNR) to compare image I_1 (original image in higher resolution) and Image I_2 (interpolated image). PSNR is calculated according to:

$$PSNR(I_1, I_2) = 20 \log_{10} \left(\frac{255}{MSE} \right) \quad (5)$$

Where MSE is the Mean Squared Error given by:

$$MSE = \frac{1}{N^2} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} [I_1(i, j) - I_2(i, j)]^2 \quad (6)$$

Where N is width and height of compared images.

Table 1. The PSNR (Db) Results for Various Interpolation Methods

	Boats	Airfield	Barbara	Fresno
Bilinear interpolation	26.85	23.67	23.90	21.41
Bicubic interpolation	27.32	23.92	24.08	21.97
Proposed method	30.02	25.42	25.49	24.22

Table 1 shows that in the conventional techniques, the PSNR values of remote sensing images (Fresno and Airfield) with many high frequency components are lower than that of standard image (Boats). The PSNR of proposed method is too, but image quality improvement degree is relatively high. The proposed method shows 0.81dB higher performance in Boats and 1.7dB higher performance in Fresno.

4. Conclusions

In this paper, a new wavelet based image interpolation algorithm is proposed for images with many high frequency components. Remote sensing images such as aerial and satellite photograph images include many mid and high frequency elements. These frequency elements contain important information. We apply the wavelet transform on pixel-by-pixel cubic interpolated image and hybrid filter to maintain information about

high frequency of images. From experimental results, it is shown the proposed method is simple and higher performance than the conventional method for images which include many high frequency elements such as satellite photograph images.

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Author



Su Young Han, received the B.S., M.S. degree and Ph. D degree from Hanyang University, Seoul, Korea in 1991, 1993 and 2004 respectively, all in electronic engineering. Currently, he is a professor of Department of Computer Science at Anyang University, Korea. His interests include multidimensional signal processing, wavelets, coding and watermarking.

