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Novel Iterative Back Projection Approach

Patel Shreyas A.
Master in Computer Science & Engineering, Parul Institute of Technology, Vadodara, Gujarat, India.
Department of Computer Science & Engineering, Parul Institute of Engineering & Technology, Vadodara, Gujarat, India

ABSTRACT: *This paper addresses the problem of recovering a super-resolved image from a single low resolution input. This is a hybrid approach of single image super resolution. The technique is based on combining an Iterative back projection (IBP) method with the edge preserving Infinite symmetrical exponential filter (ISEF). Though IBP can minimize the reconstruction error significantly in iterative manner and gives good result, it suffers from ringing effect and chessboard effect because error is back-projected without edge guidance. ISEF provides edge-smoothing image by adding high frequency information. Proposed algorithm integrates ISEF with IBP which improves visual quality with very fine edge details. The method is applied on different type of images including face image, natural image and medical image, the performance is compared with a number of other algorithms, bilinear interpolation, nearest neighbor interpolation .The method proposed in the paper is shown to be marginally superior to the existing method in terms of visual quality and peak signal to noise ratio (PSNR).*

I. Introduction

Super resolution (SR) is the method of obtaining a high-resolution (HR) image from one or more low-resolution (LR) observations of an image. High resolution image gives not only pleasing picture to viewer but also offers additional information that is significant for subsequent analysis. There are various applications in which high quality images are required. The resolution of the captured image depends on the resolution of camera system. A new approach to get high resolution image which overcomes the inherent limitations of the image acquisition system is the use of super resolution. A wide range of various Super Resolution reconstruction algorithms have been developed in the field of image processing since R. Y. Tsai and T. S. Huang's first work in 1984 [1]. In 2003, S. C. Park et al. [3] gave an excellent, detailed technical overview on the general super resolution techniques. SR reconstruction techniques can be used in the frequency or spatial domain. Simplicity in theory is a major advantage of the frequency domain approach. However, this approach allows low flexibility to add priori constraints, noise models, and spatially varying degradation models. Thus, the development in practical use is limited. On the other hand, spatial domain techniques are more flexible and have better performance in reconstructed images. However, these methods are complicated theoretical work and relatively large amount of computation load. In general, spatial domain techniques can be divided into several categories as follows:

- Non-Uniform Interpolation Methods
- Projection onto High-Resolution Grid Methods
- Probabilistic Methods
- Hybrid ML/MAP/POCS Methods
- Iterative Back Projection(IBP)method

Very famous interpolation techniques including Nearest Neighbor (NN), Bilinear (BI) and Bicubic (BC) methods are used for initial enhancement. Interpolation methods can produce smooth HR image, which are usually blurry because interpolation cannot restore the high frequency component back. To preserve edge sharpness edge directed interpolation is proposed in [4]. In [2], Irani and Peleg proposed an IBP method for SR reconstruction. This method uses multiple LR image of same scene to obtain corresponding HR image. Dai et al. in [5], Dai uses bilateral filter with this IBP method, which uses single LR image. Again improved IBP method was given by Qin [8] in which initial value is estimated through wavelet locally adaptive algorithm rather than traditional interpolation method. In [6], Dong et al. proposed a novel non-local IBP algorithm for image enlargement which is to incorporate adaptively the non-local information into the IBP process so that the reconstruction errors can be reduced. In10], Liang et al. proposed an improved NLIBP fast algorithm in which edge detection is conducted on the initially interpolated image. Use of non-local filter in the modifying process greatly reduces the time consumption. In [7], J. Wang et al. proposed the new an Estimated High Frequency Compensated (EHFC) algorithm for super resolution images. It is based on IBP method combined with compensated high frequency models according to different applications. In [9], proposed we propose an estimation of HR image using IBP method integrated with high frequency information. We combine the IBP method with the Canny edge detection. It does not back-project the error only but also back-project the high frequency component using the Canny edge detection.

In this paper, we propose an estimation of HR image using IBP method integrated with high frequency information. We combine the IBP method with the ISEF provides. IBP method can minimize the errorconsiderably by back projecting the error iteratively. But it does not provide edge detail and hence noise remains at the edges. Proposed method makes use of simple interpolation to enlarge the image and processes it according to the IBP method. It does not back-project the error only but also back-project the high frequency component using the ISEF provides. This approach of SR is fast and robust to noise with edge perseveration After multiple iterations, the blurring effect can be greatly reduced in enlarged images.

The paper is organized as follows: Section II presents brief overview of IBP algorithm. Section III presents proposed algorithm. Section IV presents Simulation results and analysis. Finally, section V concludes the paper.

II. IBP ALGORITHM

In IBP approach, process starts with the initial guess of the HR image. This initial HR image can be generated from the input LR image by decimating the pixels. The initial HR image is down sampled to simulate the observed LR image. The simulated LR image is subtracted from the observed LR image.

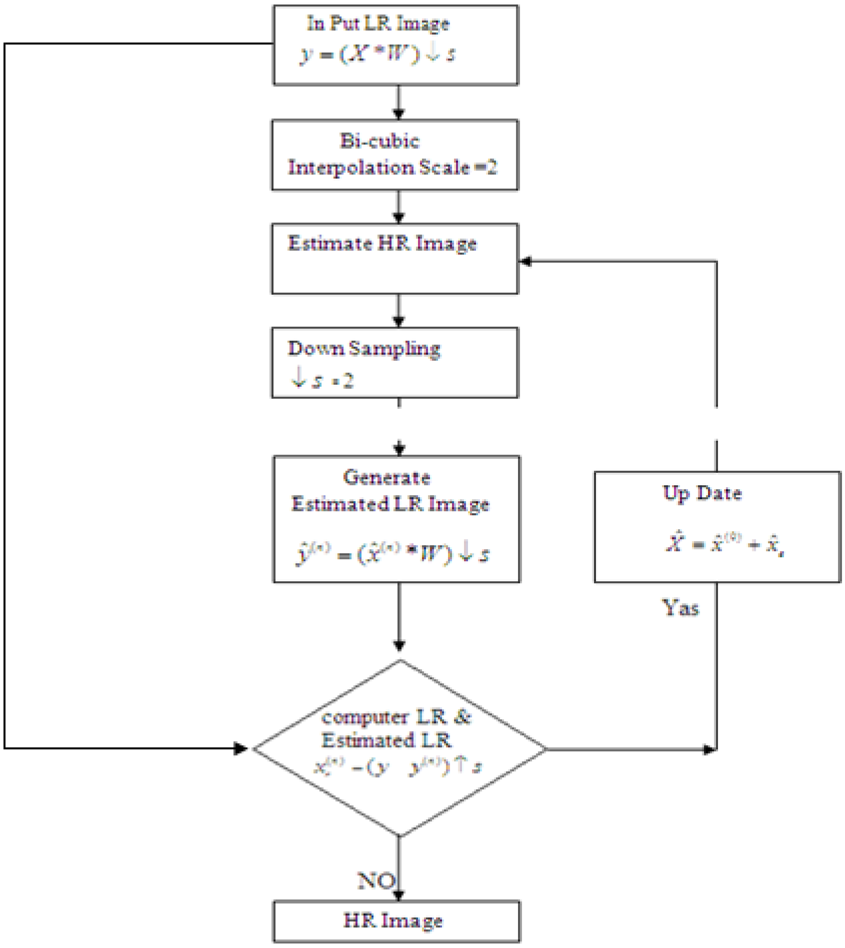

Fig.1 Diagram of IBP Algorithm

If the initial HR image is same as the observed HR image, then the simulated LR image and observed LR image are identical and their difference is zero the HR image is estimated by back projecting the error (difference) between simulated LR image via imaging blur and the observed LR image. This process is repeated iteratively to minimize the energy of the error. This iterative process of SR does iterations until the minimization of the cost function is achieved or some predefined iterations. Block diagram of IBP algorithm is shown in figure (1). Mathematically the SR steps according to IBP are written as:

(1) compute the LR error given as:

$e^{(n)} = (y_i - y_i^{(n)})^m{}_{i-1}$ (1)

(2) Update the HR image by back -projecting the error as:

$X^{(n+1)} = X^{n} + e^{(n)} \uparrow s * p$ (2)

III. PROPOSED ALGORITHM

Though IBP can minimize the reconstruction error significantly in iterative manner and gives good result, it required multiple images of same scene and error is back-projected without edge guidance

An original HR image in the natural degenerates to an LR image after being captured by camera system will be blurred. Also, there is a loss of high frequency data which gives the information about the edges. However, it still contains pixels in gray level distribution similar to the original one. In order to improve blurriness and sharpen the edges for an better visual quality or more accurate analysis in image processing, techniques related to edge enhancement are commonly used. high frequency data is developed to compensate the frequency data lost in the iteration processes including down-sampling, up-sampling and degeneration of the LR image.

ISEF algorithm iteration diagram is shown in figure 2. We consider the first interpolated image $\hat{x}^{(0)}$ by enlarging the original low resolution image y same as the IBP method. An estimated high frequency image $\hat{x}$ is degenerated from an estimation of low resolution image $\hat{y}$. So, in the iteration process, the estimated high resolution image $\hat{x}$ will be the more similar to the original HR image X. An estimated low resolution image $\hat{y}$ is then used to interpolate to get HR image x'. It could be predicated that x' will have more serious blurring effect then the $\hat{x}^{(0)}$. To overcome this effect the lost high frequency data $(\hat{x}^{(0)} - x')$ is calculated and back projected to the estimated HR image to compensate the high frequency error. The iteration process reduces the blurring effect while preserving edges. The block diagram of proposed algorithm is shown in figure 2. Mathematically SR steps are written as according to proposed algorithm is:

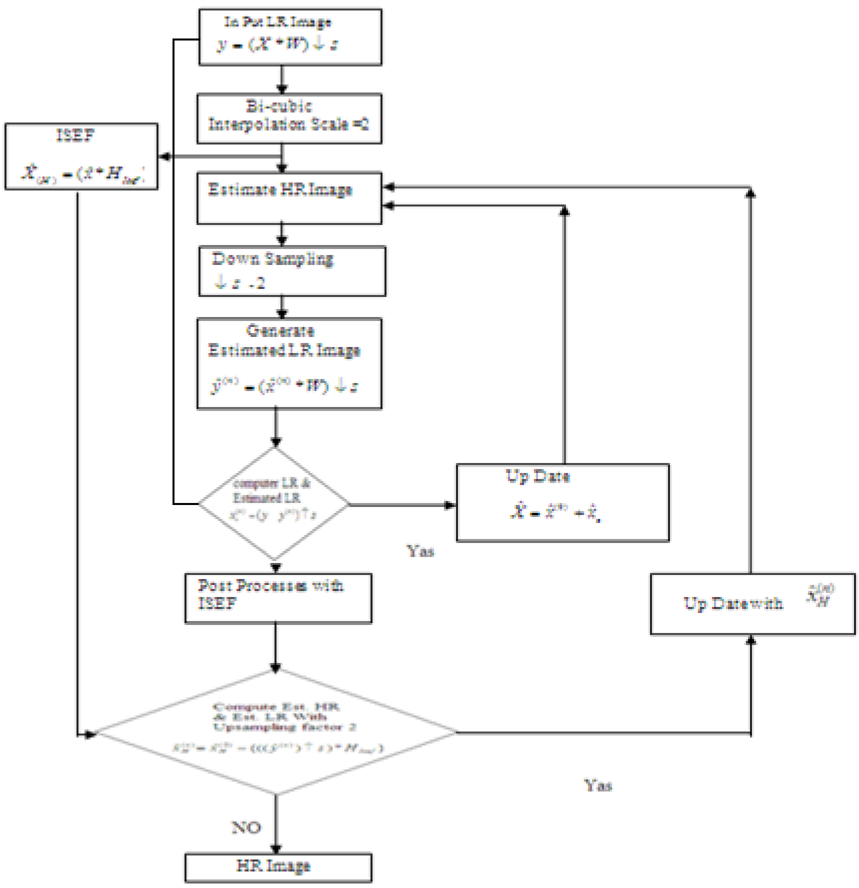

Fig (2) proposed algorithm

According to proposed algorithm, mathematically steps are written as :

$$\hat{X} = \hat{x}^{(0)} + \hat{x}_e + \hat{X}_{(H)} \qquad (3)$$

Where, $\hat{x}^{(0)}$ is interpolated image; $\hat{x}_e$ is error correction; $\hat{X}_{(H)}$ is high frequency estimation given by:

$$\hat{X}_{(H)} = (\hat{x} * H_{Isef}) \qquad (4)$$

Where, $\hat{x}$ is the estimated HR image, H_{Isef} is the ISEF filter.

In Summary, proposed algorithm in mathematical from is expressed as below. The estimated HR image after n iterations is given by:

$$\hat{x}^{(n+1)} = \hat{x}^{(n)} + \hat{x}_e^{(n)} + \hat{x}_H^{(n)} \qquad (5)$$

The estimation of the high frequency is given as:

$$\hat{x}_H^{(n)} = \hat{x}_H^{(0)} - \{((\hat{y}^{(n)}) \uparrow s) * H_{Isef}\} \qquad (6)$$

Where, $\hat{x}_H^{(0)}$ is high frequency component of image $\hat{x}^{(0)}$, this is obtained from interpolation. The equation for $\hat{x}_H^{(0)}$ is given as:

$$\hat{x}_H^{(0)} = (\hat{x}^{(0)} * H_{Isef}) \qquad \textbf{(7)}$$

So, the final iterations process given in (6) is rewritten for the combination of IBP and ISEF as:

$$\hat{x}^{(n+1)} = \hat{x}^{(n)} + (\hat{y}^{(n)} - y) \uparrow s + \{ \hat{x}_H^{(0)} - \{((\hat{y}^{(n)}) \uparrow s) * H_{Isef}\}\} \qquad (8)$$

IV. SIMULATION RESULT AND ANALYSIS

In simulations, the HR images is blurred with a 3*3 Gaussian blurring function of ϖ= 1.0 to degrade its image quality, and then to be down-sampled to produce LR image for experiments. We adopt ISEF edge detection algorithm to extract strong edges in our simulation, and we believe that more convincing results can be got by some other more appropriate edge detection algorithms. Considering that, only strong edges are cared in our algorithm, the threshold for ISEF edge detection is set a little high. The high-threshold is set to 0.99, which gives the most favorable result among groups of thresholds we have tested. As performance criteria, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are calculated. The mathematical equations for M * N image analysis are as given bellow.

PSNR =10 $\log_{10}$((255 * 255) / MSE) …(9)

MSE =[∑(X (i , j) – $X^{(n)}$ (i , j))]/M * N (10)

Where, X (i , j) is the original HR image and $X^{(n)}$ (i , j) is the estimated HR image through this algorithm. The image quality is determined based on PSNR evaluation. A good reconstruction method generally provides low value of MSE and high PSNR. Several natural Images shown in figure (3) [9][10], are taken and tested. Their results are compared with other methods including nearest neighbor interpolation, bilinear interpolation, bicubic interpolation.

(a)

(b)

The PSNR obtained using various techniques and the proposed algorithm is given in Table 1.

No	NN	BL	BC	IBP	PROPOSED
(a)	28.01	28.46	28.54	30.93	38.85
(b)	23.49	23.66	23.84	24.95	28.93

From Table I, we can find that the proposed algorithm can improve PSNR considerably. If we compare proposed algorithm result with bilinear interpolation and nearest neighbor, we get clearly improved visual quality and increased PSNR

V. Conclusion

A fast super resolution algorithm is proposed to enhance the images. In addition to IBP, edge information is incorporated using canny edge detection. The algorithm uses only single LR image to obtain high resolution image which perfectly reserves the edges in reconstructed images. Impressive results illustrate the effectiveness of back-projection of error correction and high frequency in obtaining a high resolution image.

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