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A Combination Technique of Multi-wavelets and Interpolation for Resolution Enhancement of Digital Images

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***Abstract*— This paper explains the effect of various multi-wavelet interpolation methods on digital images to enhance the resolution of the images. A high resolution image is a major challenge for any image processing application, especially in defense and medical scenario. Here resolution enhancement technique is done in wavelet domain using multi-wavelets and interpolation methods. Visual perception of an image has to be improved by various enhancement techniques since the hardware image acquisition methods drops to a limit. Some spectral and spatial problems such as motion blur, pixilation and poor perception may still prevail in digital images which requires rectification before processing further. The Super Resolution images are generated by applying enhancement techniques on a set of noisy and blurred low resolution images . In this paper, some of the resolution enhancement techniques such as Discrete Wavelet Transform, Stationery Wavelet Transform and a combination of DWT and SWT with various interpolation techniques are experimented. The DWT-SWT with Bilinear interpolation method illustrates the improvement in the resolution factor of the image, thereby improving the visual perception of images**

***Keywords*— Discrete Wavelet Transform, Stationary Wavelet Transform, Inverse Discrete Wavelet Transforms, High Resolution, Low Resolution, Interpolation techniques .**

I. INTRODUCTION

Digital image plays a vital role in this technological world. The priority of image processing spans over wide area in our routine life especially in medical applications. Other areas of application includes satellite image processing for geographical studies, weather forecasting, industrial inspection for defective manufactured parts and in Defense. Most of the images are obtained from low cost imaging sensors (such as cell phones or surveillance cameras) which are not sufficient for an application. Since Digital images are a discrete representation of its continuous signals perceived through our eyes or any imaging sensor, it requires a preprocessing mechanism to improve its perception. So enhancement of images has become a major challenge in image processing area of research. Resolution enhancement of satellite images has become an area of concern. Thus, increase in the resolution of an image affects the system performance.

There is an affective loss of high frequency components while applying spatial interpolation techniques. This is mainly due to the smoothening effect of interpolation. This can be rectified to some extent by noise removal, which may not give the desired output. It has to undergo various other processes such as blur removal or contrast enhancement.

An important aspect of an image is its resolution which refers to the number of pixels it constitutes. The processing of an image is done in order to obtain more enhanced resolution. The details contained in an image is defined by the resolution of an image. The higher the resolution, the more image details.. Spatial techniques are used for changing the gray level values of the individual pixels and hence enhance the overall quality of the image. Frequency domain techniques[1] are adapted for image processing in terms of frequency contents.

II. INTERPOLATION METHODS

Interpolation [2] ,[14] is a technique to enhance the continuous function values obtained from discrete samples. This technique is used to find the missing values so as to obtain clearer pixel information of a digital image. Interpolation techniques play important role to define many image processing applications such as image decompression, sub-pixel image registration, image resolution enhancement etc.

A.Nearest neighbor interpolation

The nearest neighbor[3] algorithm selects the value of the adjacent points and does not consider the values of neighboring points at all instead it yields a constant interpolant. The algorithm is very simple to implement and has applications in real-time 3D rendering to choose color values for a textured surface.

B.Bilinear Interpolation

The closest four pixel coordinate is taken into account and assigns that value to the output coordinates. Initially, two interpolations are performed linearly in one direction (horizontally) and then another linear interpolation is performed in the perpendicular direction. The number of grid points needed to evaluate the interpolation function for one- dimensional Linear Interpolation[2], is two and for Bilinear Interpolation[3] it is four. Bilinear Interpolation produces an image of smoother appearance than nearest neighbor interpolation, but the grey levels are altered in the process, results in blurred images[2].

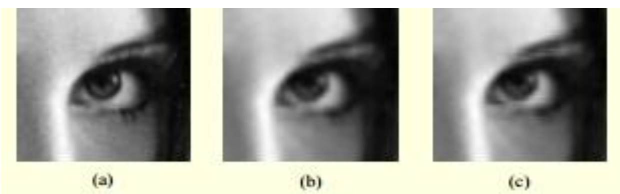

Fig1: a) original image. b) bicubic interpolated Image c) bilinear interpolated image

C.Bicubic interpolation

Bicubic interpolation[3],[15] is sophisticated and produces smoother edges than bilinear interpolation. The computational time of bicubic interpolation is more than the other two methods. A new pixel is a bicubic function of 16 pixels in the nearest 4 x 4 neighborhood of the pixel in the original image The image is slightly sharper than that produced by Bilinear Interpolation, and it does not have the disordered appearance produced in Nearest Neighbor Interpolation. Initially four one-dimension cubic convolutions are performed in one direction and then one more one-dimension cubic convolution is performed in the perpendicular direction. Thus to implement a two dimension cubic convolution, a one-dimension cubic convolution is needed.

III.PROPOSED METHODOLOGY

A.Discrete Wavelet Transform (DWT)

Discrete Wavelet Transform (DWT) [5],[11] is most widely used technique for performing image interpolation [3]. DWT use filter banks and special wavelet filters for the analysis for the reconstruction of the multi- resolution time frequency plane [8]. In this paper , it is explained how DWT is used to decompose a low resolution image into 4 subband images LL, LH, HL and HH. All low and high-frequency components of image are then interpolated. Then a difference image is obtained by subtracting LL image from the original LR image. Resulting image is then added to the interpolated high frequency components to obtain estimated form of HF subband images. Finally IDWT used to combine these estimated images along with the input image to obtain high resolution images [3].

B. DWT-SWT

DWT-SWT stands for Discrete wavelet transform - Stationary wavelet transform. In this technique DWT is used in order to preserve the high frequency components of the image (stationary wavelet transform uses high and low pass filters [8]). The DWT and SWT [7] are used to decompose the input image into different subbands. In this technique DWT is used in order to preserve the high frequency components of the image [8]. But because of DWT, information loss occurs due to the down sampling in each sub-band. Hence to minimize this loss SWT is employed.
The corresponding one level DWT is used to decompose an input image into different sub-band images. In that four coefficients LL is approximation image and remaining three are horizontal (LH), vertical(HL) and Diagonal(HH). High frequency sub-bands (LH, HL, and HH) will contain the high frequency components of the input image. In this project we propose bicubic interpolation with enlargement factor if 2 is applied to high frequency sub-band images. On those sub-bands we are applying the down sampling. In each of the DWT sub-bands, information loss is occurred in the respective sub-bands. That is why SWT is use to minimize these losses.

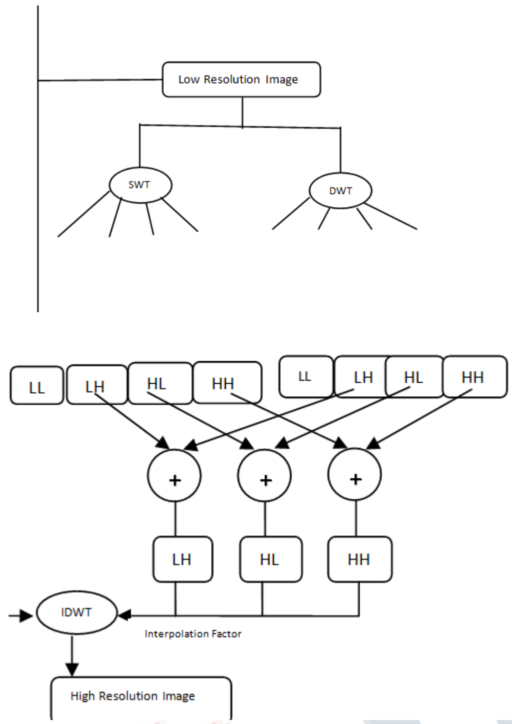

Fig2: the flowchart for generating high resolution from low resolution images using DWT-SWT

The high frequency interpolated sub-bands and the SWT[3] high frequency sub-bands have the same size which means that the same size can be added with each other. Then the corrected high frequency sub-bands can be interpolated for higher enhancements. It is known that in the wavelet domain, the low resolution image is obtained by low pass filtering of high resolution image. Instead of using the low frequency sub-bands which contains less information than the original high resolution images; here we are using the input image for the interpolation of the low frequency sub-band images. The input image by N/2 and high frequency sub-bands by 2 and N in the intermediate and final interpolation stages respectively and then applies IDWT as illustrated in the fig2. If the output image getting sharper edges then directly apply the interpolation of the input image. Due to the fact of interpolation is isolated high frequency components are in high frequency sub-bands corrected by adding the high frequency sub-bands of SWT of the input image will preserve more high frequency components after the interpolation than interpolating input image directly.

IV . RESULTS AND DISCUSSIONS

Performance analysis of various resolution enhancement algorithms in wavelet domain is measured in terms of metrics such as PSNR, MSE , RMSE and ENTROPY. The performance values are tabulated as in Table 1. Multi-wavelet transform yields better output than other methods

Methods	**MSE**	**RMSE**	**PSNR(db)**	**ENTROPY**
WZP	0.0467	0.2161	32.2722	3.4598
CS	0.0706	0.2658	27.4267	2.7994
DWT/BILINEAR	0.0387	0.1966	32.8275	5.9913
DWT/NEAREST NEIGHBOUR	0.0342	0.1849	34.0733	5.7438
DWT/BICUBIC	0.0825	0.2872	26.6816	2.9862
DWT-SWT	**0.042**	**0.0021**	**38.086**	**3.58**

V.CONCLUSION

This paper discusses about improvement in the resolution of digital images based on the multi-wavelet transform using interpolation techniques. The quantitative metrics (PSNR, MSE, entropy) of the image calculated shows the superiority of DWT-SWT technique. For achieving visually acceptable HR images, image enhancement algorithm provides wide range of approaches. Based on the image type and noise type with which it is corrupted, a slight change in individual method or combination of any methods further improves visual quality. Here we have experimented recent development methods of image enhancement and pointed out the area of research for image enhancement in spatial domain. The future scope will be the development of adaptive algorithms for effective image enhancement using Fuzzy Logic and Neural Network and curvelet enhancement techniques.

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