Single image super resolution using learned wavelets-Block wavelet method

Dr Reji A P Dr.Tessamma Thomas

Abstract— This method is based on patch based approach. It has many advantages compared with many wavelet transform based methods where DWT is applied on whole image and used parent child relation to predict the high resolution image. Results show that the new method outperforms different existing methods in terms of SNR values and visual quality

Index Terms—Super resolution,Discrete wavelet Transform,Learning,Patch

1 INTRODUCTION

Most of the Image processing applications like remote sensing, medical imaging, robot vision, industrial inspection, or video enhancement demand high resolution images. The high resolution images not only give the viewer a pleasing appearance but also offer additional information that is important for the analysis in many applications. Acquisition environment condition, the resolution of image sensors employed, etc are some of the factors that affect the quality of digital image. Getting high quality images in practical applications like satellite imaging is a difficult task since the above factors cannot be controlled. Therefore some image processing methods are needed to construct a high resolution image from one or more available low resolution images. Super resolution refers to the process of producing a high resolution image than what is afforded by the physical sensor through post processing , making use of one or more low resolution observations[1]. It includes up sampling the image, thereby increasing the maximum spatial frequency, and removing degradations that arise during the image capture, namely, aliasing and blurring.

Super resolved image reconstruction is proved to be effective in many areas including medical imaging, satellite imaging, video applications, image enlarging in web pages and restoration of old historic photographs, surveillance, tracking, and license plate recognition system etc. Techniques such as bilinear and bicubic interpolation only consider low resolution image information and the resulting image from these techniques is often blurry and contain artefacts.

In general there are two types of super resolution techniques - reconstruction based and learning based. In reconstruction based techniques, high resolution image is recovered from several low resolution observations of the input. Frequency domain approach proposed by Tsai and Huang [2] was the first method in super resolution. Impressive amount of work has been reported in this field. In 1990, Kim et al. proposed a recursive algorithm for restoration of super resolution images from noisy and blurred observations [3].

- Reji A P is currently working as assistant professor in N S S College,Rajakumari,Idukki,India,PH-9496173796,Email:rejimoodethu@yahoo.com
- *Dr.Tessamma Thomas is currently working as assistant profrssor,N.S.S College,Rajakumari,Idukki,India,, PH-9446970659. E-mail: tess@cusat.ac.in*

Ur and Gross use the Papoulis and Brown generalised sampling theorem for obtaining high resolution image from a set of spatially shifted observations [4]. Ng et al. developed a regularised, constrained total least squares solution to obtain a high resolution image [5].

In [7] Freeman proposed an example based super resolution method in which he had developed a Bayesian propagation algorithm using Markov Network. Bishop et al. [8], Pickup et al.[9], and Sun et al. [10] also adopted the Markov network as Freeman and Pasztor , did but they differed in the definition of priors and likelihoods. Baker and Kanade's hallucination algorithm [11] further inspired the work in this field. Gunturk et al. [12], Capel and Zisserman [13], Liu et al. [14], and Wang and Tang [15] all used face bases and inferred the combination coefficients of the bases, where the face bases are different. Liu et al.'s face hallucination algorithm [16] was a combination of [17] and [18] to infer the global face structure and the local details respectively. Joshy and Choudhari have proposed a learning based method for image super resolution from zoomed observations. They model high resolution image as Markov random field, the parameters of which are learned from the most zoomed observation [19]. The learned parameters are then used to obtain a maximum aposteriori estimate of the high resolution image. Several learning based methods based on wavelets are also available [1, 20,21].

2 Single image super resolution using learned wavelets

The method was proposed by Jiji et al [1] and it is also based on the assumption that images can be decomposed into low and high frequency bands. Here decomposition process is done using wavelet transform. The super resolution is considered as a problem of obtaining high resolution image, if the low band is given. For that one has to first estimate the high frequency bands, so that using inverse wavelet transform of these bands gives the original signal. To super resolve a LR image using wavelet transform, the different frequency bands (LL, LH, HL, HH) corresponding to high resolution image need to be known.

The input LR image itself is considered as approximation or

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low frequency band (LL) of the unknown HR image. For obtaining high frequency bands (LH, HL, HH), a training set which contains wavelet coefficients of available HR images is used here. Three-level wavelet decomposition of the high resolution images are taken and are used as the training set. Two level decomposition of input low resolution image is taken. The absolute difference between first and second level wavelet transform coefficients in the LR image and second and third level coefficients for each of training set images is taken. For comparing the coefficients, parent child relationship is used here. If a match is found, corresponding first level coefficients of high resolution image are taken as the first level coefficients of unknown high resolution image. The HR image is obtained by taking the inverse wavelet transform of the approximation and learned wavelet coefficients. In order to obtain a spatial coherence during the HR reconstruction, a smoothness constraint is needed. The wavelet method without smoothing is implemented here

3 Single image super resolution using learned wavelets-Block wavelet method

The method explained above needs different training set for super resolving low resolution images of different sizes. For example, to super resolve an image of size 128x128 into 256x256, one needs training set images of size 256x256. But, training set images of size 128x128 are needed to super resolve low resolution images of size 64x64, the 256x256 images can not be used. Another problem is that due to spurious learning, super resolved images have artifacts. So smoothness constraint is needed to solve this problem, which increases computational complexity of the method. Hence the above explained wavelet method is modified using patch based approach to obtain block wavelet method. In this new method, single training set with suitably selected high resolution images is used to super resolve different sized input low resolution images.

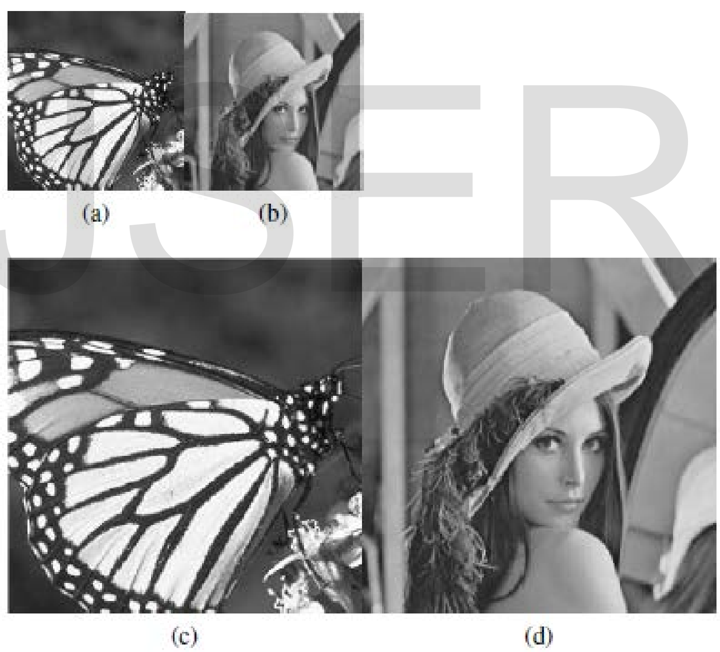

Figure 1: (a),(b)Low resolution images(c),(d)Original images

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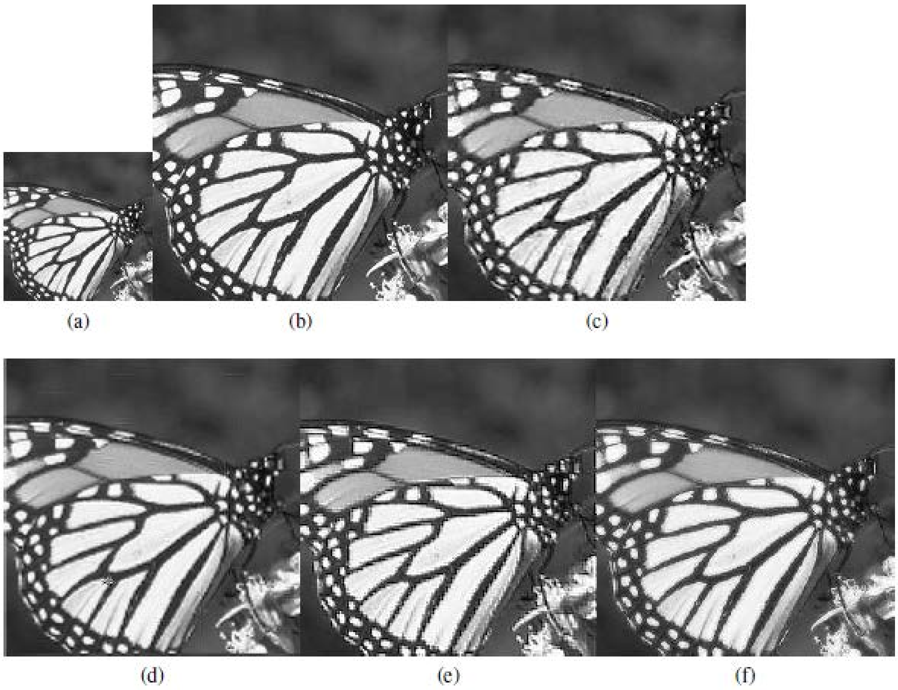

Figure 2: (a)Low resolution image (b)Original image (c)Freeman method(d)wavelet method 1(e) Sapan's wavelet method[21] (f)block wavelet method

In the block wavelet method, which is a novel approach, instead of applying wavelet transform to the full image, high resolution images and their low resolution images are divided into small overlapping blocks. Both high and low resolution patches are contrast normalized using energy of the input low resolution patch and 1-level wavelet transform is applied to these patches. The wavelet coefficients of these patches are stored in the training set. The LR image to be super resolved is also divided into patches and wavelet coefficients of these patches are compared with those of the patches in the training set. The training set patch with minimum absolute difference is found out and the wavelet coefficients of its HR patch are used as the HR coeffi-patches and coefficients corresponding to the high frequency bands H, V and D of high and cients of the input LR patch. Here also, the LR patch is considered as the approximation. Contrast normalization is undone at the end of the entire reconstruction process. The process is repeated for all the patches in the LR image in raster scan order to obtain the unknown HR image.

4.Implementation

HR images of size 256x256 and 256 grey levels are used for training. LR images are obtained from the corresponding HR images as mentioned earlier, for the purpose of evaluation. The high resolution images and their corresponding low resolution images are divided into small overlapping patches of size 8x8 and 4x4 respectively. One level wavelet transform is applied on these low resolution patches are stored as the training

Figure 3: (a)Low resolution image (b)Original image (c)Freeman method(d)wavelet method 1(e) Sapan's wavelet method[21] (f)block wavelet method

set. The input low resolution image is divided into small overlapping patches of size 4x4 and one level wavelet transform is applied to each patch. To find the missing high frequency bands of its unknown high resolution patch, wavelet coefficients of low resolution patch is compared with the corresponding coefficients of low resolution patches in the training set, by taking the absolute difference. The low resolution patch with minimum absolute difference is selected and it's corresponding HR high frequency coefficients are used as the missing HR coefficients. This is repeated for all the patches. The low resolution patch was used as the approximation. The inverse transform of the approximation and learned coefficients corresponding to H, V, D gives the unknown HR patch .

4 Results and Discussions

Figures 1(a), (b) show low resolution images which are obtained from original high resolution images of butterfly and Lena shown in Figures 1(c) and (d). SNR values of different methods are shown in table 1. From table it is clear that block wavelet method is better than other super resolution methods. For the image Barbara SNR with new block wavelet method is 17.4133dB, while it is low for other methods.

The results are shown in Figure 2. Here Figure 2 (a)low resolution image (b)original image. Figures 2(c), (d), (e) and (f) are super resolved images using Freeman method, wavelet method [1], super resolved image using Sapan et al wavelet method based super resolution method [21], block wavelet method.

Another result is shown in Figure 3 . Here Figure 3 (a) is the low resolution image, (b)original image. Figures3(c), (d), (e) and (f) are super resolved images using Freeman method, wavelet method 1, Super resolved image using Sapan et al wavelet based super resolution method, block wavelet method. It is clear that the block wavelet method removes artifacts much better compared with the super resolved images. There is no need of regularization step. There is no constraint about the size of training set images and and LR images of any size can be super resolved using this method

Table 1 SNR values with different methods

Method	SNR in DB		
	Barbara	Butterfly	Tiger
Freeman Method	13.3849	22.3943	19.9744
Wavelet Method 1	8.7688	3.1185	3.6367
Sapan et al's based method	16.1121	20.9643	19.1132
BlockWavelet Method	17.4133	24.8016	24.1414

Conclusion

This paper explains single image super resolution using Discrete wavelet transform.The block wavelet method outperforms other existing methods.

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