Iterative Back Projection based Image Resolution Enhancement

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Abstract—In this paper, we propose a new super resolution technique based on the interpolation followed by registering them using iterative back projection (IBP). Firstly the low resolution image is interpolated and then decimate it to four lower low resolution images. The four low resolution images are interpolated and registered by using IBP in order to generate a sharper high resolution image. The proposed method has been tested on Lena, Elaine, Pepper, and Baboon. The quantitative peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM) results as well as the visual results show the superiority of the proposed technique over the conventional and alternative image super resolution techniques. For Lena’s image, the PSNR is 6.21 dB higher than the bicubic interpolation.

Keywords —Super resolution, Iterative Back Projection, Image Registration.

I. INTRODUCTION

These days many applications need high resolution (HR) images to process. High resolution images obtained by two principal approaches, hardware and software. There are some limitations of a hardware approach such as cost and size. Another approach for enhancing the resolution is by employing various signal processing tools. These techniques are specifically referred to as Super-Resolution (SR) reconstruction [1,2].

In 1984 started research about SR by Huang and Tsay [3]. There was a significant spearad in this field after that Approaches using Frequency Domain [4–6], Bayesian [7], Example-Based [7-11], Set Theoretic [12,13] and Interpolation [14] have been applied to SR techniques.

Super-resolution (SR) is the process of combining multiple low resolution (LR) images to form a higher resolution one. The application of SR techniques covers a wide range of purposes such as Surveillance video [15-16], remote sensing [17], Medical imaging such as Computerized Tomography (CT) scan, Magnetic Resonance Imaging (MRI), Ultrasound [18-21].

The basic idea behind SR is to combine the non-redundant information contained in multiple LR frames to generate an HR image. A closely related technique with SR is the single-image interpolation approach, which increase the size of the image. However, since the estimated pixel values in interpolation process are generated based on a pre-defined so called interpolation formula which is independent of the nature of the image, e.g. the high and low frequency components of the image, the quality of the single-image interpolation is very much limited due to the ill-posed nature of the problem.

Interpolation is the process of determining the values of a function between its samples. This process accomplishes by conforming to a continuous function through the discrete input samples. The famous Interpolation techniques are nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation.

Nearest neighbor from a computational standpoint is the simplest method of interpolation. Each interpolated output pixel is assigned the value of the nearest sample point in the input image.

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

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

Lanczos interpolation computes new pixels using a Lanczos-windowed sinc kernal. When upsampling, these methods operate on the 4x4, 6x 6, or 8x8 cell of pixels surrounding each new pixel location. The 4x4 method is nearly identical to the bicubic method with no sharpening; the 6x6 and 8x8 methods produce slightly more accurate results than bicubic but take a little longer to compute.

A fundamental step in SR is image registration [22]. Image registration is a process of overlaying two or more images acquired by same/different sensors, at different times or from different viewpoint [23]. There are various techniques of registration [24-27] in which here in this research work iterative back projection (IBP) registration [22] is the used.

The proposed technique is using Iterative back projection (IBP) method in the registration stage. Two critical steps
considered for IBP method, first is to construct the model for imaging process that can be described as

$$g_k(y) = DH_{psf} \times f(x) + n_k$$  \hspace{1cm} (1)$$

where $g_k$ are $k$th observed LR images, $y$ denote the pixel of LR images influenced by the area of $x$ of the SR image $f$, $H_{psf}$ is the PSF of blur kernel, $D$ means decimating operator and $n_k$ is an additive noise term. The second step is registration.

In this method firstly a true SR image is assumed. Based on the imaging model given in eqn. (1), different LR images are evaluated. Given the calculated LR images a new SR image is being obtained. Afterwards this new SR image is used to generate the new set of LR images. If this new set of LR images is the same the earlier set, then the assumed SR image is the true SR image, otherwise the error image obtained from the difference between then LR images are back projected to the assumed SR image. This process is being repeated till no error image is left. IBP can be mathematically represented as

$$f^{(n+1)}(x) = f^n(x) + \sum_{y} (g_k(y) - g^n_k(y)) \times H_{bp}$$  \hspace{1cm} (2)$$

where $f^n$ is estimated SR image after n iteration, $g_k(n)$ are calculated LR images from the imaging model of $f^n$ after n iteration and HBP is the back projection kernel.

The second part deals with the image registration. Irani and Peleg [22] studied on the image registration method in order to achieve a more general motion model. Since previous works done in [22] limits its efficiency due to taking account on remote sensing images.

The proposed SR technique is benefitting from different methods of interpolation and IBP registration technique. The proposed SR technique is also compared with conventional bicubic interpolation, and wavelet zero padding (WZP) as well as the state-of-the-art technique proposed by Irani and Peleg [22].

THE PROPOSED RESOLUTION ENHANCEMENT TECHNIQUE

The proposed SR technique is benefiting from both interpolation and IBP registration. First the LR image is interpolated by using different models of interpolation then is decimated that to four LR images. The four LR images obtained by taking some sequential images or artificially generated by using blurring filter, are being interpolated by using interpolation. The interpolated images are not sharp and due to the smoothing caused by interpolation, a sharpening is required. Hence these four interpolated images are being used as input to the IBP registration technique. Finally The output HR image returns to the first step. This process repeats until the amount of error function will become smaller. In proposed method after each iteration output image has better resolution and in next iteration input image is better that first one. Fig. 1 is showing The standard IBP process super resolving $n*n$ image to $\alpha n*\alpha n$ and Fig2 is illustrating the block diagram of the proposed SR technique.

The experimental results given in the next section are showing the superiority of the proposed technique over the conventional and the alternative techniques.
II. EXPERIMENTAL RESULTS AND DISCUSSION

For comparison purposes, the proposed SR techniques as well as other conventional and the alternative techniques are being tested on several well-known images namely, Lena, Elaine, Pepper, and Baboon. Table 1 shows the PSNR values in dB for Bicubic interpolation, WZP, Irani and Peleg, and the proposed SR technique of the aforementioned images. The LR images are 128x128 and the HR images are 256x256.

Table 1: The PSNR values (dB) for resolution enhancement of different images by using several SR techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>PSNR Value in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena</td>
<td>Baboon</td>
</tr>
<tr>
<td>Bicubic Interpolation</td>
<td>18.60</td>
</tr>
<tr>
<td>Irani and Peleg [22]</td>
<td>24.47</td>
</tr>
<tr>
<td>WZP (db.9/7)</td>
<td>23.59</td>
</tr>
<tr>
<td>Proposed method by nearest interpolation</td>
<td>23.92</td>
</tr>
<tr>
<td>Proposed method by bilinear interpolation</td>
<td>24.81</td>
</tr>
<tr>
<td>Proposed method by bicubic interpolation</td>
<td>24.73</td>
</tr>
<tr>
<td>Proposed method by lanczos3 interpolation</td>
<td>24.56</td>
</tr>
</tbody>
</table>

For further comparison, Table 2 is prepared which shows the performance of the proposed SR technique compared to the other techniques from structural similarity index (SSIM) point of view [28].

Table 2: The SSIM for resolution enhancement of different images by using several SR techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>SSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena</td>
<td>Baboon</td>
</tr>
<tr>
<td>Bicubic Interpolation</td>
<td>0.5827</td>
</tr>
<tr>
<td>Irani and Peleg [22]</td>
<td>0.8384</td>
</tr>
<tr>
<td>WZP (db.9/7)</td>
<td>0.8111</td>
</tr>
<tr>
<td>Proposed method by nearest interpolation</td>
<td>0.8349</td>
</tr>
<tr>
<td>Proposed method by bilinear interpolation</td>
<td>0.8508</td>
</tr>
<tr>
<td>Proposed method by bicubic interpolation</td>
<td>0.8579</td>
</tr>
<tr>
<td>Proposed method by lanczos3 interpolation</td>
<td>0.8535</td>
</tr>
</tbody>
</table>

Fig. 3 is showing the visual comparison between bicubic interpolation, Irani and Peleg SR technique and the proposed SR technique for peppers image. Fig 4 illustrate visual result by different methods of interpolation.

Fig. 3: The visual comparison between: (a) original low resolution Peppers image (128x128) and the super resolved image (256x256) by using (b) bicubic interpolation, (c) Irani and Peleg SR technique, and (d) the proposed technique by lanczos3 interpolation.

Fig. 4: The visual result of Proposed method by: (a) nearest neighbor interpolation, (b) bilinear interpolation, (c) bicubic interpolation, and (d) lanczos3 interpolation.
III. CONCLUSION

In this research work a new SR technique based on the interpolation followed by registering them using IBP was proposed. Firstly the low resolution image is interpolated and then decimate it to four lower low resolution images. The four low resolution images are interpolated and registered by using IBP in order to generate a sharper high resolution. The proposed technique was tested on Lena, Elaine, Pepper, and Baboon and compared by conventional and the alternative techniques by means of PSNR and SSIM. Quantitative and qualitative results showed the superiority of the proposed technique over the other SR techniques.

IV. REFERENCES