Image Resolution Enhancement Using Spatially Invariant Point Spread Function

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Abstract — This paper presents an image resolution enhancement algorithm using spatially invariant point spread function. Point spread function is used to constrain the solution space. This parameter is computed at each iteration step using partially restored image at each iteration, and High pass filter is used to impose the degree of edge smoothness on the solution. The resulting iterative algorithm exhibits the increased PSNR better than Bicubic interpolation approach.

Keywords — Resolution, Enhancement, Bicubic, Iteration

1 Introduction

High resolution images are required in many visual applications, and their demand is steadily increasing. When resolution can not improved by replacing sensors, either because of cost or hardware physical limits, super resolution image reconstruction method can be used. Recently, the development of resolution enhancement approaches has been one of the most active research areas, and it is referred to as super resolution (SR) image reconstruction or simply resolution enhancement. Super Resolution image reconstruction method is to use signal processing toward resolution enhancement techniques to obtain an HR image from observed multiple LR image. We applied the Gradient-Projection iteration algorithm using the Point Spread Function(PSF) to video sequence image that is one of the major methods in super resolution construction.

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2 Proposed Algorithm

An Image captured by an imaging system represents the degraded version of an original image due to blurring and additive noise. For size $M \times N$ image, a typical degradation model can be written as

$$y = (H + \hat{H})x = Hx + \hat{H}x = Hx + n$$  \hspace{1cm} (1)

Where the vectors $x, y,$ and $n$ are the lexicographically ordered original image, the observed image, and the additive noise of size $MN \times 1$ that matrix of size $MN \times MN$ to represent a spatially invariant or spatially varying PSF.
Regularized equation has been widely used to obtain a solution about Eq. (1), and the solution is obtained by minimizing the following functional with respect to $n$.

$$M(x) = \|y - Hx\|^2 + \alpha \|Cx\|^2,$$

(2)

Where $\alpha$ denotes the regularization parameter to control the trade-off between fidelity to the data and smoothness, and $C$ typically represents a high-pass operator to sharpen the edge area.

The gradient iteration of the regularized smoothing functional in Eq. (2) can be written as

$$x_{k+1} = x_k + [H^T (y - (H^T H + \alpha C^T C)x_k)] = Gx_k,$$

(3)

There exist various ways for determining the regularization parameter $\alpha$. According to Ref. [7],

$$\alpha(x_k) = \frac{\|y - Hx_k\|^2 + \theta \|Cx_k\|^2}{2},$$

(4)

Where $\theta \geq 2\|x\|^2$. This paper assumes the degraded image is a filtered linear space-invariant system, Figure 1 shows the block diagram of proposed algorithm.

Figure 1. The block diagram of Proposed Algorithm

Figure 1 (b) and (c) show the observed image after down-sampling from original image (a), down-sampled image from observed image (b) and (d). (e) show the up-sampling image from (c), (b) using Bicubic interpolation.

We had estimated PSF that system H between (b) and (d) on the frequency domain, adapted to image enhancement for (f) from (e) using $3 \times 3$ matrix on PSF.

3 Experimental Result
The proposed algorithm was tested with the CIF size “Mobile”, “Stepan” sequences are described in here. For evaluating the objective and subjective performance of the algorithm, PSNR and UIQI (Universal Image Quality Index) in Ref.[8] were used( $-1 \leq UIQI \leq 1$ ). In this experiment, 3 iteration was used. The value of the PSNR is defined as

$$\text{PSNR} = 10 \log_{10} \frac{MN \times 255^2}{\|x-y\|^2}$$  \hspace{1cm} (5)

The again existing PSNR method is WPSNR in RGB or the article that I watched by the relations that did not consider the resolution of each signal expressed in a YCbCr form WPSNR(Weighted PSNR). I added a method and used it in performance inspection, and resolution of YCbCr defined it with the next expression each on the $W_1 : W_2 : W_3$

$$W_{PSNR} = \frac{1}{\sum_{i=1}^{3} W_i} \sum_{i=1}^{3} W_i \cdot PSNR_i$$ \hspace{1cm} (6)

Figure 2 (a), (b), (c) and (d) show the original 28’s frame of [Setpan.cif], interpolated image with Bicubic, and restored image with proposed algorithm, restored image with proposed algorithm with fixed PSF.

(d) restored image with proposed algorithm on fixed PSF

Table 1 and 2 summarizes the performance comparisons-PSNR, WPSNR, UIQI, WUIQI at operation for Bicubic and proposed algorithm, respectively. For all cases, the proposed algorithm outperforms Bicubic, as expected, the performance gain of the proposed algorithm increases as the 1.5dB.

<table>
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<th>Sequence</th>
<th>Method</th>
<th>PSNR(dB)</th>
<th>WPSNR(dB)</th>
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<tr>
<td>Y</td>
<td>Cb</td>
<td>Cr</td>
<td>YCbCr</td>
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<tr>
<td>Mobile</td>
<td>Bicubic</td>
<td>20.96</td>
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<td>Fixed</td>
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<table>
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<th>Sequence</th>
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4 Conclusion and Future Work

In this paper, we propose an iterative algorithm using point spread function. Each pixel in an image is projected onto PSF set which is determined by between observed image and low quality low resolution image, resulting in the operation time slowly, the other side increasing 1.5dB and effectively sharpness the edge area.

Next, Optimization of the iteration solution for reduce the operation time and adapt the HPF depending on the direction of edge area.


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