Review on Enhancement Techniques of Images

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Abstract - ***Most of the images in the real world suffer from blurriness due to their low frequencies. Images may also be affected by a number of factors such as noise, absorption, distortion, artifacts, faulty scanning, improper transmitting devices etc. Therefore, in order to attain an image with higher resolution, image resolution enhancement is used as it is an important technique in the area of image processing. Image enhancement using wavelet transform is needed in modern times to produce a high quality image with finer and well-defined edges. Image resolution enhancement is the most important as they produce a sharper and finer image than other techniques. Enhancement of an image also involves the improvement of the number of pixels that are used to represent the image. This paper studies various wavelet transformation techniques such as: Wavelet Zero Padding, Wavelet Zero Padding with Cycle Spinning, Stationery Wavelet Transform, Discrete Wavelet Transform, Dual Tree Complex wavelet Transform and Stationery Wavelet Transform-Discrete Wavelet Transform. Each of these techniques takes a low resolution image as input, applies a wavelet transform followed by the inverse of wavelet transform and produces a high resolution image. The transform co-efficients and the interpolation factors are also used in these processes. Out of these, Stationery Wavelet Transform and Discrete Wavelet Transform produce the most efficient results as they produce images of higher resolution without losing any contents. The performance of these techniques can be measured using some performance measures namely: Noise variance, Mean Square Error, Signal-to-noise ratio and Peak Signal-Noise-Ratio. This paper also studies these performance measures.***

Key Words: *enhancement, wavelets, transformation, WZP, WZP-CS, SWT, DWT.*

1. INTODUCTION

In digital image processing, an image is a collection of pixels that represent a physical object or a person. The resolution of an image is the most important area for image processing [21]. It represents the details an image holds. Image processing is the treatment of an image and it takes input in the form of an image and produces image as an output. This includes Image Enhancement, Image Segmentation, Image Compression, Noise Removal, etc [1]. Here image enhancement is a very important technique that is used to process low resolution images in order to attain high resolution images and to obtain a clear image that is much suitable than initial image. The basic goal of image resolution enhancement is to extract the independent information from individual low resolution (LR) image and combine the collected knowledge into a single high resolution (HR) image. The main application area of enhancement is satellite imaging, aerial image processing, medical image processing, ultrasound imaging, infrared imaging, facial image enhancement, text images improvement, fingerprint image enhancement etc [2][3]. The Resolution Enhancement can be classified as:

- *Pixel Resolution:* In this, resolution is measured by the count of pixels in horizontal and vertical direction. It considers the rows and columns of pixels present in the image.

- *Spatial Resolution: It* measures the image resolution in terms of how closely the lines can be resolved in an image [22].

- *Spectral Resolution:* Images may contain different colors. Color images are capable of distinguishing between light of different spectra. The normal color images have lesser spectral resolution than multi spectral images.

- *Temporal Resolution:* It measures the resolution with respect to different points of time as in the case of movie cameras and high speed. The movies generally use time resolution of 24 to 48 frames/sec and high-speed cameras may use 50 to 300 frames/s, or even more.

- *Radiometric Resolution:* It determines the resolution of an image with respect to different intensity values that a system can represent. It is generally expressed as number of levels or bits.

Nowadays, wavelets are a very powerful aspect in many areas of image processing. Resolution enhancement of images using wavelet domain is rapidly growing and in recent times new techniques have been designed. Discrete wavelets transform (DWT) and stationary wavelet transform (SWT) are two fundamental wavelet transforms that are being used in the field of enhancement of images. In *DWT*, the image is decomposed into various distinct sub-band images, namely low-low (LL) sub-band, low-high (LH) sub-band, high-low (HL) sub-band, and high-high (HH) sub-band. *SWT* is identical to *DWT* but there is no down sampling operation performed in *SWT*, but a contrast enhancement of images is done using singular value decomposition (SVD) on low frequency sub-band of both input and histogram equalized images [4][5][7].

2. STUDIED TECHNIQUES

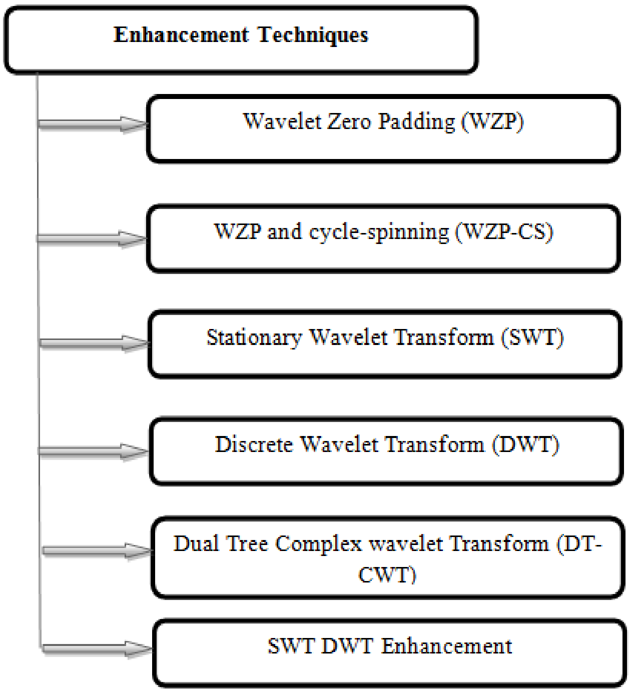

Fig 1.Enhancement Techniques [18]

2.1 Wavelet zero padding (WZP)

Wavelet zero padding is the easiest method for image enhancement which is shown in Fig. 2. First of all, a low resolution image is taken, and then a string of samples with zero values(zero matrix) is attached to the endpoint of the transformed image by ignoring the sub bands of high frequency, using the inverse of wavelet transform and thus the high resolution image is achieved [6].

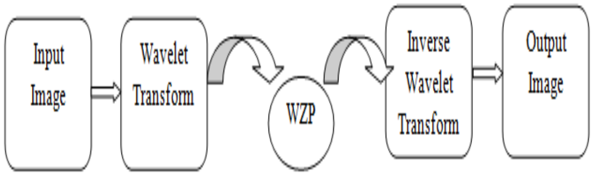

Fig 2.WZP Technique

2.2 Wavelet Zero Padding and cycle-spinning (WZP-CS)

As stated in [2], this follows the WZP technique with an addition as shown in Fig. 3. In this method a high resolution image is attained by adopting the following steps:

i. First of all, a high resolution image is obtained through WZP method that acts as an intermediate image [22].
ii. Using this high resolution image, N images of low resolution are obtained through spatial shifting and wavelet transforming and the high frequency components are discarded [8].
iii. After that, the WZP process is carried upon all these low resolution images to obtain a number of images of high resolution.
iv. Finally, reconstruction of the higher resolution image is taken up by realignment and taking out the average of these intermediate HR images which serves as the final output.

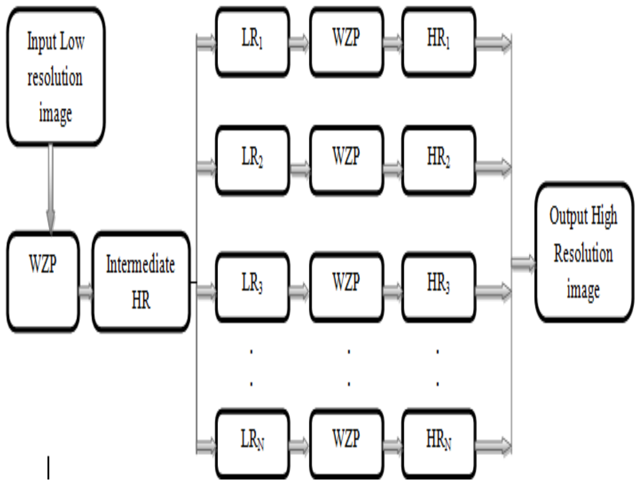

Fig 3.WZP-CS Technique

2.3 Stationery Wavelet Transform (SWT)

The SWT is a redundant scheme of wavelet transformation. It divides the input image into various distinct sub bands as shown in Fig. 4 and there is same number of samples in the output of SWT as that in the input, thus in wavelet coefficients, there is a redundancy of N for N levels. It adopts the following steps:

i. Firstly, the input LR image is subjected to WZP to obtain a high resolution image.
ii. Then SWT is carried upon the estimated HR image which decomposes it into two bands called estimated details and approximation coefficients [9].
iii. Finally, the approximation coefficients are replaced by initially estimated high resolution image and inverse SWT is taken to obtain the final high resolution image [23].

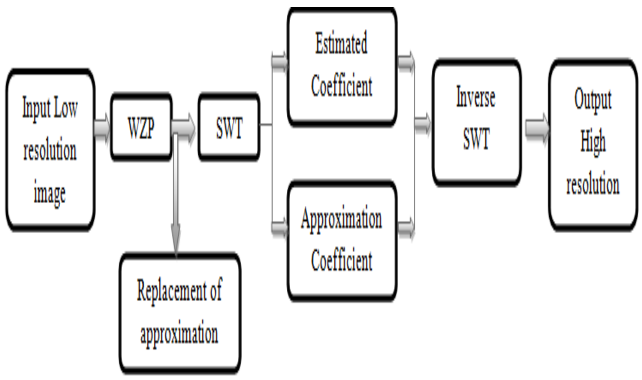

Fig 4.SWT Technique

2.4 Discrete Wavelet Transform (DWT)

DWT approach is the most commonly practiced technique in modern times to enhance a low resolution image. The DWT technique captures both frequency and location information of an image as represented in Fig 5. This technique decomposes a low resolution input image into 4 sub-band images particularly, Low-Low (LL) sub-band, Low-High (LH) sub-band, High-Low (HL) sub-band and High-High (HH) sub-band where the high-frequency components of the input image are embodied into LH, HL, and HH sub-band images. These components of image are then interpolated by bi-cubic interpolation. The LL sub-band image is the low resolution of the initial image. So instead of using LL, the input image is used for interpolation as it contains more information than the LL sub band. The steps followed are:

i. The interpolation of the LR image is done with half of the interpolation factor 'α/2', that helps in the interpolation of the higher frequency sub-bands in order to improve the quality and nature of the image [15][16].
ii. Also the high frequency sub-bands (LH, HL, and HH) are subjected to interpolation with a factor of α.
iii. Then, inverse DWT is exercised to achieve a high resolution output image that contains finer edges than the interpolated image resulting from the direct interpolation of the low resolution initial image[11].

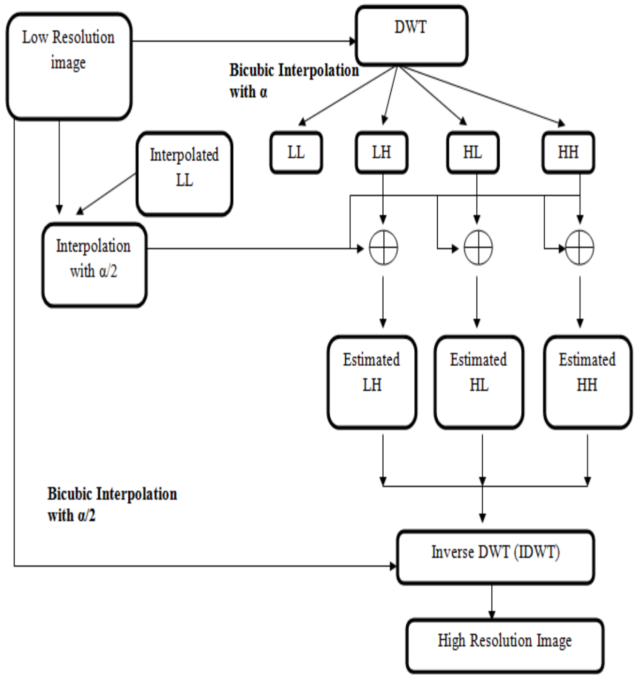

Fig 5.DWT Technique

2.5 Dual Tree Complex Wavelet Transform (DT-CWT) [6]

DT-CWT is far better than the DWT technique as it has better directional sensitivity and exhibits less redundancy as compared to DWT (see Fig 6). Following steps are adopted in this technique:

i. Firstly, the input image with lower resolution is divided into different sub-bands. From these sub-bands produced, the higher-frequency units of the input image are contained in six high-frequency sub-band images.
ii. Then, the sub-band images of high frequency are passed through filters in order to eliminate or reduce the noise present in them [12][13].
iii. After that, the interpolation of the low resolution input image and these sub-band images of high frequency is carried out.
iv. Lastly, the filtered sub-band images of high frequency and the interpolated low resolution image are merged by applying the inverse of DT-CWT to produce an output image of high resolution.

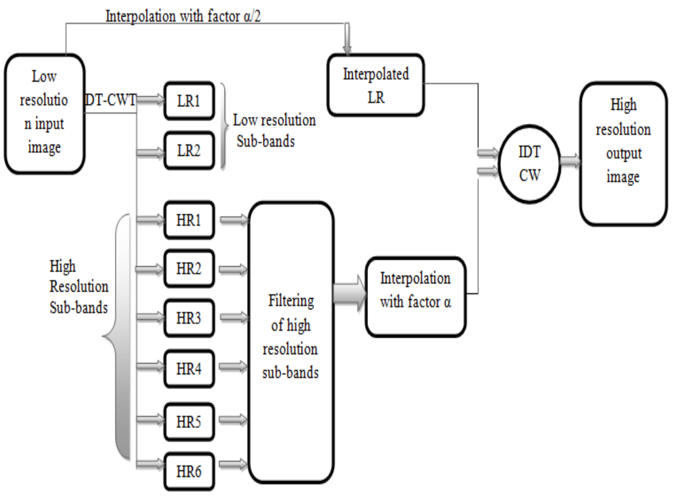

Fig 6.DT-CWT Technique

2.6 SWT DWT Enhancement

The most important part of an image is its edges. But, the biggest failure in enhancement of an image by interpolating it is on its edges are the high frequency units, which occurs because of smoothing caused by interpolation and thus, to improve the nature of the resolved image, it is necessary to retain all the edges/boundaries of the image. In practice, DWT is used for this purpose [14]. Single level DWT is needed to break down the initial image into distinct sub-band images as shown in Fig 7. Out of these sub-bands, the three sub-bands of high frequency namely: HL, LH and HH contain the edges. In this technique,

i. First of all, high frequency sub-band images are subjected to bi-cubic interpolation, by a factor of 2. As a result, the loss of information occurs in the sub-bands due to down sampling. Thus SWT is used to lessen this failure.
ii. The magnitude or the volume of high frequency sub-bands that have been interpolated and the SWT sub-bands of high frequency is equal and thus can be combined with each other [18].
iii. Now, the newly resolved high frequency sub-bands are subjected to interpolation.
iv. The sub-band of lower frequency represents the low resolution of the initial image. Thus, instead of considering low frequency sub-band, that carries a small amount of information than the initial high resolution image, the initial image is used for the interpolating the low frequency sub-band image [19]. This improves the nature of the image that is being resolved.
v. After that, interpolation of the input LR image is done by a factor of 'α/2' and that of sub-bands of high frequency with a factor of 2 and α in intermediary and end phases correspondingly.
vi. Lastly, the Inverse DWT is exercised to obtain the output image that contains finer boundaries than the interpolated image attained by interpolating the input image straightly.

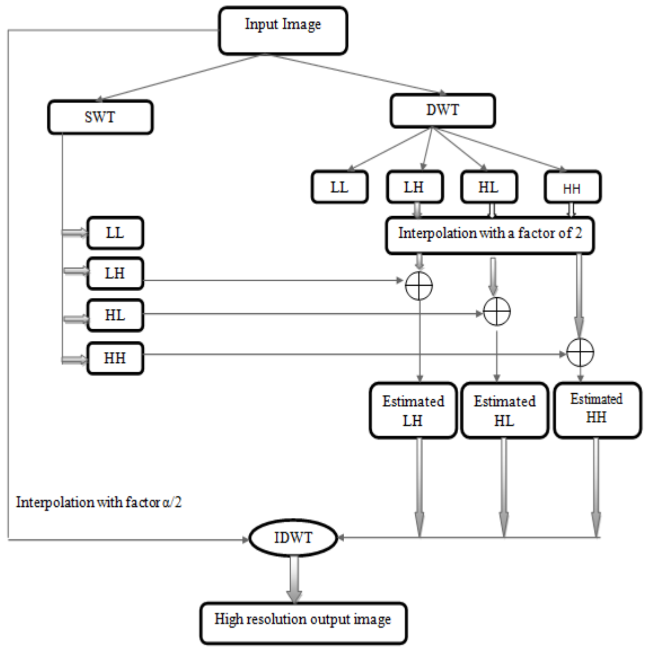

Fig 7.SWT-DWT Technique

3. COMPARISON ANALYSIS

Table-1 Comparison of various Enhancement Techniques

Enhancement Techniques	Advantages	Disadvantages
WZP	Easiest and simplest	Quality may vary
WZP-CS	High resolution image is attained	Information may get lost
SWT	Most Redundant scheme	Image gets distorted
DWT	Produces a highly fine and sharp image	High frequency components are lost
DT-CWT	Minimizes the artifacts	Spectral images can't be handled
DWT-SWT	Combines the benefits of DWT and SWT.	High frequency components may get lost.

4. PERFORMANCE PARAMETERS

4.1 Noise Variance: It measures the amount of the noise or disturbance present in the image. Lesser the variance, sharper and clearer is the image. It is calculated using the below given formula:

$$\sigma = \frac{\sum_{i=0}^{N-1} x_i^2}{N} \quad (1)$$

Here, X represents the original image at N different points.

4.2 Mean Square Error: Usually, the methods adopted for image enhancement, lead to debasement of the resulting image. In order to quantify the image reliability for an image, we calculate the MSE as:

$$\mathrm{MSE} = \frac{1}{N} \sum_{j=0}^{N-1} (Y_j - X_j)^2 \quad (2)$$

Here, X is the original image and Y represents the denoised image.

4.3 Signal-to-noise ratio: It measures the extent of the error with respect to the signal. It is the ratio of the average squared value of the initial image and the Mean Square Error as follows:

$$\mathrm{SNR} = 10 \log_{10}\left(\frac{\sigma_g}{\sigma_e}\right) \quad (3)$$

4.4 Peak Signal-Noise-Ratio (PSNR): It quantifies the error analogous to the peak value of the signal and is computed as:

$$\mathrm{PSNR} = 10 \log_{10}\left(\frac{s^2}{MSE}\right) \quad (4)$$

Here, MSE is the mean squared error value of the original image.

5. CONCLUSION

This paper analyses the performance of different resolution enhancement techniques used to attain a high resolution image from a low resolution image. The enhancement methods not based on wavelets suffer from a disadvantage that higher frequency components get lost. The various performance measures for these techniques have been also discussed and it is observed that images are divided into blocks using wavelet transformation techniques and are refined by applying the inverses on each divided blocks of image and combining those blocks. It can be seen from the proposed approaches that various methods of wavelets are easy to implement and provide a better refined image with less noise ratio.

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