# Enhanced High Resolution Colour Image Using Discrete and Stationary Wavelet Transform

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## ABSTRACT

**The resolution of an image can be enhanced using a 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). DWT is applied in order to decompose an input image into different subbands. Then the high frequency subbands as well as the input image are interpolated. 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). This white balance is to average the brightest and darkest pixels on the image. Gaussian filters are a class of linear smoothing filters with the pixels chosen according to the shape of a Gaussian function. The amount of smoothing performed by the filter will be the same in all directions.**

*Keywords*- Discrete wavelet transform, Stationary wavelet transform, Image resolution enhancement, Interpolation techniques, subband images, white balance, Gaussian filter.

## I. INTRODUCTION

Resolution has been frequently referred as an important property of an image. One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple description coding, and super resolution

Interpolation in image processing is a method to increase the number of pixels in a digital image. Interpolation-based super resolution 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 interpolation, bilinear interpolation, and bicubic interpolation. Bicubic interpolation is more sophisticated than the other two techniques but produces smoother edges than bilinear interpolation.

Image resolution enhancement in the wavelet domain is a relatively new research addition, and recently, many new algorithms have been proposed. Carey and others have estimated the unknown details of wavelet coefficients in an effort to improve the sharpness of the reconstructed images. Their estimation was carried out by investigating the evolution of wavelet transform extreme among the same type of subbands. Edges identified by an edge detection algorithm in lower frequency subbands were used to prepare a model for estimating edges in higher-frequency subbands, and only the coefficients with significant values were estimated as the evolution of the wavelet coefficients. These significant coefficients correspond to salient image discontinuities, and consequently, only the portrayal of those can be targeted with this approach.

Discrete wavelet transform (DWT) [2] is one of the recent wavelet transforms used in image processing. DWT decomposes an image into different sub band images, namely low-low (LL), low- high (LH), high-low (HL), and high-high (HH). Another recent wavelet transform which has been used in several image processing applications is stationary wavelet transform (SWT). In short, SWT is similar to DWT but it does not use down-sampling, hence the sub bands will have the same size as the input image. Resolution has been frequently referred as an important aspect of an image. One of the commonly used techniques for image resolution enhancement is Interpolation, but the main loss of it is high frequency components (edges) in the image

The high frequency subbands obtained by SWT of the input image are corrected by the interpolated high frequency subbands of DWT to obtain the estimated coefficients. In parallel, the input image is also interpolated separately. Finally applyiny inverse DWT (IDWT) to the estimated coefficients and interpolated input image a high resolution image is obtained. In this work, we are proposing an image resolution enhancement technique which generates sharper high resolution image.

In this work, we have proposed a new resolution enhancement technique by wavelet transforms these wavelet transforms decompose a low-resolution image into different subband images. Then the high-frequency subband images are interpolated using bicubic interpolation. In parallel, the input image is also interpolated separately. Finally, the estimated coefficients of the image and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high-resolution output image.

The conventional techniques used are:

- Interpolation techniques namely,
    - nearest interpolation
    - bilinear interpolation and
    - bicubic interpolation
- Wavelet zero padding (WZP).

## II. PROPOSED IMAGE RESOLUTION ENHANCEMENT TECHNIQUE

The main loss when enhancing the resolution of an image by applying interpolation is its high-

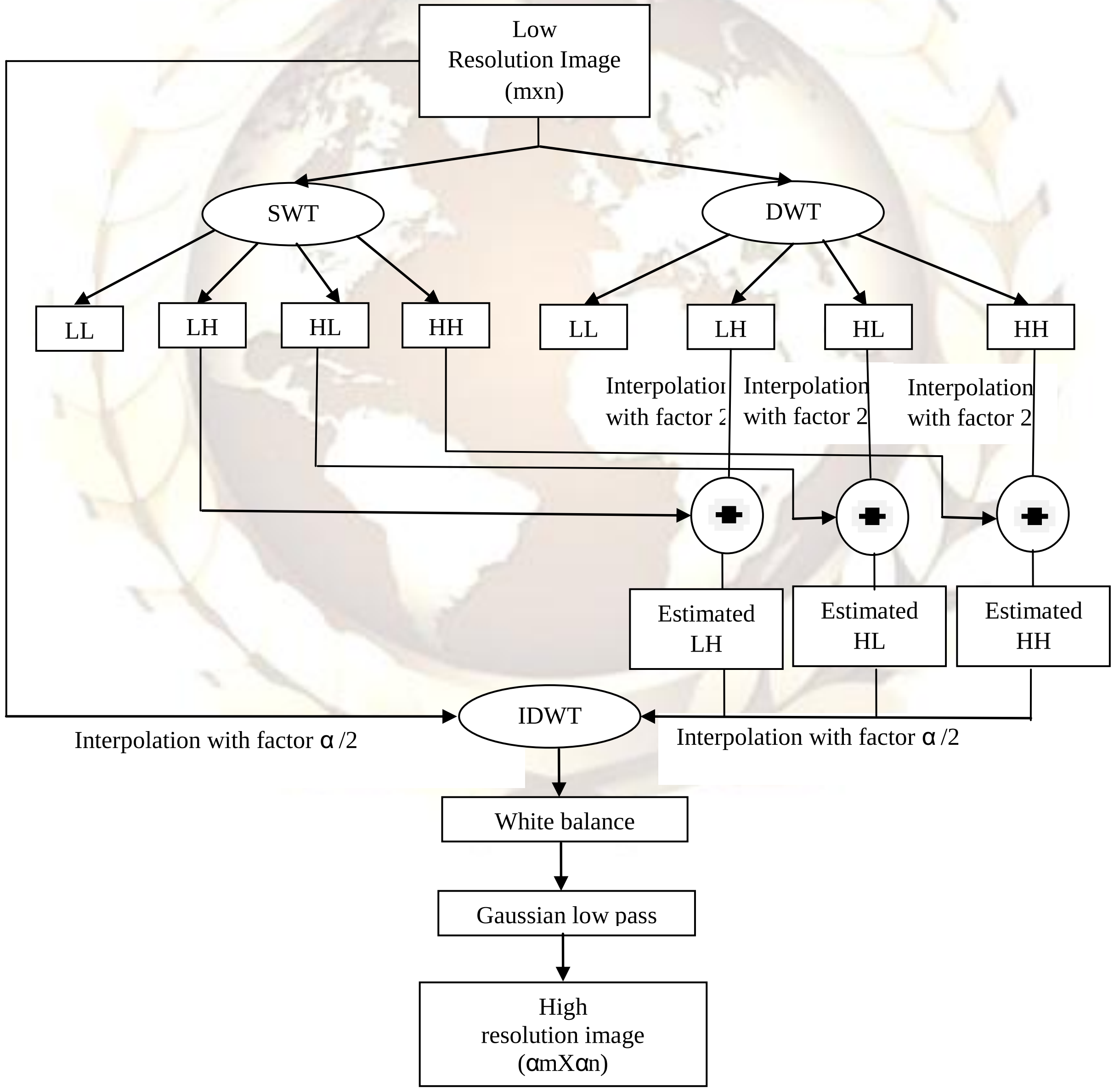



Fig.1 Block diagram of the proposed image resolution Enhancement algorithm

frequency components, that is, the edges. This loss occurs because the interpolation smoothen the image. Hence, in order to increase the quality of the super-resolution image, preserving the edges is essential. In this work, discrete wavelet transform (DWT) has been employed in order to preserve the high-frequency components of the image. DWT decomposes an image into different subband images; namely, low-low (LL), low-high (LH), high-low (HL), and high-high (HH). LH, HL, and HH subband images contain the high-frequency components of the input image. In this paper, one level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different subband images. Three high frequency subbands (LH, HL and HH) contain the high frequency components of the input image. In the proposed technique, bi-cubic interpolation with enlargement factor of 2 is applied to high frequency subband images

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 [3]. Down sampling in each of the DWT subbands causes information loss in the respective subbands. That is why 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 low pass filtering of the high resolution image [5]. 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, we are using the input image for the interpolation of low frequency subband image.

Using input image instead of low frequency subband increases the quality of the super resolution image. Fig. 1 illustrates the block diagram of the proposed image resolution enhancement technique. By interpolating input image and estimated high frequency subbands by $\alpha/2$ (here $\alpha$ is the interpolation factor) at final interpolation stages respectively, and then by applying IDWT, as illustrated in Fig. 1, the output image will contain sharper edges than the high resolution 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.

After applying the IDWT we proposed white balance [3] for Enhancement the image. White balance is a technique that is used to remove the colour cast in a particular and unwanted color that is dominating in an image. This is used to simulate the complex color stability that humans have. The purpose of the white balance is to maintain as close as possible the colors in the image. This command automatically adjusts the colors of the image by stretching the red, green and blue channels individually. This is achieved by changing the ratio between the three color channels of the image such as red, green and blue. The basic concept of this white balance is refinement of the sharpness of edges due to this reason white balance is widely used in digital cameras. White Balance computes the average amount of each color present in the input image and then applies to ensure that the output image has an equal amount of each color. White balance is the process of removing unrealistic color casts, so that objects which appear white in person are rendered white in the image. This white balance is to average the brightest and darkest pixels on the image. Edges and other sharp intensity transitions such as noise in an image contribute significantly to the high frequency content. Hence smoothing is achieved by high frequency attenuation; that is by low pass filtering. The Gaussian filters are mainly classified in to two types. They are High pass filter (sharpening filter) and Low pass filter (smoothing filter). Edges enhancement is associated with high frequency components. Gaussian filters [4] are a class of linear smoothing filters with the pixels chosen according to the shape of a Gaussian function. Gaussian smoothing filters are effective low-pass filters from the perspective of both the spatial and frequency domains, are efficient to implement, and can be used effectively by engineers in practical vision applications. The amount of smoothing performed by the filter will be the same in all directions. In general, the edges in an image will not be oriented in some particular direction that is known in advance; consequently, there is no reason a priori to smooth more in one direction than in another. The function fspecial creates a two-dimensional filter of specified type. fspecial returns a correlation kernel, which is the appropriate form to use with imfilter. The default value for the kernel size is [3 3]. The default value for the $\sigma$ (sigma) is 0.5. As $\sigma$ increases, more samples must be obtained to represent the Gaussian function accurately. Therefore, σ controls the amount of smoothing. In all steps of the proposed satellite image resolution enhancement technique, Daubechies wavelet transform as mother wavelet function and bicubic interpolation as interpolation technique have been used.

## RESULTS

In order to show the effectiveness of the proposed method over the conventional and state-of-art image resolution enhancement techniques, four well-known test images (Lena, Elaine, Baboon, and Peppers) with different features are used for comparison.


(a)


(b)


(c)

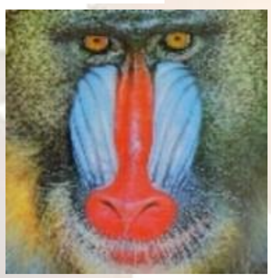
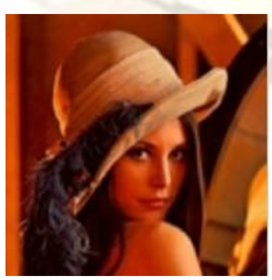

(d)

Fig.2 (a) original low resolution baboon's image
(b) bicubic interpolated image
(c) super resolved image using WZP
(d) proposed technique


(a)


(b)


(c)

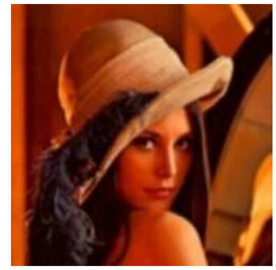

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Fig.3 (a) original low resolution lenas's image
(b) bicubic interpolated image
(c) super resolved image using WZP
(d) proposed technique


(a)


(b)


(c)


(d)

Fig.4 (a) original low resolution pepper's image
(b) bicubic interpolated image
(c) super resolved image using WZP
(d) proposed technique

Table I compares the PSNR performance of the proposed technique using bicubic interpolation with conventional and state-of-art resolution enhancement techniques: bilinear, bicubic and WZP. Additionally, in order to have more comprehensive comparison, the performance of the super resolved image by using SWT only (SWT-SR) is also included in the table. The results in Table I indicate that the proposed technique over-performs the aforementioned conventional and state-of-art image resolution enhancement techniques. Table I also indicates that the proposed technique over-performs the aforementioned conventional and state-of-art image resolution enhancement techniques.

## CONCLUSION

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency subbands obtained by DWT, correcting the high frequency subband estimation by using SWT high frequency subbands, and the input image. The proposed technique uses DWT to decompose an image into different subbands, and then the high frequency subband images have been interpolated. The interpolated high frequency subband coefficients have been corrected by using the high frequency subbands achieved by SWT of the input image. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency subbands. 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.

### TABLE I

PSNR (DB) RESULTS FOR RESOLUTION ENHANCEMENT FROM 128x128 TO 1024x1024 OF THE PROPOSED TECHNIQUE COMPARED WITH THE CONVENTIONAL AND STATE-OF-ART IMAGE RESOLUTION ENHANCEMENT TECHNIQUES

| | PSNR(db) | | |
|---|---|---|---|
| **Techniques\images** | **Lena** | **Baboon** | **Pepper** |
| Bilinear | 49.76 | 53.24 | 47.47 |
| Bicubic | 50.10 | 53.88 | 46.86 |
| WZP | 50.36 | 54.15 | 44.47 |
| **Proposed technique** | **61.97** | **61.64** | **52.21** |

## REFERENCES


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