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Image Super-resolution using Wavelet Transform and Bicubic Interpolation

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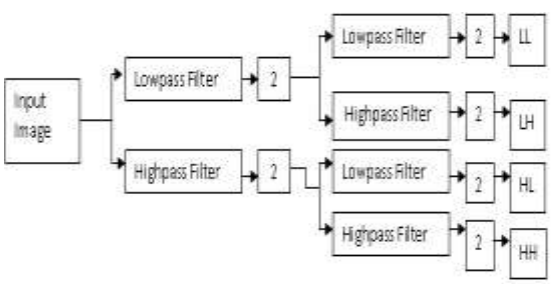
Abstract

This paper entitles the different method available for quality image super-resolution. Nowadays images are widely used over the internet and also in medical and security areas. Interpolation method is used for image super-resolution but this method does not give you better results. This paper, proposes an image super-resolution technique based on Bicubic interpolation of high frequency subbands obtained from Discrete Wavelet Transform and the input image. Discrete Wavelet Transform is applied in order to decompose an input image into different subbands. The estimated high frequency subbands are being modified by using high frequency subbands obtained from Stationary Wavelet Transform. All these images are combined to generate new resolution enhanced image by using Inverse Discrete Wavelet Transform which gives you better quality output image. The proposed technique is tested on benchmark images. The quantitative (Peak signal-to-noise ratio) and visual results show the superiority of the proposed technique over conventional and state-of-art image enhancement technique. The PSNR improvement of the proposed technique is up to 5.04dB compared with standard bicubic interpolation.

Keywords: Discrete Wavelet Transform(DWT);Bicubic Interpolation; Stationary Wavelet Transform(SWT); Discrete Wavelet Transform(IDWT).

Introduction

Image is nothing but two dimensional function composed of pixels. Image resolution refers to number of pixels in an image which also shows the quality of an image .Image super-



resolution is important parameter. Many techniques are available to enhance the resolution of image, more generally interpolation is used. Interpolation has been widely used in facial reconstruction [2], multiple description coding [3] and super resolution [4]-[7], there are many techniques available for interpolation such as nearest neighbor interpolation, bilinear interpolation and bicubic interpolation. Wavelet is also new and very efficient way to use for image resolution enhancement. Many new algorithms have been proposed using wavelets [5]-[8]. Discrete wavelet transform (DWT) [9] is one of the recent wavelet transforms used in image processing.

The 2-d wavelet decomposition of an image is performed by applying the 1-d discrete wavelet transform along the rows first and then results are decomposed along the columns. This operation decomposes an image into different subband images referred to low-low, low-high, high-low, and high-high. Theoretically, a filter bank is shown in Fig.1 and will operate on image in order to generate different subband frequency images. In this approach a resolution enhanced image obtained this is done by first decomposing an input image into different subbands using DWT as illustrated in Fig 2. Then high frequency subbands of image have been interpolated by using bicubic interpolation. The high frequency subbands obtained by SWT of the input image are being incremented into the interpolated high frequency subband in order to correct estimated coefficient. At the same time input image is interpolated using bicubic interpolation. Finally, corrected high frequency subband and interpolated image are combined by using IDWT to achieve high resolution image.

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Fig. 2. LL, LH, HL and HH subbands of Lena's image obtained by using DWT.

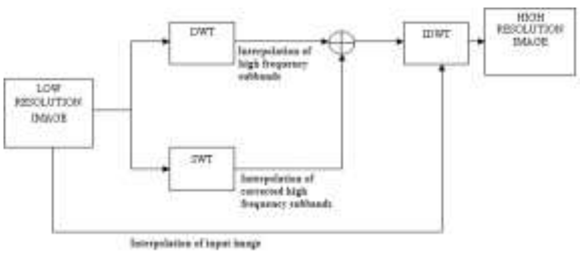

Fig. 3. Block diagram of the proposed super-resolution method

Proposed super-resolution method

Image Resolution is an important feature in imaging, which makes resolution enhancement of images to be more important as it directly affect the performance of system using these images as input. In image resolution enhancement using interpolation the main loss is on its high frequency component (i.e. edges in the image), which is due to smoothing caused by interpolation. as to increase the quality of super resolved images, preserving the edges is essential. Fig 3.illustrate the block diagram of the proposed image resolution enhancement technique.

DWT

DWT has been used in order to preserve the high frequency component of the image [6]. The shift invariance and redundancy makes DWT coefficients inherently interpolable [10]. In the paper one level DWT with db1 as wavelet function is used to decompose an input image into different subbands. The high frequency subbands are then interpolated using bicubic interpolation. Decimation in each of DWT subbands causes loss of information in the respective subbands.

SWT

The Stationary wavelet transform is a wavelet transform algorithm designed to overcome the lack of translation-invariance of the discrete wavelet transform. Translation-invariance is achieved by removing the downsampler and upsampler in the DWT. The SWT is redundant scheme as output of each level of SWT contains the same number of samples as the input. The interpolated high frequency subbands and the SWT high frequency subbands have the same size so they can be added with each other. The new high frequency subbands (corrected) can be interpolated further for higher enlargement.

Interpolation

Interpolation is the process of determining the values of function between its samples here it determines the intermediate pixels. This process accomplishes by conforming to a continuous function through the discrete input samples. The well-known interpolation techniques are nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation.

Nearest neighbor from a computational stand point is the simplest method of interpolation. Each interpolated output pixel is assigned the value of the nearest samples point in the input image. For nearest neighbor defines the kernel as

$$h(x) = \begin{cases} 1, & 0 \le |x| < 0.5 \\ 0, & 0.5 \le |x| \end{cases} \quad (1)$$

Bilinear passes a straight line through every two consecutive points of the input signal. Bilinear interpolation is corresponding to convolving the sampled input with the following kernel in spatial domain.

$$h(x) = \begin{cases} 1 - |x|, & 0 \le |x| < 1 \\ 0, & 1 \le |x| \end{cases} \quad (2)$$

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For bicubic interpolation the block uses the weighted average of four translated pixel values for each output pixel value. For bicubic interpolation defines the interpolation kernel as

$$h(x) = \begin{cases} (a+2)|x|^3 - (a+3)|x|^3 + 1 & ,0 \leq |x| < 1 \\ a|x|^3 - 5a|x|^2 + 8a|x| - 4a & ,1 \leq |x| < 2 \\ 0 & ,2 \leq |x| \end{cases}$$

(3)

In the paper bicubic interpolation with enlargement factor two is used. In wavelet domain the low resolution is obtained by lowpass filtering of high resolution image []. Low frequency subband is the low resolution of the original image. Therefore, instead of using low frequency subband we are using original image (input image) for the interpolation of low frequency subband image. Using input image instead of low frequency subband increases the quality of superresolved image [11], as illustrated in Fig. 3. By interpolating input image by α/2,high frequency subbands by 2 and α in the intermediate and final interpolation stages respectively, and by applying inverse discrete wavelet transform we get output image that contain sharper edges than interpolating images directly. The more high frequency components are preserved here as we have added high frequency subbands of stationary wavelet transform of the input image.

Algorithm

Step. 1. Read an input low resolution image.

Step. 2. Apply discrete wallet transform to input image.

Step. 3. Apply interpolation to high frequency band.

Step. 4. Apply stationary wavelet transform to input image.

Step. 5. Correct high frequency band using SWT.

Step. 6.Take interpolation of input image consider as low frequency band.

Step. 7. Take IDWT of all subbands.

Step. 8. Output is a high resolution image.

Results and discussions

The proposed technique is tested on several different images. In order to show the superiority of the proposed method over the conventional and state of art technique from visual point of you Fig. 4. is included. Fig. 4. Shows that super resolved image of Lena's picture in (d) using proposed technique is much better than the low resolution image in (a), super resolved image by using bicubic interpolation (b), and super resolved image by using DWT SR[13] (c).

Not only visual comparison but also quantitative comparisons are conforming the superiority of the proposed method. Peak signal-to-noise ratio (PSNR) and Mean square error have been implemented in order to obtain some quantitative results for comparison. PSNR can be obtained using following formula [12]:

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

Where R is the maximum fluctuation in the input image (255 in here as the image is represented by 8 bit); and MSE is representing the MSE between the given input image I_{in} and I_{out} output image which can be obtained by following:

$$MSE = \frac{\sum_{i,j}(I_{in}(i,j) - I_{out}(i,j))^2}{M \times N} \quad (5)$$

Table I compares the proposed technique using bicubic interpolation and proposed technique using bilinear interpolation with conventional and state of art technique: bilinear, bicubic and DWT SR respectively. The result in Table I show that the proposed technique performs well than conventional and state of art techniques mentioned above.

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Fig. 4. (a) Original low resolution Lena's image. (b) Bicubic interpolation image. (c) Super resolved image using DWT. (d) Proposed technique.

TABLE I.

PSNR RESULT FOR SUPER-RESOLUTION USING PROPOSED TECHNIQUE COMPARED WITH CONVENTIONAL AND STATE-OF-ART IMAGE RESOLUTION ENHANCEMENT TECHNIQUE

	PSNR(dB)		
Techniques/images	**Lena**	**Baboon**	**Peppers**
Bilinear	60.23	60.81	61.12
Bicubic	60.73	61.12	61.22
DWT SR [13]	65.62	65.60	64.43
Proposed Technique using Bilinear	65.67	65.58	64.42
Proposed Technique using Bicubic	**65.69**	**65.64**	**64.48**

Conclusion

This paper proposes an image super-resolution using DWT and SWT. It involves interpolation of high frequency subbands obtained from DWT,and correcting the estimated subbands using SWT high frequency subbands. Instead of low frequency subband input image is used which increases the quality of output 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 subbands coefficient have been corrected by using the high frequency subbands obtained from SWT. An input image is interpolated with half of the interpolation factor used for interpolation the low frequency subband. After all these images have been combined using IDWT to obtain super resolved image. The proposed technique is tested on different images, where their PSNR and visual results show the superiority of proposed technique over other techniques such as bilinear interpolation, bicubic interpolation, DWT SR techniques.

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