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SWT-ICBI based Single Image Super Resolution

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Abstract— Resolution of the image plays a key role in each and every field. Resolution is really very important aspect of the image. Inorder to achieve the natural look and feel removing of artifacts is essential.In order to extract out important information from the image, an image with super resolution is needed.The need of single super resolution image arised when the enhanced images lost its natural look and feel it. In this paper we describe a new upscaling method (ICBI, Iterative Curvature Based Interpolation) based on a two step grid filling and an iterative correction of the interpolated pixels with SWT wavelet transform. We show that this method is able to obtain very good results, especially for its ability of removing artifacts without creating "artificial" detail and is superior to the existing techniques in terms of quantitative as well as qualitative aspects.

Index Terms— Interpolation,Iterative Curvature based Interpolation(ICBI),Image Quality Index,Peak Signal to Noise Ratio(PSNR),Structural Similarity Index(SSIM),Super Resolution(SR),Stationary Wavelet Transform(SWT).

1 INTRODUCTION

The goal of Super-Resolution (SR) methods is to recover a high resolution image from one or more low resolution input images. HR image can be created by different hardware devices like charge-coupled devices (CCD) and CMOS image sensors. The desire for high resolution images from two principal application areas: improvement of pictorial information for human interpretation and helping representation for automatic machine perception.Super resolution image plays a major role for various technological fields. Super resolution techniques can be classified into categories like interpolation based, reconstruction based, learning based. Interpolation methods are simple and fast. No additional information is offered by this approach. High resolution(HR) image generated by single low resolution(LR) is quite challenging because less information is available due to single image, while incase of multiple low resolution(LR) image more detail is available. Reconstruction based approach uses prior knowledge to generate high resolution image. Learning based approach uses multiple low resolution images.

Image resolution describes the amount of information contained by images. Lower resolution less would be the amount of information, higher resolution more would be amount of information in images. Super resolution is a technique that enhances the resolution of an image. In electronic imaging applications, image with high resolution are described. The high resolution means that pixel density within an image is high, and HR images can offer more details in various applications. This approach is to use signal processing techniques to obtain an HR image from the observed multiple low resolution images. A resolution enhancement approach has been one of the most active research areas and it is called super resolution image reconstruction or simply image resolution enhancement.

Image super resolution enhancement in the wavelet domain is relatively new research topic and recently many existing algorithms have been proposed [4],[6]. The wavelet transform technique used is one of the best wavelet transform techniques used in image processing. Discrete Wavelet Transform (DWT) decomposes image into various sub-band images namely low-low (LL), low-high (LH), high-low (HL), and high-high (HH). This decomposing is done based on the concept of subband coding. Another recent wavelet transform which has been used in various image processing applications is stationary wavelet transform (SWT) [5]. The SWT is similar to DWT but it does not used down-sampling, the sub-bands will have size same as the input image.

Interpolation techniques are mainly divided in two categories:

1. Non-adaptive techniques
2. Adaptive techniques

Non-adaptive interpolation techniques are based on direct manipulation on pixels instead of considering any feature or content of an image. These techniques follow the same pattern for all pixels and are easy to perform and have less calculation cost. Various non-adaptive techniques are nearest neighbor, bilinear and bicubic. Adaptive techniques consider image feature like intensity value, edge information, texture etc. Non-adaptive interpolation techniques have problems of blurring edges or artifacts around edges and its only store the low frequency components of original image. For better visual quality image must have to preserve high frequency components and this task can be possible with adaptive interpolation techniques. These techniques give better result than non-adaptive techniques but take more computational time. Various adaptive techniques are NEDI, DDT, ICBI and many more.

2 RELATED WORKS

Image upscaling, or single image super-resolution has recently become a hot topic in computer vision and computer graphics communities due to the increasing number of practical applications of the algorithms proposed. Xin Li et al [7] proposed a new edge-directed interpolation (NEDI) that use the geometric duality between low-resolution covariance and high-resolution covariance of image which groups the pixels along the same direction. However this covariance-based interpolation have computational complexity at about two times higher than linear interpolation techniques. To reduce this complexity, trade off between visual quality and computation usually established by applying the edge directed interpolation for pixels around the edges while bilinear interpolation for non-edge pixels. As the number of pixels around the edge is less, computational burden is eased.

Gholamreza Anbarjafari and Hasan Demirel[4] proposed a image resolution enhancement 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 being 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). Nicola Asuni, Andrea Giachetti proposed an improved NEDI [8] by non-edge pixel handling, window shape, edge segmentation, value adjust and matrix conditioning, error propagation and minimum norm solution. Jan Allebach and Ping Wah Wong proposed edge directed interpolation [15] which creates high resolution edge map from low resolution image using sub-pixel edge estimation technique. Using high resolution edge map, high resolution image is created from low resolution image.

3. PROPOSED METHODOLOGY

In this paper, a low resolution input image f, is considered it is resized to a specific resolution.To this input image f, Stationary Wavelet Transform is performed and upsampled to specific dimension and simultaneously to this input image f,Iterative Curvature Based Interpolation(ICBI) is performed. In this paper we described a new upscaling method (ICBI, Iterative Curvature Based Interpolation) based on a two step grid filling and an iterative correction of the interpolated pixels obtained by minimizing an objective function depending on the second order directional derivatives of the image intensity. We show that the constraints used to derive the function are related with those applied in another well known interpolation method providing good results.The output of ICBI technique is edge preserved detailed image. SWT is applied to the edge preserved image.The output of this two methods are combined and inverse SWT is performed. The final output is a single super resolution image with high PSNR value,SSIM and Image Quality Index.The detailed description is given in fig1.

3.1 SWT-Based Resolution Enhancement

The SWT is an inherently redundant scheme as the output of each level of SWT contains the same number of samples as the input so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients. 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, lowpass filtering of the high resolution image produce the low resolution image. In other words, low frequency subband is the low resolution of the original image.

3.2 Iterative Curvature-based Interpolation

Iterative curvature-based interpolation technique focuses on estimation of direction and based on second order derivatives. Main purpose of introducing ICBI technique to minimize the artifacts presented in image compare to other technique like NEDI and other linear and non-linear interpolation techniques.

ICBI technique has lower computational cost then other non-adaptive techniques. ICBI technique is a combination of two techniques. In first technique, the new pixels are computed by interpolating along the direction (FCBI, Fast Curvature Based Interpolation). In second technique, we modified the interpolated pixels using iterative method with energy term for edge preservation purpose [2]. First technique, FCBI is same the Data Dependent Triangulation interpolation technique, but instead of taking the average value of two opposite neighbor pixels, we consider second order derivatives in two diagonal direction and compute new pixel values in such a direction where the estimated derivative is low.

In second technique, the energy term is sum of the curvature continuity, curvature enhancement and iso-levels curves .First we compute, for each new pixel, the energy function U(2i+1; 2j+1) and the two modified energies U+(2*i*+1;2*j*+1) and U-(2*i*+1;2*j*+1), i.e. the energy values obtained by adding or subtracting a fixed value called threshold value to the local pixel value I(2*i*+1;2*j*+1) [2] and assign this intensity value to pixel. This procedure is iteratively repeated until the sum of the modified pixels at the current iteration is lower than a fixed threshold value.

Overall procedure for ICBI technique is as follows [2]:

Step 1: Put original pixels in the enlarged grid at locations 2i,2j
Step 2: Insert pixels at locations 2i+1,2j+1 with the FCBI method
Step 3: Apply iterative correction until the image variation is above a given threshold
Step 4: Insert pixels in the remaining locations with the FCBI method
Step 5: Apply iterative correction to the added pixels
Step 6: Repeat the whole procedure on the new image for further enlargements

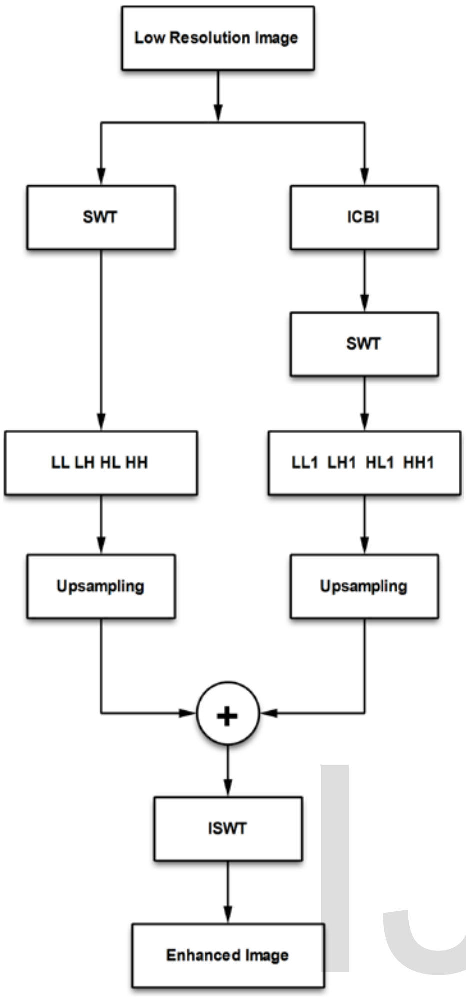

Fig1: Block Diagram of proposed methodology

4. EXPERIMENTAL RESULTS

We tested the algorithms proposed on a database of 25 natural images selected from the Caltech256 dataset. However, we performed both subjective and objective tests in order to compare quantitatively the quality of the images created with different methods and the related computational cost.From this methods a super resolution image was obtained.Table 1 shows the quantitative results on existing system and proposed system.

Table 1

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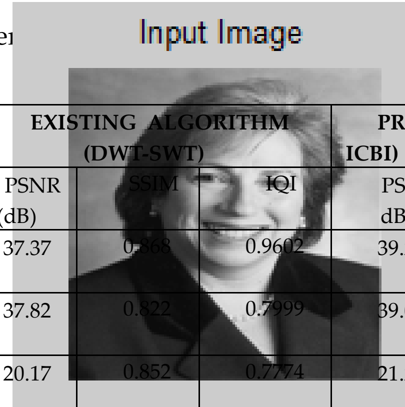

IMAGE SAMPLE	EXISTING ALGORITHM (DWT-SWT)			PROPOSED ALGORITHM(SWT-ICBI)		
	PSNR (dB)	SSIM	IQI	PSNR(dB)	SSIM	IQI
Image 1	37.37	0.868	0.9602	39.21	0.9009	0.9865
Image 2	37.82	0.822	0.7999	39.08	0.8443	0.8389
Image 3	20.17	0.852	0.7774	21.25	0.8653	0.8307
Image 4	31.89	0.918	0.9547	32.13	0.9315	0.9746
Image 5	31.20	0.721	0.6055	32.20	0.7242	0.6189

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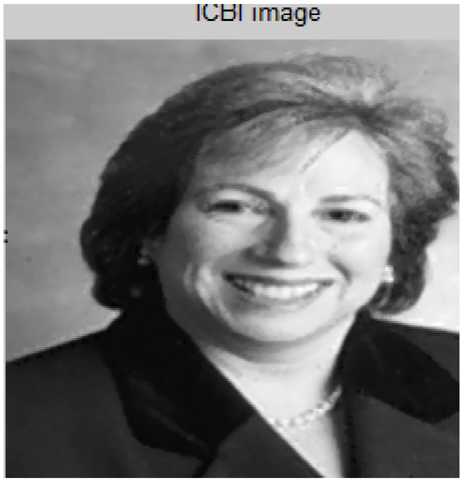

Fig3:ICBI image

FIG4: SUPER RESOLUTION IMAGE

5 CONCLUSION

Increasing spatial resolution becomes a mandatory requirement in many applications. The resolution of image can be enhanced by increasing sensors in two dimensional matrixes. Increasing sensors increases the hardware cost. The size of sensors reduces as the number of CMOS sensors increase. Beyond a limit it causes shot noise in images. This problem gives way to develop techniques to increase the resolution of images. Although several schemes have been developed for super-resolution still there are scopes to improve the results. Two contributions are made in this regard. The idea behind both the techniques is to generate the high frequency sub-band images using SWT and later they are interpolated using ICBI and again SWT is applied to obtain a single super resolution image.When compared with existing techniques SWT-ICBI is superior to all methods. The future scope will be the development of adaptive algorithms for effective image enhancement using Fuzzy Logic and Neural Network.

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