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Enhanced DCT Interpolation for better 2D Image Up-sampling

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***Abstract*-- The up-sampling technique plays an important role in resolution enhancement. The conventional up-sampling techniques using interpolation cause undesirable blurring artifacts when a low resolution image is converted to its high resolution counterpart. The loss of high frequency information during up-sampling is the cause for these blurring artifacts. These artifacts deteriorate the signal quality which causes loss of fine details and edge information. This can be resolved by edge enhancing the low resolution image before up-sampling. In this paper, a hybrid DCT based up-sampling technique is used which incorporates DCT variance fusion and diffusion filtering to increase the information content and preserving the edges of the up-sampled image respectively. This method helps to restore the fine details and edge information in the reconstructed image, thus increases the quality of the up-sampled image. Experimental results show that there is significant improvement in the performance by using the proposed method in terms of PSNR and SSIM compared to the state-of art techniques for various test images.**

Keywords-- Image fusion, Diffusion filter, Image interpolation, Discrete Cosine Transform (DCT), Up-sampling, Interpolation filter.

I. INTRODUCTION

Image interpolation is the generation of a high resolution image from an input low resolution image. Image interpolation is widely used in 2D image processing. The interpolation processes have properties such as scalability, compatibility and restored image quality. Up-sampling or Interpolation of digital images can be used for providing additional information such as inspection and recognition of images. Image up-sampling plays a crucial role in medical imaging, satellite remote sensing where it is required to improve the resolution of the acquired image. Image interpolation aims at obtaining a high resolution image from the acquired low resolution image. Hence, image interpolation plays a crucial role in digital image processing.

There is several interpolation techniques used for the up-sampling of images. One of the simplest interpolation techniques is the bilinear interpolation technique [1]. In this technique, the value of a new point is computed by the linear interpolation of the surrounding four pixels of the new point. It is simple and less complex but has undesirable blurring artifacts. Some of the commonly used interpolation techniques are Bicubic and B-Spline interpolation techniques. These techniques consider sixteen neighboring pixels to determine a new interpolated pixel value. They give a lesser degree of blurring compared to bilinear interpolation technique. Though
these interpolation techniques provide better performance and quality, they are computationally complex [2-5]. Lancoz is also a spatial domain interpolation technique. In this method, a sinc function is multiplied with a sinc window and scaled to be wider. It is truncated to zero outside a range[6]. It gives good result but it is slower than other approaches and reconstructed image has blurring artifacts.

There are many up-sampling techniques which are developed in the transform domain[7-9]. One of the techniques in the transform domain is the discrete cosine transform (DCT) based up-sampling [7]. This is implemented by padding zero coefficients to the high frequency side of the low resolution image. It gives very good result in terms of scalability and image quality. The DCT based up-sampling make use of the fact that the low resolution image preserves the low frequency DCT coefficients of the original high resolution image. It has good energy compatibility, so, the low frequency DCT coefficients contain the most important information. So, it provides better result than the conventional methods of interpolation. But, this technique results in undesirable blurring and ringing artifacts. Therefore, an efficient interpolation technique is required which have less amount of blurring and also improves the quality of the up-sampled image. The hybrid DCT-Weiner based interpolation method combines spatial interpolation and DCT interpolation [7]. It combines the advantages of both spatial domain and DCT domain interpolation techniques. The low resolution image has the low frequency information of the DCT. The performance of the proposed scheme mainly depends on the spatial domain approach. The spatial domain approach makes use of a 6-tap interpolation filter for up-sampling [10]. This method also suffers from blocking and ringing artifacts.

The method proposed in this paper describes a novel hybrid DCT based up-sampling technique which uses image fusion [11] and diffusion filtering [12] before up-sampling to eliminate ringing artifacts and enhance the edges. This method performs interpolation both in the spatial domain and the transform domain approach for up-sampling the image.

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The proposed method mainly consists of three steps. First step is DCT variance fusion [11], where the low resolution images undergo fusion to obtain the fused image. This helps to increase the information content of the image. Second step is diffusion filtering which is used to preserve the edges of the fused image. A non-linear anisotropic diffusion filter [12] is used which helps to reduce the edge artifacts. Final step is the hybrid DCT up-sampling which combines both the transform domain and spatial domain up-sampling using DCT up-sampling and interpolation filter respectively.

II. PROPOSED METHOD

A. Overview

The low resolution input images are fused to obtain a single fused image to increase the information content of the low resolution image. It then undergoes diffusion filtering by passing it through a non-linear diffusion filter to enhance the edges of the fused image. It is then interpolated using the hybrid DCT- Weiner up-sampling technique. The proposed method is described in detail in this session.

B. DCT Variance Fusion

The low resolution images are fused using the DCT variance fusion method [11]. This helps to increase the information content in the image. The algorithm is described as follows:

Algorithm

(a). Get input image size

(b). Level shifting

(c).Divide source images into 8*8 blocks and perform the fusion

- *(i) Compute the 2-D DCT of 8*8 blocks*
- *(ii) Calculate normalized transform coefficients*
- *(iii) Mean value of 8*8 block of images (Measure for surrounding luminance)*
- *(iv) Variance of 8*8 block of images*
- *(v) Perform Fusion*
- *(vi) Compute the 2-D inverse DCT of 8*8 blocks and construct fused image*

(d). Inverse level shifting

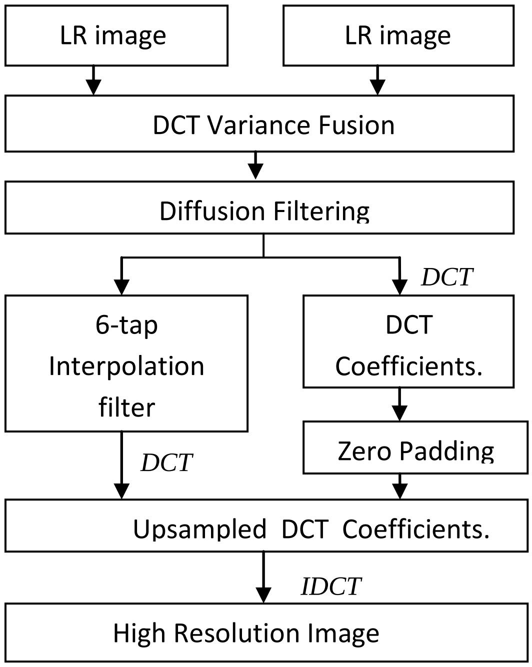

Fig. 1. Proposed Up-Sampling Method

C. Diffusion Filtering

Perona and Malik [12] proposed the nonlinear PDE for smoothing image on a continuous domain. Linear diffusion filtering is equivalent to convolving the original image with a Gaussian function, but, in diffusion filtering edges remain well localized and can even be enhanced.

D. 6 tap Interpolation filter

The interpolation filter performs the row-wise and column-wise interpolation of the input image to obtain the up sampled image [10]. The input image is resized by adding the filter coefficients in the alternate rows and columns when passing through the interpolation filter.

C. DCT Up-sampling

In DCT domain, up-sampling [7] is done by adding *N* zeros in the high frequency regions, where *N* is the signal length. Then, the two fold up-sampled data is obtained by performing type-*II IDCT* of the extended *2N* samples. The steps include:

- *(i) Obtain the 2D- DCT of the N *N image*
- *(ii) Zero padding to obtain 2N*2N samples*
- *(iii) Obtain the IDCT of the 2N*2N samples.*

III. EXPERIMENTAL RESULTS

The performance of the proposed method is compared with the existing techniques. To, demonstrate this; the input image is down sampled by a factor 2 in the spatial domain. The image is interpolated back to the original size by using each of the interpolation schemes. The methods are compared using different quality

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assessment parameters. The experimental results show that the proposed hybrid interpolation technique gives better performance compared to spatial domain and DCT interpolation techniques in terms of objective and subjective image quality. The experiment is conducted for both gray scale and color images.

Table I illustrates the PSNR (dB) comparison of various existing techniques such as, bicubic, DCT, and hybrid method with the proposed interpolation technique. The experimental results show that the proposed algorithm provides a considerable PSNR improvement in comparison to the existing techniques. Also, in Table II and Table III the performance analysis is done in terms of SSIM and VIF parameters. Figure 2 gives the plot of PSNR value for different methods for various test images.

Figure 3 illustrates the results of various up-sampling schemes for subjective evaluation for gray scale images. Experimental results show, the blurring is much reduced and the edges are enhanced with fine detail preservation in comparison to other existing interpolation techniques. Thus, the proposed method yields considerably better subjective performance than DCT and other techniques.

The experiment is repeated for color images also. Table IV, V and IV gives the comparison of PSNR, SSIM and VIF for color images respectively. Fig.4. gives the corresponding PSNR plot for different schemes for color images. Fig.5. gives the results of various up-sampling schemes performed on color images. In this experiment, a low resolution input image of size 128 $\times$128 is up-sampled by a factor 2 to obtain a high resolution image of size 256$\times$ 256.

Table I. Comparison of Peak Signal to Noise Ratio (PSNR) (dB) for gray scale images

Input images	PSNR(dB)			
	Bicubic	*DCT*	*Hybrid*	*Proposed*
Lena	29.9968	32.0564	37.8236	40.0146
Barbara	28.3402	30.1834	37.6784	39.8485
Boat	27.7294	28.8809	35.7951	38.0229

Table II. Comparison of Structural Similarity Index (SSIM) for gray scale images

Input images	SSIM			
	Bicubic	DCT	Hybrid	Proposed
Lena	0.8934	0.9160	0.9784	0.9793
Barbara	0.8272	0.8525	0.9813	0.9819
Boat	0.8177	0.8450	0.9648	0.9667

Table III. Comparison of Visual Index Fidelity (VIF) for gray scale images

Input images	VIF			
	Bicubic	DCT	Hybrid	Proposed
Lena	0.5522	0.6443	0.8392	0.8398
Barbara	0.5071	0.5868	0.8554	0.8562
Boat	0.4454	0.4971	0.7780	0.7804

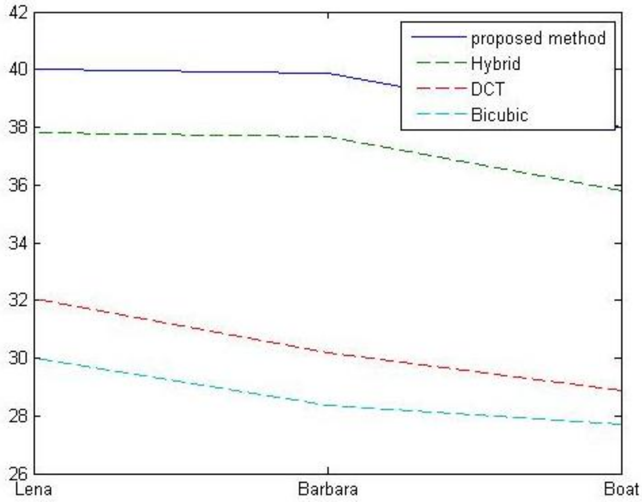

Fig.2. PSNR plot for various schemes corresponding to different gray scale images.

(a)

(b)

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(c)

(d)

(e)

Fig.3. (a)Original low resolution image; (b)Bicubic Interpolation; (c)DCT Up-sampling; (d)Hybrid DCT Up-sampling; (e)Proposed Method for gray scale image

Table IV. Comparison of Peak Signal to Noise Ratio (PSNR) (dB) for color images

Input images	*PSNR(dB)*			
	Bicubic	*DCT*	*Hybrid*	*Proposed*
Baboon	22.1161	26.2366	26.9995	27.2802
Lena	23.2689	30.1262	32.1416	33.1636
Peppers	23.3440	30.2076	32.6323	33.7606

Table V. Comparison of Structural Similarity Index (SSIM) for color images

Input images	SSIM			
	Bicubic	*DCT*	*Hybrid*	*Proposed*
Baboon	0.6744	0.7707	0.7767	0.7768
Lena	0.8847	0.9278	0.9442	0.9252
Peppers	0.9168	0.9403	0.9258	0.9436

Table IV. Comparison of Visual Index Fidelity (VIF) for color images

Input images	VIF			
	Bicubic	*DCT*	*Hybrid*	*Proposed*
Baboon	0.9410	0.9648	0.9767	0.9849
Lena	0.9444	0.9716	0.9821	0.9900
Peppers	0.9464	0.9703	0.9799	0.9878

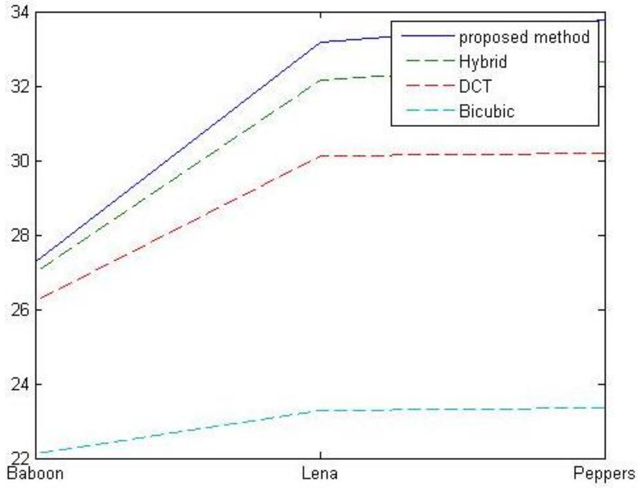

Fig.4. PSNR plot for various schemes corresponding to different color images.

(a)

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(b)

(c)

(d)

(e)

Fig:5. (a)Original low resolution image; (b)Bicubic Interpolation; (c)DCT Upsampling; (d)Hybrid DCT Upsampling; (e)Proposed Method for color image.

IV. CONCLUSION

In this paper, an improved hybrid DCT based up-sampling technique is proposed. Most of the existing image up-sampling techniques produce blurring artifacts which is due to the loss of fine details in the up-sampled image. The proposed method helps to increase the information content and preserve the fine details of the image. Hence, it helps to improve the signal quality.

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