AN ADAPTIVE IMAGE RESOLUTION ENHANCEMENT BY USING MULTI RESOLUTION TRANSFOM

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ABSTRACT

In this paper an image resolution enhancement technique which generates sharper high resolution image is proposed. The proposed technique uses DWT to decompose a low resolution image into different sub-bands. Then the three high frequency sub-band images have been interpolated using bi-cubic interpolation. The high frequency sub-bands obtained by SWT of the input image are being incremented into the interpolated high frequency sub-bands in order to correct the estimated coefficients. In parallel, the input image is also interpolated separately.

Finally, corrected interpolated high frequency sub-bands and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high resolution output image. The proposed technique has been compared with conventional and standard interpolation techniques, wavelet zero padding (WZP), where the unknown coefficients in high-frequency sub bands are replaced with zeros, state-of-art techniques. The performance of the proposed technique over performs all available state-of-art methods for image resolution enhancement. In all steps of the proposed satellite image resolution enhancement technique, Daubechies wavelet transform as mother wavelet function and bi-cubic interpolation as interpolation technique have been used.

INTRODUCTION:

RESOLUTION of an image has been always an important issue in many image and video-processing applications, such as video resolution enhancement, feature extraction, and satellite image resolution enhancement. Interpolation in image processing is a method to increase the number of pixels in a digital image. Interpolation has been widely used in many image processing applications, such as facial reconstruction, multiple description coding, and image resolution enhancement. The interpolation-based image resolution enhancement has been used for a long time and many interpolation techniques have been developed to increase the quality of this task. There are three well-known interpolation techniques, namely, nearest neighbor, bilinear, and bi-cubic. Bi-cubic interpolation is more sophisticated than the other two techniques and produces smoother edges. Wavelets are also playing a significant role in many image processing applications. The 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform (DWT) along the rows of the image first, and then finally, corrected interpolated high frequency sub bands and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high resolution output image.

The results are decomposed along the columns. This operation results in four decomposed sub band images referred to low low(LL), low-high (LH), high-low (HL), and high-high (HH).The frequency components of those sub bands cover the full frequency spectrum of the original image.

Image resolution enhancement using wavelets is a relatively new subject and recently many new algorithms have been proposed. Their estimation was carried out by investigating the evolution of wavelet transform extreme among the same type of sub bands.

Edges identified by an edge detection algorithm in lower frequency sub bands were used to prepare a model for estimating edges in higher frequency sub bands and only the coefficients with significant values were estimated as the evolution of the wavelet coefficients. In many researches, hidden Markov has been also implemented in order to estimate the coefficients. The proposed technique has been compared with conventional and state-of-art image resolution enhancement techniques. The conventional interpolation techniques used are the follows: bilinear interpolation, bi-cubic interpolation and wavelet zero padding (WZP).

The state-of-art techniques used for comparison purposes are the following:

- regularity-preserving image interpolation
- new edge-directed interpolation (NEDI)
- hidden Markov model (HMM)
- HMM-based image super resolution (HMM SR)
- WZP and cycle-spinning (WZP-CS)
- WZP, CS, and edge rectification (WZP-CS-ER)
- DWT based super resolution (DWT SR)
- complex wavelet transform based super resolution (CWT SR)

MULTIRESOLUTION ANALYSIS

The time and frequency resolution problems are results of a physical phenomenon (the Heisenberg uncertainty principle) and exist regardless of the transform used, it is possible to analyze any signal by using an alternative approach called the multi resolution analysis (MRA) .

MRA, as implied by its name, analyzes the signal at different frequencies with different resolutions. Every spectral component is not resolved equally as was the case in the STFT.MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. This approach makes sense especially when the signal at hand has high frequency components for short durations and low frequency components for long durations. Fortunately, the signals that are encountered in practical applications are often of this type. For example, the following Figure 1 shows a signal of this type. It has a relatively low frequency component throughout the entire signal and relatively high frequency components for a short duration somewhere around the middle.

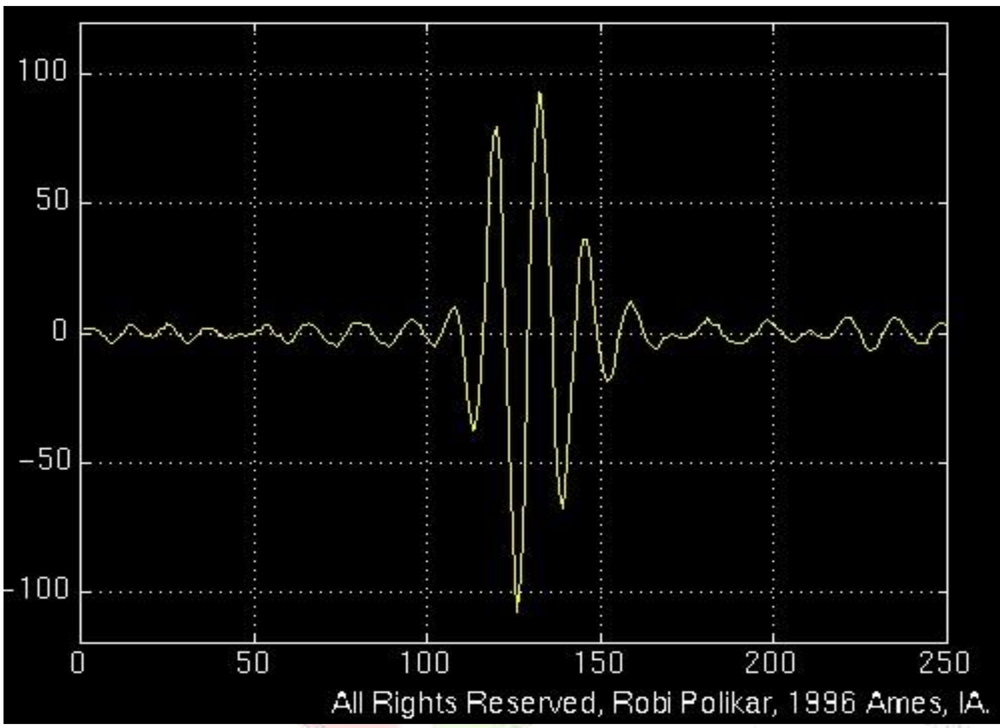


Figure 1

Multi-Resolution Analysis using Filter Banks:

Filters are one of the most widely used signal processing functions. Wavelets can be realized by iteration of filters with rescaling. The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations, and the scale is determined by up sampling and down sampling (sub sampling) operations.

The DWT is computed by successive low pass and high pass filtering of the discrete timedomain signal as shown in Figure 2. This is called the Mallat algorithm or Mallat-tree decomposition. Its significance is in the manner it connects the continuous-time multi resolution to discrete-time filters. In the Figure 2, the signal is denoted by the sequence x[n], where n is an integer. The low pass filter is denoted by G_0 while the high pass filter is denoted by H_0. At each level, the high pass filter produces detail information; d[n], while the low pass filter associated with scaling function produces coarse approximations, a[n].

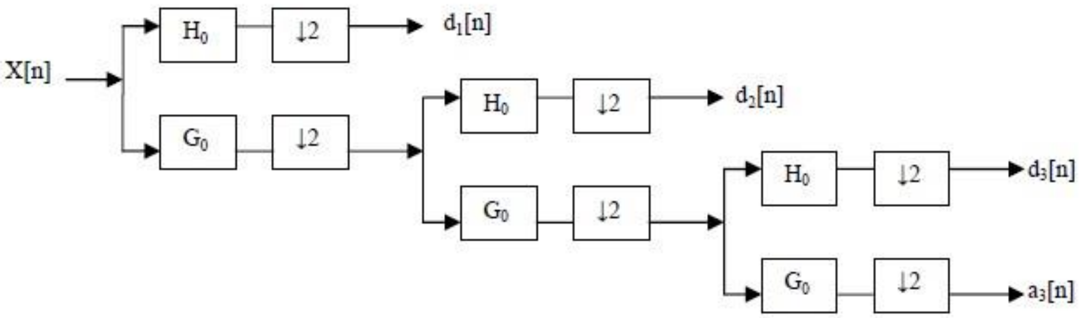


Figure 2 : Threelevel wavelet decomposition tree

At each decomposition level, the half band filters produce signals spanning only half the frequency band. This doubles the frequency resolution as the UN certainty in frequency is reduced by half. In accordance with Nyquist's rule if the original signal has highest frequency of ω, which requires a sampling frequency of 2ω radians, then it now has a highest frequency of ω/2 radians. It can now be sampled at a frequency of ω radians thus discarding half the samples with no loss of information. This decimation by 2 halves the time resolution as the entire signal is now represented by only half the number of samples. Thus, while the half band low pass filtering removes half of the frequencies and thus halves the resolution, the decimation by 2 doubles the scale. With this approach, the time resolution becomes arbitrarily good at high frequencies, while the frequency resolution becomes arbitrarily good at low frequencies. The filtering and decimation process is continued until the desired level is reached. The maximum number of levels depends on the length of the signal.

The DWT of the original signal is then obtained by concatenating all the coefficients, a[n] and d[n], starting from the last level of decomposition.

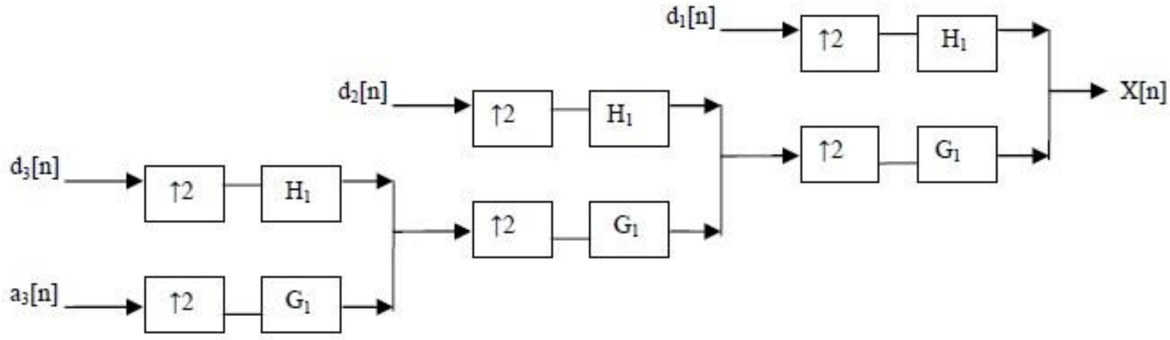


Figure 3: Three-level wavelet reconstruction tree.

Figure 3 shows the reconstruction of the original signal from the wavelet coefficients. Basically, the reconstruction is the reverse process of decomposition. The approximation and detail coefficients at every level are up sampled by two, passed through the low pass and high pass synthesis filters and then added. This process is continued through the same number of levels as in the decomposition process to obtain and H the original signal.

One-Stage Filtering: Approximations and Details:

For many signals, the low-frequency content is the most important part. It gives the signal its identity. The high-frequency content on the other hand imparts flavor. Consider the human voice. If the highfrequency components are removed, the voice sounds different but one can still tell what's being said. However, if you remove enough of the low-frequency components, you hear gibberish. In wavelet analysis, we often speak of approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components. **:**

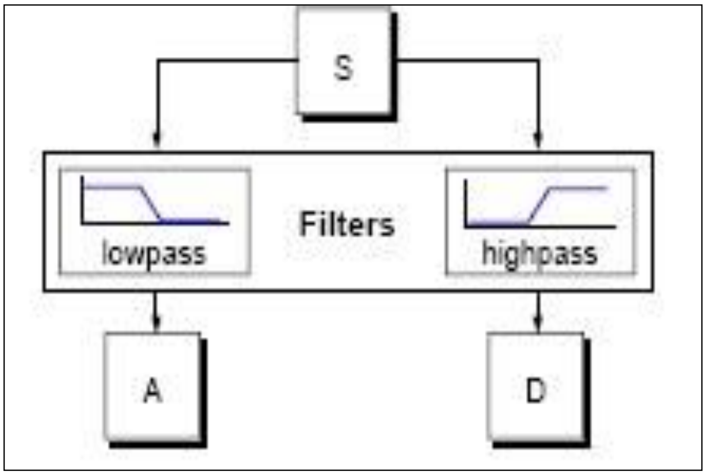


Figure 4: Filtering Process

The original signal S passes through two complementary filters and emerges as two signals. if the same operation performed on a real digital signal, it gives twice as much data as given as input. The signals A and D are interesting, but the output produces 2000 values instead of the 1000 . There exists a more subtle way to perform the decomposition using wavelets. By looking carefully at the computation, to get the complete information only one point out of two in each of the two 2000-length samples is required. This is the notion of own sampling. Hence two sequences called cA and cD are produced.

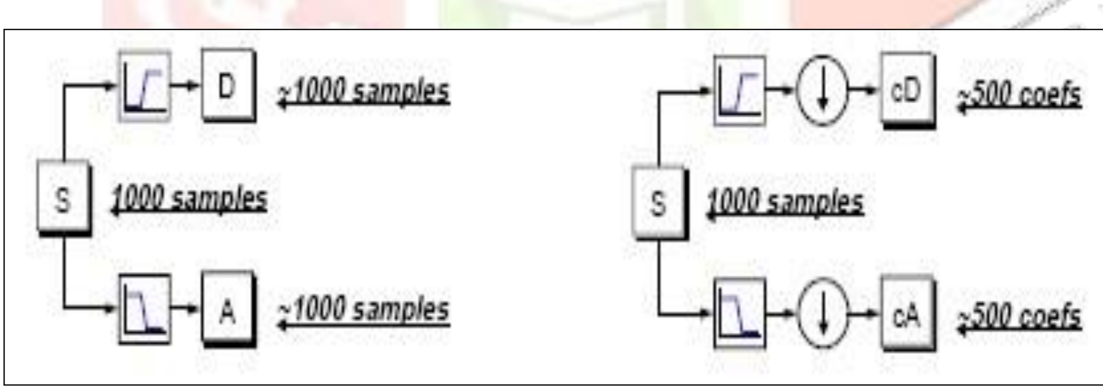


Figure 5: Sampling

The process on the right which includes down sampling produces DWT Coefficients. To gain a better appreciation of this process a one-stage discrete wavelet transform is performed on the signal .The signal will be a pure sinusoid with high- frequency noise added to it.

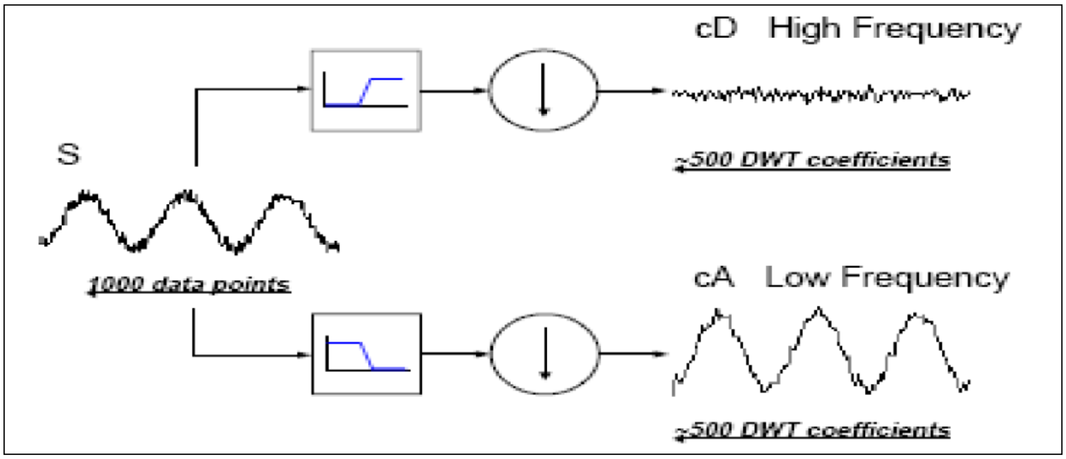


Figure 6: Schematic Diagram

Multiple-Level Decomposition:

The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. This is called the wavelet decomposition tree.

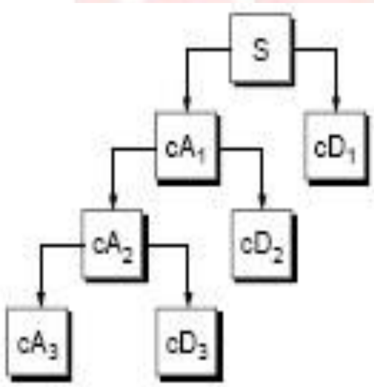


Figure7 : Wavelet Decomposition Tree

The signal's wavelet decomposition tree yields valuable information.

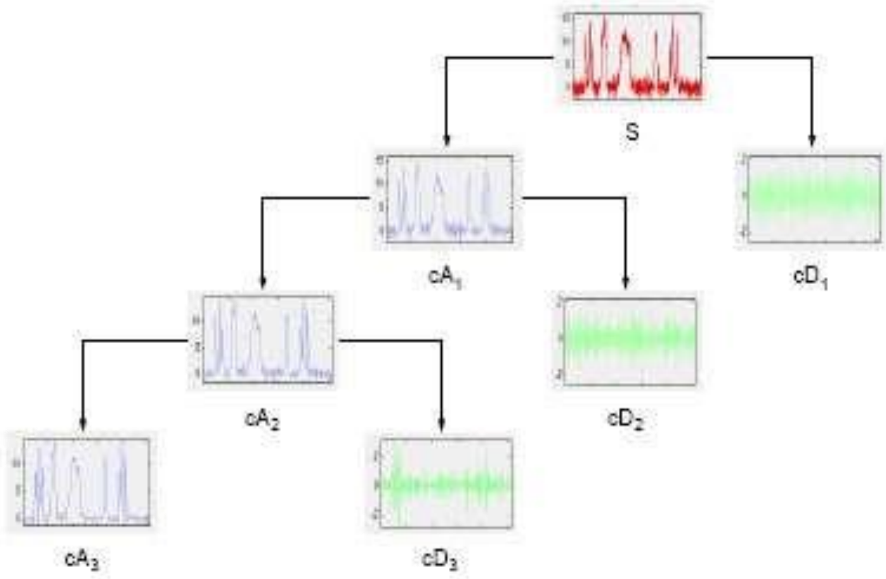


Figure 8 : Wavelet Decomposition Tree

Number of Levels:

Since the analysis process is iterative, in theory it can be continued indefinitely. In reality, the decomposition can proceed only until the individual details consist of a single sample or pixel. In practice, a suitable number of levels based on the nature of the signal, or on a suitable criterion such as entropy can be selected.

Wavelet Reconstruction:

The discrete wavelet transform can be used to analyze, or decompose, signals and images. This process is called decomposition or analysis. The other half is how those components can be assembled back into the original signal without loss of information. This process is called reconstruction, or synthesis. The mathematical manipulation that effects synthesis is called the inverse discrete wavelet transform (IDWT). To synthesize a signal using Wavelet Toolbox™ software, we reconstruct it from the wavelet coefficients:

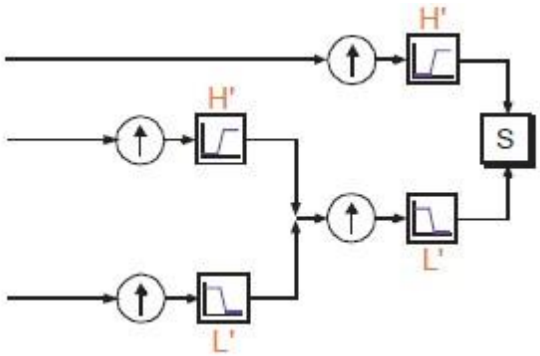


Figure 9

Where wavelet analysis involves filtering and down sampling, the wavelet reconstruction process consists of up sampling and filtering. Up sampling is the process of lengthening a signal component by inserting zeros between samples:

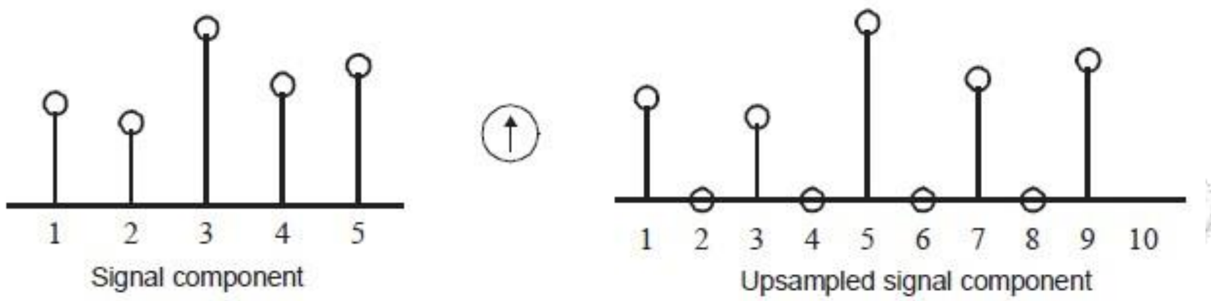


Figure 10

The toolbox includes commands, like idwt and waverec, that performs single-level or multilevel reconstruction, respectively, on the components of one-dimensional signals. These commands have their two-dimensional analogs, idwt2 and waverec2.

Reconstruction Filters:

The choice of filters is crucial in achieving perfect reconstruction of the original signal. The down sampling performed during the decomposition phase introduces a distortion called aliasing. It turns out that by carefully choosing filters for the decomposition and reconstruction phases that are closely related (but not identical), we can “cancel out” the effects of aliasing. The low- and high-pass decomposition filters (L and H), together with their associated reconstruction filters (L' and H'), form a system called as quadrature mirror filters:

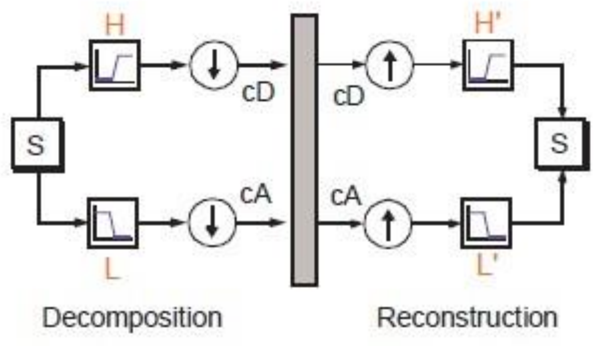


Figure 11

Reconstructing Approximations and Details

It is possible to reconstruct our original signal from the coefficients of the approximations and details.

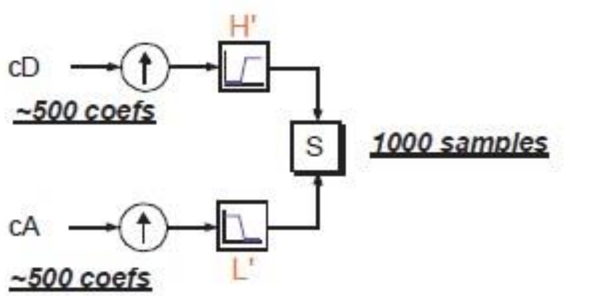


Figure 12

It is also possible to reconstruct the approximations and details themselves from their coefficient vectors. For example, the first-level approximation A1 can be from the coefficient vector cA1. The coefficient vector cA1 is passed through the same process which used to reconstruct the original signal. However, instead of combining it with the level-one detail cD1, It is fed in a vector of zeros in place of the detail coefficients vector:

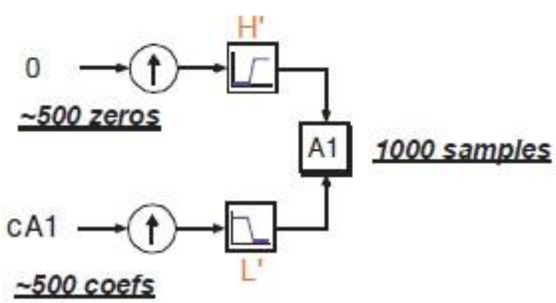


Figure 13

The process yields a reconstructed approximation A1, which has the same length as the original signal S and which is a real approximation of it. Similarly, the first-level detail D1 is reconstructed, using the analogous process:

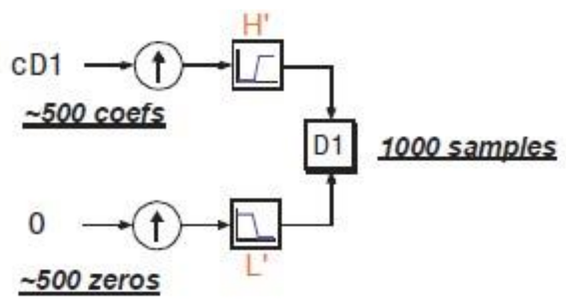
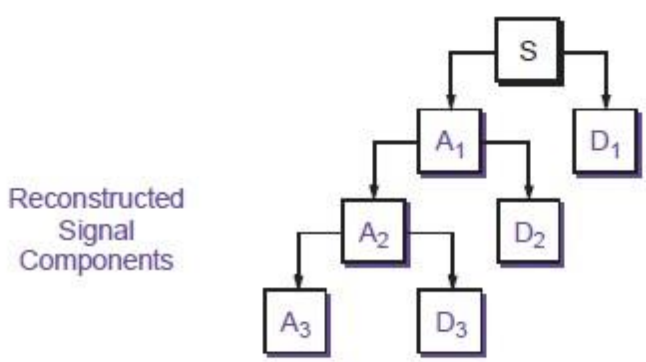


Figure 14

The reconstructed details and approximations are true constituents of the original signal. In fact, when they are combined then

$$A_1 + D_1 = S$$

Note that the coefficient vectors cA1 and cD1 are only half the length of the original signal(because they were produced by downsampling),cannot directly be combined to reproduce the signal.Hence,it is necessary to reconstruct the approximations and details before combining them. Extending this technique to the components of a multilevel analysis, similar relationships hold for all the reconstructed signal constituents. That is, there are several ways to reassemble the original signal:



$$S = A_1 + D_1$$
$$= A_2 + D_2 + D_1$$
$$= A_3 + D_3 + D_2 + D_1$$

Figure 15

PROPOSED IMAGE RESOLUTION ENHANCEMENT

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. In this work, DWT has been employed in order to preserve the high frequency components of the image. The redundancy and shift invariance of the DWT mean that DWT coefficients are inherently interpolable .

In this correspondence, one level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different sub-band images. Three high frequency sub-bands (LH, HL, and HH) contain the high frequency components of the input image. In the proposed technique, bicubic interpolation with enlargement factor of 2 is applied to high frequency sub-band images. Downsampling in each of the DWT sub-bands causes information loss in the respective sub-bands. Hence SWT is employed to minimize this loss.

The interpolated high frequency subbands and the SWT high frequency subbands have the same size which means they can be added with each other. The new corrected high frequency subbands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution image is obtained by lowpass filtering of the high resolution image. In other words, low frequency subband is the low resolution of the original image. Therefore, instead of using low frequency subband, which contains less information than the original high resolution image, the input image for the interpolation of low frequency subband image is used. Using input image instead of low frequency subband increases the quality of the super resolved image. Fig. 1 illustrates the block diagram of the proposed image resolution enhancement technique.

By interpolating input image by $\alpha/2$, and high frequency subbands by 2 and α in the intermediate and final interpolation stages respectively, and then by applying IDWT, as illustrated in Fig. 1, the output image will contain sharper edges than the interpolated image obtained by interpolation of the input image directly. This is due to the fact that, the interpolation of isolated high frequency components in high frequency subbands and using the corrections obtained by adding high frequency subbands of SWT of the input image, will preserve more high frequency components after the interpolation than interpolating input image directly

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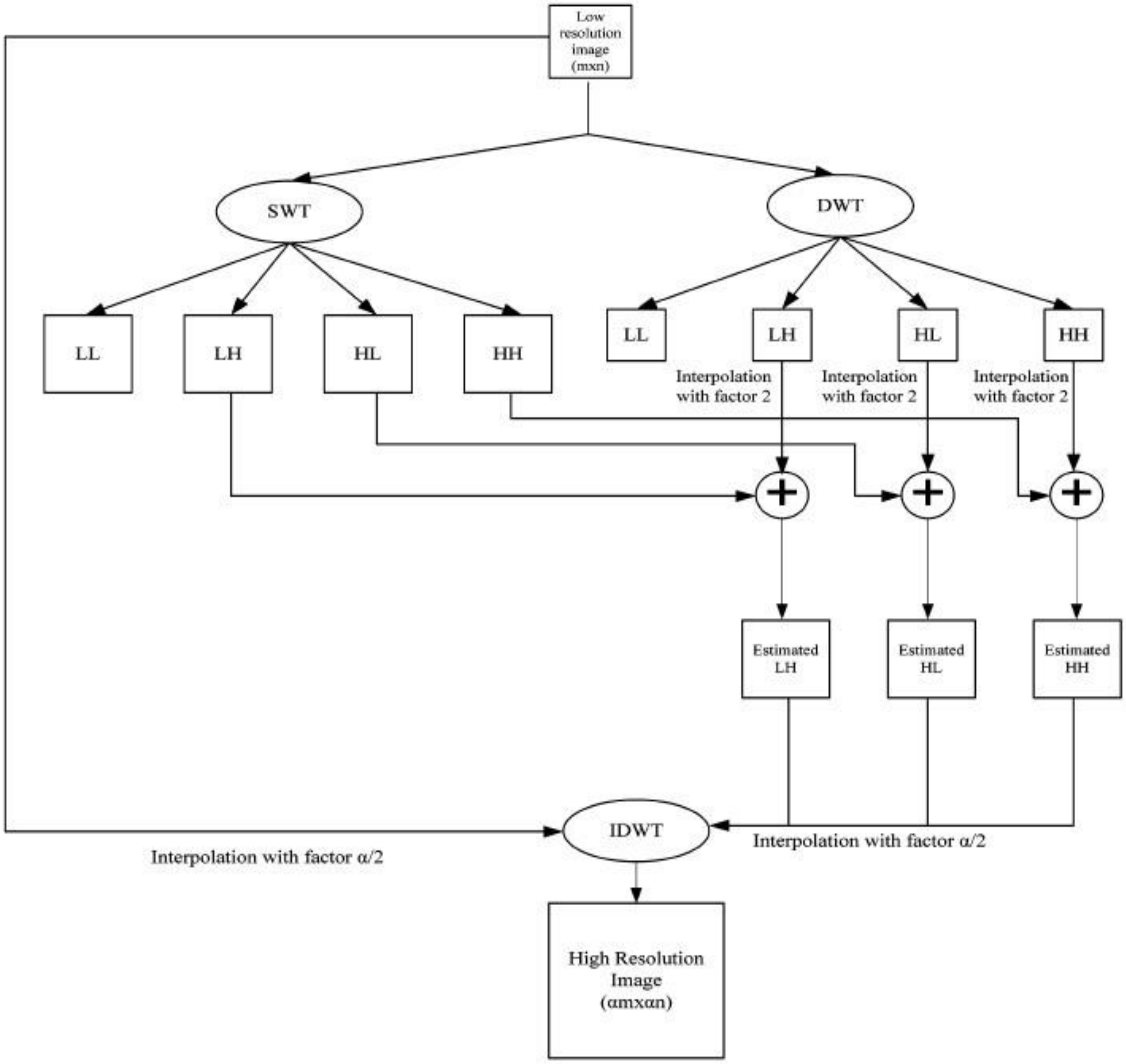

Fig. 16: Block diagram of the proposed super resolution algorithm.

IMPROVED ALGORITHM (EXTENSION)

As it was mentioned before, resolution is an important feature in satellite imaging, which makes the resolution enhancement of such images to be of vital importance as increasing the resolution of these images will directly affect the performance of the system using these images as input. The main loss of an image after being resolution enhanced by applying interpolation is on its high-frequency components, which is due to the smoothing caused by interpolation.

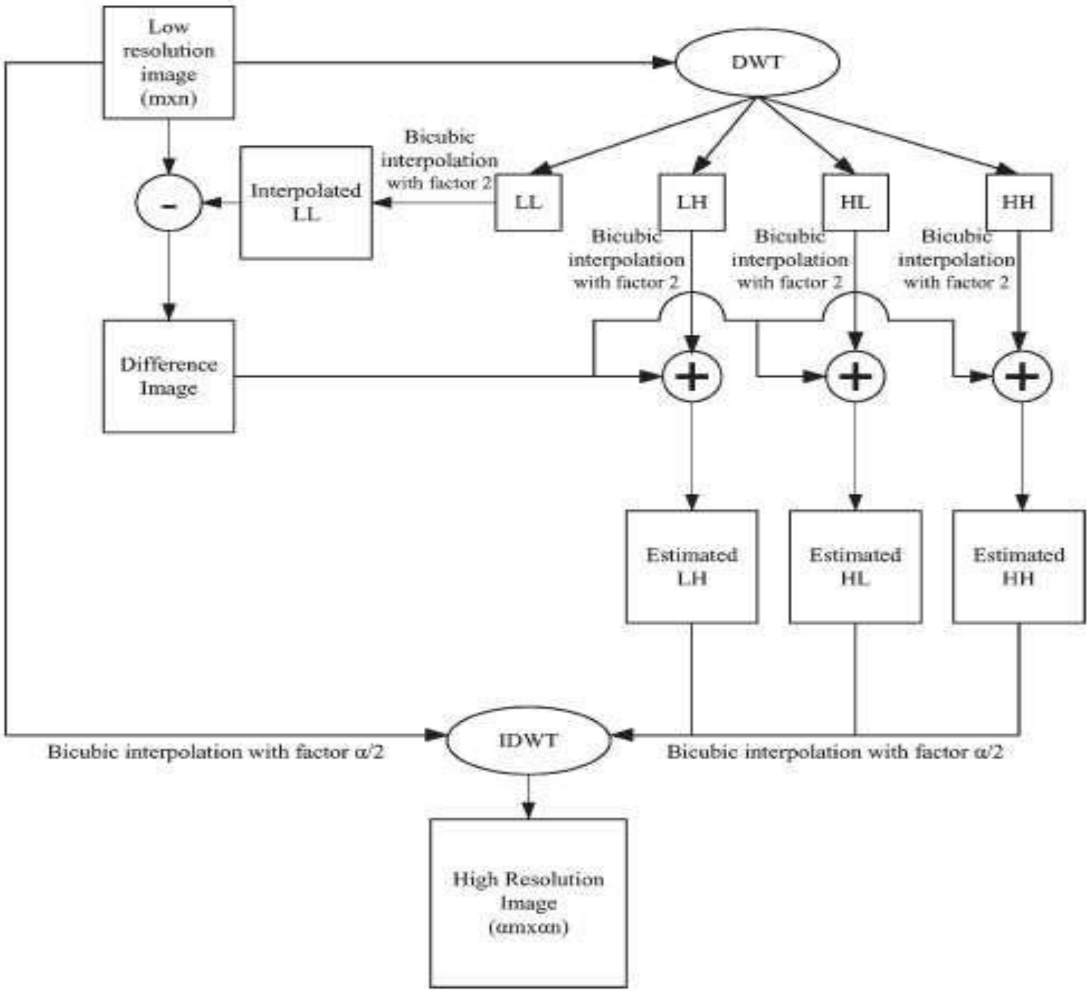

Fig. 17: Block Diagram of improved algorithm

Hence, in order to increase the quality of the enhanced image, preserving the edges is essential. In this paper, DWT has been employed in order to preserve the high-frequency components of the image.

DWT separates the image into different sub band images, namely, LL, LH, HL, and HH. A highfrequency sub band contains the high frequency component of the image.

The interpolation can be applied to these four sub band images. In the wavelet domain, the lowresolution image is obtained by low-pass filtering of the high-resolution image. The low resolution image (LL sub band), without quantization (i.e., with double-precision pixel values) is used as the input for the proposed resolution enhancement process.

In other words, low frequency sub band images are the low resolution of the original image. Therefore, instead of using low-frequency sub band images, which contains less information than the original input image,The input image through the interpolation process is used.

Hence, the input low-resolution image is interpolated with the half of the interpolation factor, α/2, used to interpolate the high-frequency sub bands, as shown in Fig. 17 In order to preserve more edge information, i.e., obtaining a sharper enhanced image, an intermediate stage in high frequency sub band interpolation process is proposed. As shown in Fig. 17 ,the low-resolution input satellite image and the interpolated LL image with factor 2 are highly correlated. The difference between the LL sub band image and the low-resolution input image are in their high-frequency components. Hence, this difference image can be use in the intermediate process to correct the estimated high-frequency components. This estimation is performed by interpolating the high-frequency sub bands by factor 2 and then including the difference image (which is high-frequency components on low-resolution input image)into the estimated high-frequency images, followed by another interpolation with factor α/2 in order to reach the required size for IDWT process. The intermediate process of adding the difference image, containing high-frequency components,

SIMULATION RESULTS

Figure 18 shows that super resolved image of Baboon's picture using proposed technique in (d) are much better than the low resolution image in (a), super resolved image by using the interpolation (b), and WZP (c). Note that the input low resolution images have been obtained by down-sampling the original high resolution images. In order to show the effectiveness of the proposed method over the conventional and stateof-art image resolution enhancement techniques, four well-known test images (Lena, Elaine, Baboon, and Peppers) with different features are used for comparison.

The PSNR performance of the proposed technique using bicubic interpolation with conventional and state-of-art resolution enhancement techniques: bilinear, bicubic, WZP, NEDI, HMM, HMM SR, WZP-CS, WZP-CS-ER, DWT SR, CWT SR, and regularity-preserving image interpolation. Additionally, in order to have more comprehensive comparison, the performance of the super resolved image. The results indicate that the proposed technique over-performs the afore mentioned conventional and state-of-art image resolution enhancement techniques.

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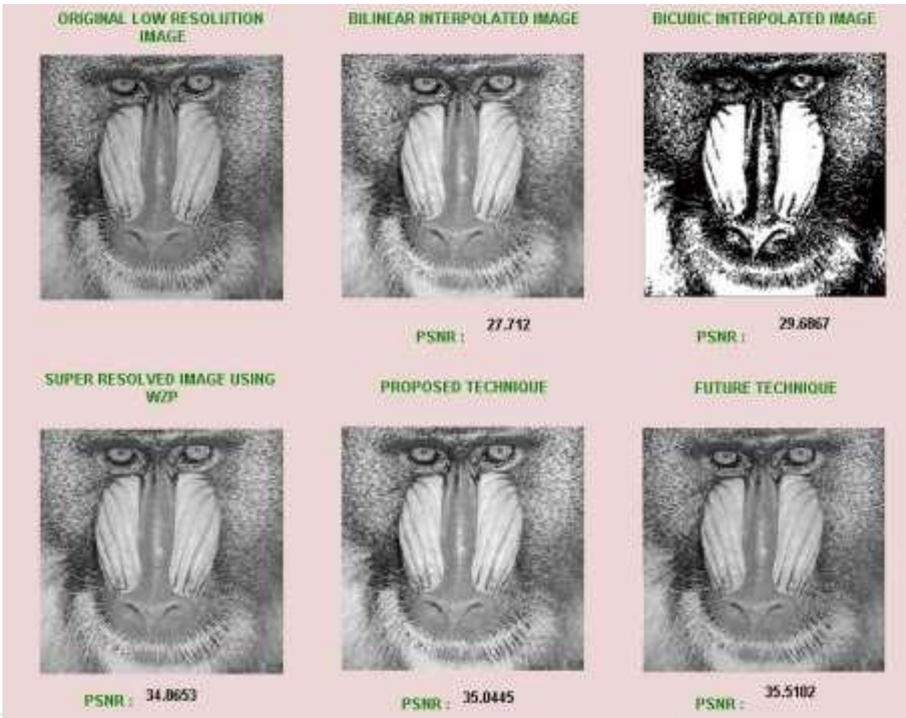

Figure 18: Simulation Results

CONCLUSION

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency sub bands obtained by DWT, This paper has proposed a new resolution enhancement technique based on the interpolation of the high-frequency sub band images obtained by DWT and the input image. The proposed technique has been tested on well-known benchmark images, where their PSNR and visual results show the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques.

The PSNR improvement of the proposed technique will be Increased compared with the standard bicubic interpolation. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency sub bands. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. The proposed technique has been tested on well-known benchmark images, where their PSNR and visual results show the superiority of proposed technique over the conventional and state-of-art image resolution enhancement techniques.

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