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Image Resolution Enhancement Using DWT And Interpolation Techniques

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Abstract: **Resolution plays an important role in today's world. CCTV footages are used for various investigation purposes by the authorities and government. Resolution of the footages is one of the major issue. This paper proposes one of the resolution enhancement technique which bases the interpolation of the high frequency subbands which are obtained by applying DWT to the low resolution image. The first step goes like the low resolution image is decomposed into Subbands using the DWT technique. Secondly the high Frequency subbands and the low resolution images are interpolated. Finally combining the resultant images applied by the inverse DWT gives us a new resolution enhanced image. An intermediate stage of estimation is introduced for improving the sharpness of the image. The proposed technique have been tested on a few benchmark images. The experimental results show the superiority of the proposed technique over the conventional technique by comparing the PSNR and RMSE values.**

Key words—Discrete wavelet transform (DWT), interpolation, satellite image resolution enhancement, wavelet zero padding (WZP).

I. INTRODUCTION:

Image resolution have always played an important role in image processing applications like feature extraction[2] and resolution enhancement techniques[3]. The image resolution enhancement with the help of wavelets have been a new subject with many algorithms proposed[9]–[15]. The paper is proposed with an Interpolated DWT resolution enhancement technique. DWT transform when applied to an image it decomposes the image into four sub-bands. The 2D wavelet decomposition of an image is performed by applying the 1D DWT along the rows of the image first, then the resultant images are decomposed along the columns which results in four decomposed sub band images – low-low(LL), low-high (LH), high-low (HL), and high-high (HH). The full frequency spectrum of the original image is covered by the frequency components of these subbands.

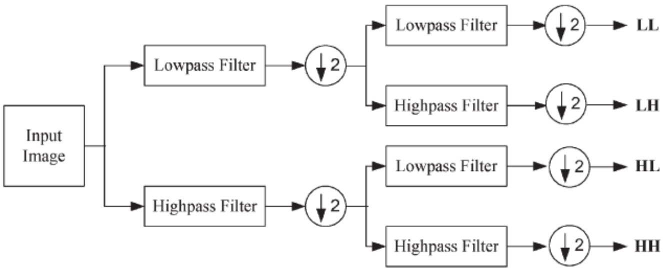

Fig. 1. Block diagram of DWT filter banks of level 1.

The figure 1 shows a theoretical filter bank 2D DWT technique which results in four different frequency subbands. Fig. 2 shows different subbands of a CCTV footage where the top left image is the LL subband, and the bottom right image is the HH subband. Now the three high frequency subband images are interpolated in parallel with the input image interpolated separately.

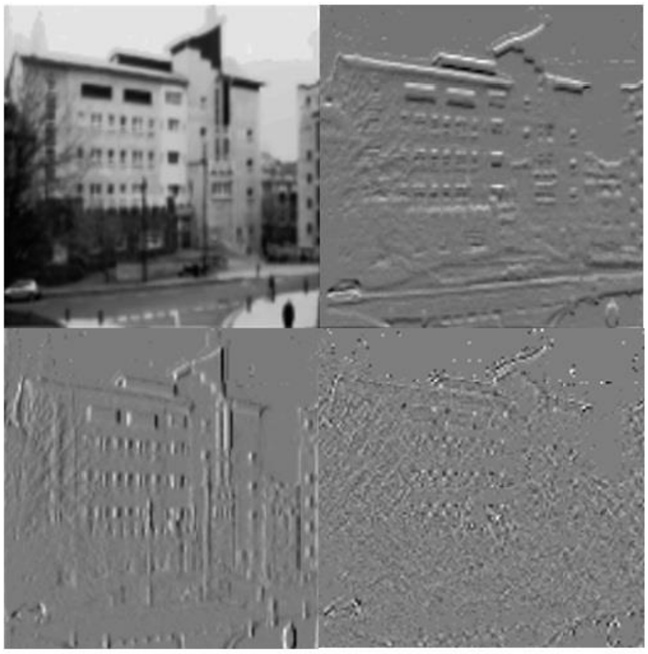

Fig.2. LL, LH, HL, and HH subbands of a CCTV image obtained by using DWT.

Interpolation in image processing refers to increasing the number of pixels in a digital image. Interpolation is used in many image processing applications, such as facial reconstruction [4], multiple description coding [5], and image resolution enhancement [6]–[8]. The three well-known interpolation techniques are nearest neighbor, bilinear, and bicubic. Interpolation is the process of using known data values to estimate unknown data values.

Nearest Neighbour Interpolation: Nearest- neighbor interpolation also known as point sampling is a method of multivariate interpolation in one or more dimensions. The nearest neighbor algorithm selects the value of the nearest point ignoring the values of neighboring points, yielding a piecewise-constant interpolant.

Bilinear Interpolation: Bilinear Interpolation is different from the other techniques which use only the 4 nearest pixel values which are located in diagonal directions from a given pixel in order to find the appropriate color intensity values of that pixel. It considers the closest 2 * 2 neighborhood of known pixel values surrounding the unknown pixel's computed location.

Bi-Cubic Interpolation: In image processing, bi-cubic interpolation is chosen over other two techniques for image re-sampling, where speed is not an issue. Images re-sampled with bi-cubic interpolation are smoother and have fewer interpolation artifacts.

Carey et al. have attempted to estimate the unknown details of wavelet coefficients in an effort to improve the sharpness of the reconstructed images [9]. For achieving a sharper image, an intermediate stage of Estimation is introduced. It estimates the high frequency subbands by utilizing the difference image obtained by subtracting the input image and its interpolated LL subband. Edges are identified using edge detection algorithm in the lower frequency subband and are used to estimate the edges in the high frequency subbands. Applying IDWT (Inverse DWT) to the image obtained by combining the subbands results in a final resolution enhanced image. The proposed technique proves to be better when compared with the standard interpolation and wavelet techniques (WZP & CWT).

II. WAVELET-BASED IMAGE RESOLUTION ENHANCEMENT

Many techniques were introduced for the image enhancement techniques and here we have compared with two of them. Firstly the WZP and CS and secondly CWT_ based image resolution enhancement technique.

A. CS Based Image Resolution Enhancement

The algorithm consists of two main steps and the method mainly adopts the CS methodology i9n wavelet domain.

1. Using the wavelet domain zero padding the unknown high resolution image is generated.

2. The cycle-spinning methodology is adopted to operate the following tasks:

a) A number of low resolution images are generated from the obtained estimated high resolution image in part (1) by spatial shifting, wavelet transforming, and discarding the high frequency subbands.

b) The WZP processing is applied to all those low resolution images yielding N high resolution images.

c) These intermediated high resolution images are realigned and averaged to give the final high resolution reconstructed image.

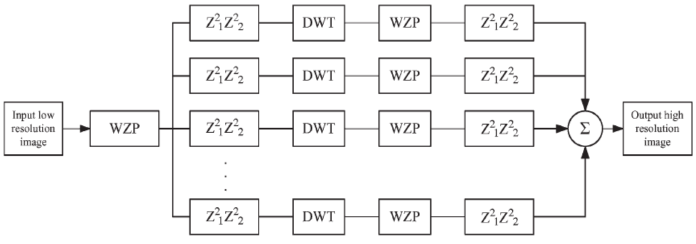

Fig.3 Block diagram of the WZP- and CS-based image resolution enhancement [17].

B. CWT-Based Image Resolution Enhancement

In this technique decompose an input image into different subband images. Secondly the high-frequency subband images and the input image are interpolated, combining all these images generate a new high-resolution image when applied with inverse DT-CWT. The resolution is enhanced by using directional selectivity provided by the CWT, where the high-frequency subbands in six different directions contribute to the sharpness of the high-frequency details, such as edges.

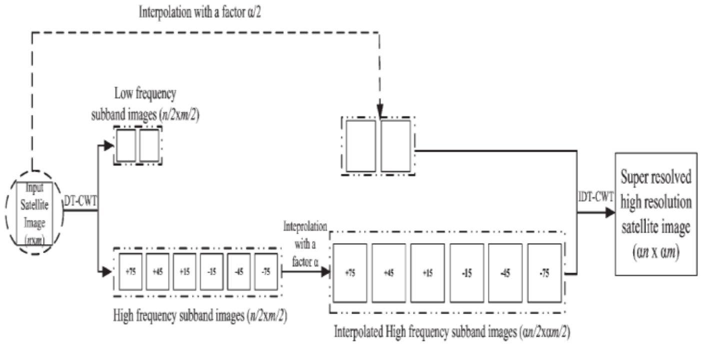

Fig.4 Block diagram of the proposed resolution enhancement algorithm [3].

III. DISCRETE WAVELET TRANSFORM BASED RESOLUTION ENHANCEMENT

As mentioned earlier the resolution to be an important feature in image processing makes the resolution enhancement of the images to increase the resolution of the images would affect the performance of the system when these images given as input. The enhanced image when obtained by the interpolation on its high frequency components causes loss of image. Apart from increasing the quality of the image edged should also be preserved.

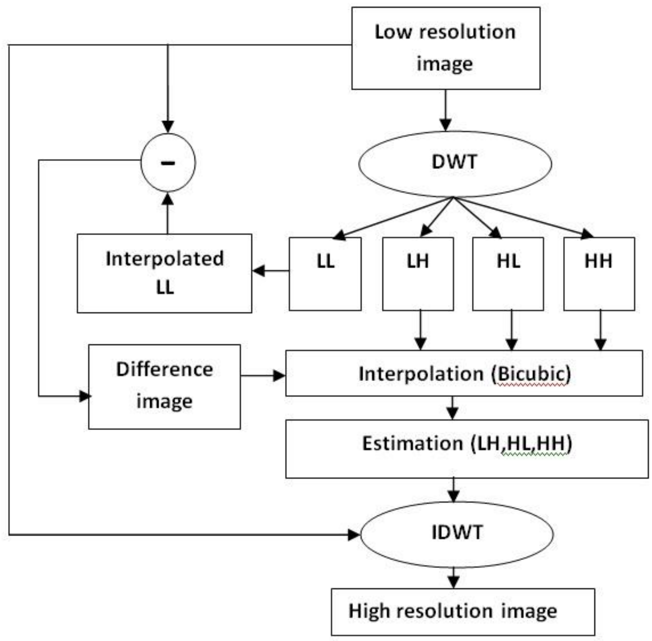

Fig.5 Block diagram of the proposed resolution enhancement algorithm.

DWT is applied along the rows of the low resolution input image first, then the resultant images are again decomposed along the columns which results in four decomposed sub band images - low low(LL), low-high (LH), high-low (HL), and high-high (HH). The full frequency spectrum of the original image is covered by the frequency components of these subbands. High-frequency subbands contains the high frequency components of the image. The interpolation is applied to the four resultant subband images. In the wavelet domain, by low-pass filtering of the high-resolution image the low-resolution image is obtained as in [14], [17], and [19]. without any quantization (i.e., with double-precision pixel values) The low resolution image (LL subband), is taken as the input . low frequency subband image is the low resolution image of the original image. low-frequency subband images contains less information than the original input image, so we use the input image through the interpolation process instead of using low-frequency subband images.

The input low-resolution image is interpolated with the half of the interpolation factor, α/2 which is used to interpolate the high-frequency subbands. For preserving more edge information or to obtain a sharper enhanced image, we proposed an intermediate stage in high frequency subband interpolation process. the input CCTV image and the interpolated LL image with factor 2 are highly correlated directly. The difference between the low-resolution input image and the LL subband image are in their high-frequency components. Therefore the difference image is used in the intermediate process to correct the estimated high-frequency components. Estimation is performed by interpolating the high-frequency subbands by factor 2 and adding the difference image (which is high-frequency components on low-resolution input image) to the estimated high-frequency images, followed with another interpolation with factor α/2 to achive required size for IDWT process. The intermediate process to add the difference image contains the high-frequency components which generates a sharper and enhanced final image. The sharpness is achieved because of interpolation of High-frequency components in HH, HL, and LH which preserves more high-frequency components than interpolating the low-resolution image directly.

IV. RESULTS AND DISCUSSIONS

The proposed technique has been tested on different CCTV images. The difference between the high resolution image and the input image could be observed from the below table 1.

Input image	**Output image**
	

Table 1- Shows the input image and the output image of the proposed system.

Not only visual comparison, the quantitative comparisons also confirm the superiority of the proposed method. Peak signal-to-noise ratio (PSNR) and root mean square error (RMSE) have been implemented in order to obtain some quantitative results for comparison.

PSNR is obtained by the formula [20]:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (1)$$

Where R is the maximum fluctuation in the input image (255 in here as the images are represented by 8 bit, i.e., 8-bit grayscale have been used—radiometric resolution is 8 bit).

MSE is representing the MSE between the given input image Iin and the original image Iorg which can be obtained by the following:

$$MSE = \frac{\sum_{i,j}\left(I_{in}(i,j) - I_{org}(i,j)\right)^2}{M \times N} \quad (2)$$

where M and N are the size of the images. RMSE value is calculated by the formula:

$$RMSE = \sqrt{\frac{\sum_{i,j}\left(I_{in}(i,j) - I_{org}(i,j)\right)^2}{M \times N}}. \quad (3)$$

The difference between the proposed technique and the previous techniques WZP- and CS-based image resolution enhancement Technique in terms of PSNR and MSE values are shown in below table-2.

Parameter	**Previous technique (CWT & WZP)**	**Proposed technique (DWT)**
PSNR	**33.35**	**26.1481**
RMSE	**13.27**	**12.5642**

Table 2- comparison between the values of the previously used and the proposed techniques.

V. CONCLUSION

The paper proposes a new technique of resolution enhancement which includes the interpolation of the high-frequency subband images which are the resultant of DWT and the input image. This technique is tested on a few CCTV footage images and the obtained PSNR and RMSE and visual of the proposed technique are better as compared to the conventional and state-of-art image resolution enhancement techniques. The PSNR improvement of the proposed technique is to be 7.21 dB when compared with the standard bicubic interpolation.

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