COMPARATIVE STUDY OF THE INTERPOLATION TECHNIQUES USED FOR ENHANCEMENT OF IMAGES

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Abstract— Image enhancement is the method by which we try to develop an image so that it looks subjectively better. We do not really know how the image should look, but we can tell whether it's appearance has been improved or not. I.e. whether more detail can be seen, or whether unwanted flickering has been removed, or the contrast is made better etc. Image enhancement is needed in various fields. A vital aspect of image quality is its resolution. Interpolation in image handling is a familiar method to increase the resolution of a digital image. The technique resolution enhancement is used as a process that enlarges the given input in the way that the output is sharper. In the paper, basic techniques for image resolution enhancement using interpolation are compared, concluding bicubic to give better results than nearest neighbor and bilinear.

Keywords— Discrete Wavelet Transform, Stationary Wavelet Transform, Interpolation, Kriging, B-splines.

I. INTRODUCTION

In digital processing applications, Image Enhancement is quiet useful and effective technique. It's used to process an image so as to improve the appearance of image, making it more suitable than original image for a specific application. Digital image enhancement technique improves the visual quality of image. Many of the medical images, aerial images, satellite images, real life photos suffer from issue of poor contrast and noise. Using appropriate image enhancement technique, we need to enhance the contrast and remove noise from image so as to increase its quality. Image Enhancement is applied in fields like medical diagnosis, remote sensing, agriculture, geology, oceanography and many more. The image enhancement techniques can be spatial domain method or frequency domain method. The spatial domain methods are the procedures that can directly operate on pixels composing an image. Fourier domain methods compute Fourier transform of an image, multiply the result by filter, take inverse transform to produce enhanced image. Interpolation is a technique that is used to enhance an image. Resolution is an important aspect to enhance an image.

Interpolation is the technique used to enhance the resolution of an image. Using Interpolation, a low resolution image can be converted to high resolution image. We can hence view the image with high clarity. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple description coding, and super resolution. Image interpolation is the process of transferring image from one resolution to another without losing image quality. There are different interpolation techniques like nearest neighbor, bilinear, bicubic, B-splines, lanczos2, discrete wavelet transform, Kriging. Various applications of interpolation include image resizing, image zooming, image enhancement, image reduction, sub pixel image registration, image decomposition, image shrinking, rotating, geometric corrections and to correct spatial distortions and many more. It can be used to resample the image either to decrease or increase the resolution. Interpolation techniques are mainly divided in two categories: 1. Non-adaptive techniques 2. Adaptive techniques. Non-adaptive techniques are based on direct manipulation of pixels rather than considering the content of image. Nearest neighbor, bilinear, bicubic are all non-adaptive techniques. These techniques follow the same pattern for all the pixels. These are easy to implement. Adaptive techniques consider image feature like intensity value, edge information, texture etc. Examples for adaptive techniques include New Edge Directed Interpolation, Data Dependent Triangulation, Iterative Curvature based interpolation. In this paper, the non-adaptive techniques are explained in details.

In image resolution enhancement by using interpolation, the main loss is on its high frequency components (i.e., edges), which is due to the smoothing caused by interpolation. In order to increase the quality of the super resolved image, preserving the edges is essential. DWT[1] can be employed in order to preserve the high frequency components of the image. For questions on paper guidelines, please contact us via e-mail.

II. LITERATURE SURVEY

Resolution is a major issue in satellite images. In [1], H. Demirel et.al. have proposed a satellite image resolution technique. They initially applied DWT to the input image, and then applied Interpolation technique to the high frequency sub band images, thus achieving sharper images. The authors in [2] proposed an image resolution enhancement technique based on interpolation of the high frequency subband images obtained by discrete wavelet transform (DWT) and the input image. The edges are enhanced by introducing an intermediate stage by using stationary wavelet transform (SWT). The estimated high frequency subbands are modified by using high frequency subband obtained through SWT. Then all these subbands are combined to generate a new high resolution image by using inverse DWT (IDWT). In [3], a satellite image resolution enhancement technique based on interpolation of the high-frequency subband images obtained by dual-tree complex wavelet transform (DT-CWT) is proposed. On decomposing the input image, H. Demirel et.al interpolated the high frequency sub band image and the input image, further combined all these images by using inverse DT-CWT.

III. INTERPOLATION METHODS

Interpolation in image processing is a method to increase the number of pixels in a digital image. Interpolation works by using known data to estimate values at unknown points. Interpolation happens in both the directions. It tries to achieve a best approximation of pixels color and intensity based on the values at surrounding pixels. Interpolation also occurs each time one rotates or distorts an image.

A. Nearest Neighbor Interpolation

It is the simplest interpolation technique. In this method each interpolated output pixel is assigned the value of the nearest sample point in the input image. Rather than calculating an average value by some weighting criteria or generate an intermediate value based on complicated rules, this method simply determines the "nearest" neighboring pixel, and assumes the intensity value of it. It assigns to each new location the intensity of its nearest neighbor in the original image.

Suppose we need to interpolate the point (u,v). Consider four neighboring points (i, j) , (i, j + 1) , (i+ 1, j) and (i+ 1,j + 1) with their intensity values f(i, j), f(i, j + 1) , f(i+ 1, j) and f(i+ 1,j + 1) respectively. The distance between (u,v) and (i, j), (i, j + 1) , (i+ 1, j) and (i+ 1,j + 1) should be calculated, then the values of (u,v) should be set as the value of the point which is nearest to (u,v).

Nearest Neighbor Interpolation has the tendency to produce undesirable artifacts, such as severe distortion of straight edges. For this reason, it is used infrequently in practice.

B. Bilinear Interpolation

A more suitable approach is bilinear interpolation, in which we use the four nearest neighbors to estimate the intensity at a given location. Bilinear interpolation is an extension of linear interpolation for interpolating functions of two variables (e.g., *x* and *y*) on a rectilinear 2D grid. The key idea is to perform linear interpolation first in one direction, and then again in the other direction. Although each step is linear in the sampled values and in the position, the interpolation as a whole is not linear but rather quadratic in the sample location. Bilinear interpolation considers the closest 2 by 2 neighborhood of known pixel values surrounding the unknown pixel. It then takes the weighted average of these four pixels to arrive at final interpolated value. This results in much smoother interpolated image than nearest neighbor. In the given figure, P is the desired point, Q stands for four closest known points, R is the point on the line with known points. The point P is interpolated using following formula.

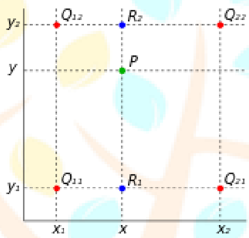

Figure 1: Bilinear Interpolation

$$P \approx \frac{(x_2-x)(y_2-y)}{(x_2-x_1)(y_2-y_1)}Q_{11} + \frac{(x-x_1)(y_2-y)}{(x_2-x_1)(y_2-y_1)}Q_{21} + \frac{(x_2-x)(y-y_1)}{(x_2-x_1)(y_2-y_1)}Q_{12} + \frac{(x-x_1)(y-y_1)}{(x_2-x_1)(y_2-y_1)}Q_{22} \qquad (1)$$

Bilinear interpolation gives much better results than nearest neighbor interpolation, with a modest increase in computational burden. This algorithm reduces some of the visual distortion caused by resizing an image to a non-integral zoom factor, as opposed to nearest-neighbor interpolation, which will make some pixels appear larger than others in the resized image.

C. Bicubic Interpolation

When Bicubic interpolation is performed, we are generating a smooth surface that interpolates data points on a 2D grid. The interpolated dataset is smooth in the x-direction, y-direction, and the xy-direction. For any point in our interpolated data set, we should be able to compute not only the intensity (ie: height/grayscale) value, but also it's derivative in any direction along x, y, or xy. It involves the sixteen nearest neighbors of a point. Bicubic interpolation solves for the value at a new point by analyzing the 16 data points surrounding the interpolation region. Initially, a cubic must be defined for each row of the 4x4 pixel region using following formula.

$$R_i = A_i x^3 + B_i x^2 + C_i x^1 + D_i \qquad (2)$$

The values of *x* relative to the current location are inserted into the cubic and solved for each of the 4 pixels in the row. This develops a system of linear equations that can be used to solve for the coefficients $A - D$. The solution for the first row is calculated as below with points are -1,0,1,2.

$$Z_{11}=A_1(-1)^3+B_1(-1)^2+C_1(-1)^1+D_1$$
$$Z_{12}=A_1(0)^3+B_1(0)^2+C_1(0)^1+D_1$$
$$Z_{13}=A_1(1)^3+B_1(1)^2+C_1(1)^1+D_1$$
$$Z_{14}=A_1(2)^3+B_1(2)^2+C_1(2)^1+D_1$$

where the value of Z_{ij} is the pixel intensity. Rewriting these equations in matrix form gives:

$$[A_1\ B_1\ C_1\ D_1].\begin{bmatrix} x_1^3 & x_2^3 & x_3^3 & x_4^3 \\ x_1^2 & x_2^2 & x_3^2 & x_4^2 \\ x_1^1 & x_2^1 & x_3^1 & x_4^1 \\ 1 & 1 & 1 & 1 \end{bmatrix} = [Z_{11}\ Z_{12}\ Z_{13}\ Z_{14}] \qquad (3)$$

Since the offsets of are consistent for all four rows, all four rows can be solved for simultaneously as:

$$\begin{bmatrix} A_1 & B_1 & C_1 & D_1 \\ A_2 & B_2 & C_2 & D_2 \\ A_3 & B_3 & C_3 & D_3 \\ A_4 & B_4 & C_4 & D_4 \end{bmatrix} \cdot \begin{bmatrix} x_1^3 & x_2^3 & x_3^3 & x_4^3 \\ x_1^2 & x_2^2 & x_3^2 & x_4^2 \\ x_1^1 & x_2^1 & x_3^1 & x_4^1 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{bmatrix} \qquad (4)$$

For simplicity, this is rewritten in shorthand notation as: $[C_R].[X] = Z$

where $[\mathbf{C_R}]$ is the cubic coefficients for the four rows, $[\boldsymbol{Z}]$ is the pixel intensity values for the surrounding pixels and $[\boldsymbol{X}]$ is a constant array of offsets as given below. The coefficients of the row cubics can be solved using $[C_R] = [Z].[X^{-1}]$.

$$[X] = \begin{bmatrix} -1^3 & 0 & 1^3 & 2^3 \\ -1^2 & 0 & 1^2 & 2^2 \\ -1^1 & 0 & 1^1 & 2^1 \\ 1 & 1 & 1 & 1 \end{bmatrix} \qquad X^{-1} = \begin{bmatrix} -\frac{1}{6} & \frac{1}{2} & -\frac{1}{6} & 0 \\ \frac{1}{2} & -1 & -\frac{1}{2} & 1 \\ -\frac{1}{2} & \frac{1}{2} & 1 & 0 \\ \frac{1}{6} & 0 & -\frac{1}{6} & 0 \end{bmatrix}$$

$$[Y] = \begin{bmatrix} -1^3 & -1^2 & -1^1 & 1 \\ 0 & 0 & 0 & 1 \\ 1^3 & 1^2 & 1^1 & 1 \\ 2^3 & 2^2 & 2^1 & 1 \end{bmatrix} \qquad Y^{-1} = \begin{bmatrix} -\frac{1}{6} & \frac{1}{2} & -\frac{1}{2} & \frac{1}{6} \\ \frac{1}{2} & -1 & \frac{1}{2} & 1 \\ -\frac{1}{3} & -\frac{1}{2} & 1 & -\frac{1}{6} \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

Our final aim is to compute P using the following equation. Further compute P_x and P_y using the given equations.

$$P = f(x,y) = [P_y][Y^{-1}][Z][X^{-1}][P_x] \qquad (5)$$

where Z is the given matrix whose data at point f(x,y) has to be interpolated.

$$P_x = [x^3 \;\; x^2 \;\; x^1 \;\; x^0]' \;\; \text{and} \;\; P_y = [y^3 \;\; y^2 \;\; y^1 \;\; y^0] \qquad (6)$$

Bicubic spline interpolation is a special case of generalized bicubic interpolation. One has to carry out 1D cubic spline interpolation along each axis.

IV. RESULTS AND DISCUSSION

We have used DWT to decompose the given low resolution image into sub bands. We get four different sub bands. To each of these sub bands, interpolation is applied. Following are the results for applying nearest, bilinear, bicubic interpolation techniques one by one to all the four bands. Bicubic interpolation is more sophisticated than the other two techniques; it produces smoother edges. The system has been tested on several different images like airport, railway stations, commercials, forest, industrial, parking etc.

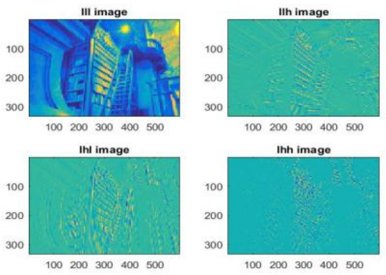

Figure 2: Output of Nearest Neighbor Interpolation applied to 4 frequency frequency Interpolation applied to 4 components.

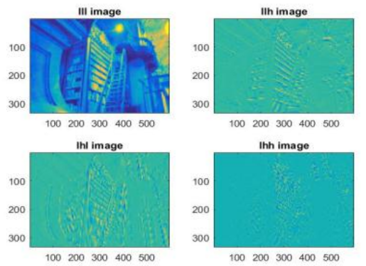

Figure 3: Output of Bilinear Interpolation applied to 4 frequency components

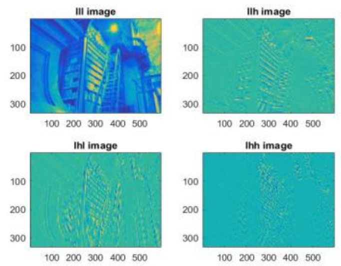

Figure 4: Output of Bicubic Interpolation applied to 4 frequency components

V. CONCLUSION

In this paper, we have seen various interpolation techniques that can be used for image enhancement. In order to increase the quality of the super resolved image, preserving the edges is essential. DWT is employed in this work so as to preserve the high frequency components of the image. Thus, image resolution enhancement technique is based on the interpolation of the frequency subbands obtained by DWT. All the three interpolation techniques were applied to the frequency bands. Bicubic interpolation is more sophisticated than the other two techniques; it produces smoother edges. This work is restricted to the comparison of interpolation techniques. In future, the work will be extended to generate super resolved image.

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