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A Survey on Image Super Resolution Techniques

Prachi Patel[a], Prof. Prashant B. Swadas[b], Prof. Udesang K. Jaliya[b]
[a]Master of Computer Engineering, Birla Vishwakarma Mahavidyalaya, Vallabh Vidyanagar, Gujarat, India.
[b]Department of Computer Engineering, Birla Vishwakarma Mahavidyalaya, Vallabh Vidyanagar, Gujarat, India.

ABSTRACT:
The aim of this survey is to review different super resolution techniques, classify them into different categories and discuss the different types of super resolution algorithms. The SR imaging has been one of the fundamental image processing research areas. It can overcome or compensate the inherent hardware limitations of the imaging system to provide a clearer image with a richer and informative content. This paper reviews some of these methods. Super-resolution is the methodology of recouping a high-resolution image from numerous low-resolution images of the same scene. The objective of super resolution is to invert the impact of the down sampling, blurring and wrapping that relate the LR image to imagined HR image. In this survey paper we arrange the super resolution techniques, provide detailed of every techniques in every categories, as well as, describe the pros and cons of those methods.

Keywords: Low Resolution (LR), High Resolution (HR), Super Resolution (SR), Interpolation, Iterative Back-Projection (IBP), Projection onto Convex Sets (POCS), Point Spread Function (PSF).

I. INTRODUCTION

Super resolution is the methodology of recovering a high-resolution image from different low-resolution images of the same edge. The fundamental goal of super-resolution (SR) imaging is to reproduce a higher-resolution image focused around a set of images, gained from the same scene and signified as low-resolution images.
Most existing single-image super resolution methods upscale a low-resolution image by either spatial-domain based or wavelet-domain based algorithms. Edge information in the spatial domain can be recognized and upgraded to develop a sharp high-resolution image while in the wavelet domain [8], the support of filters to model the consistency of natural images is exploited. Super resolution was initially proposed to reproduce a high resolution image from various low-resolution inputs. Truth be told, as of late, other than this idea has been further examined and enhanced, single-image super resolution and continuous super resolution have been broadly developed.
The objective of the SR algorithms is to recover this missing information in a manner that approximates the first high-resolution image as nearly as could be allowed. This is an important issue in a few groups and has applications which incorporate object recognition, video transmission, image compression, etc. [10]. Traditionally, SR approaches have applied a set of low resolution images that were caught with sub-pixel precision to attempt to tackle for the missing high-frequency information.

This paper is organized as follows. Section II describe the phases of super resolution. Section III categorize and describe the various algorithm of super resolution technique. Section IV justifies appropriate method for Super Resolution. Section V concludes this paper.

II. SUPER RESOLUTION PROCESSING

Given a set of low resolution images that result from the perception of the same scene from somewhat diverse perspectives, super resolution algorithm create a single high resolution image by combining the information LR images such that the last HR image repeats the scene with a superior constancy than any of the LR images [4]. The focal thought in super resolution processing is to change over the fleeting resolution into spatial resolution. In wide sense, this methodology can be utilized to perform any blend of the following image processing phase:

- Registration
- Interpolation
- De-blurring

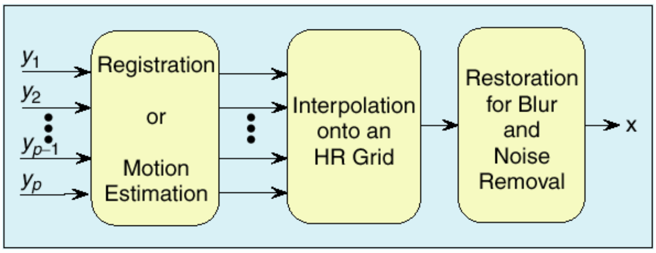


Figure 1. Phase of Super Resolution [4]

To begin with, the SR algorithm get a few low-resolution debased images as the inputs then the registration or Motion Estimation process appraise the relative moves between LR images contrasted with the reference LR image with fragmentary pixel exactness. Clearly, exact sub-pixel movement estimation is an imperative component in the achievement of the SR algorithm. Since the shifts between LR images are self-assertive, the enlisted HR image won't generally match up to a uniformly separated HR lattice. In this way, non-uniform interpolation is important to get a uniformly dispersed HR image from a composite of non-uniformly divided LR images. At last, image restoration (De-blurring) is connected to the up-inspected image to uproot blurring and noise. Before introducing the survey of existing SR algorithms, we first model the LR image obtaining process.

III. SUPER RESOLUTION ALGORITHMS

A. *Nearest Neighbour Interpolation*

The Nearest Neighbour interpolation is the quickest and most straightforward alternative method. It just takes the color of a pixel and assigns it to the new pixels that are made from that pixel. Because of this short sighted methodology, it doesn't make an anti-aliasing effect. This prompts issues with jaggies [6]. Therefore, nearest neighbour interpolation is thought to be unequipped for delivering photographic quality work. It chooses the estimation of the closest pixel by adjusting the coordinates of the fancied interpolation point $x > 0$.with an expansion to the two-dimensional case. Let $\lfloor\bullet\rfloor$ is the floor administrator: the biggest number short of what or equivalent to the argument [6]. As an effect of this simplified interpolation scheme, closest neighbour doesn't have sub pixel precision and produces solid discontinuities, particularly when discretionary pivots and scale changes are included. The main intriguing property of this algorithm is the way that it saves the original noise distribution in the changed picture, which can be helpful in some picture examination applications. It essentially makes the pixels greater, and the color of another pixel is the same as the closest original.

B. *Bilinear Interpolation*

Bilinear interpolation utilizes the information from a pixel and four of the pixels that touch it to focus the color of the new pixels that are made from the original pixel. Bilinear uses rather basic, direct counts to do this [6]. The Bilinear interpolation has an anti-aliasing effect. It is not viewed as sufficient for photo quality pictures. This takes the information from an original pixel and four of the pixels that touch it, to settle on the color of another pixel. It delivers genuinely smooth results, yet it decreases the quality essentially. Pictures can get to be blurry [6].

C. *Bicubic Interpolation*

Bicubic interpolation utilizes the information from an original pixel and sixteen of the encompassing pixels to focus the color of the new pixels that are made from the original pixel. Bicubic interpolation is a huge change over the closest neighbour interpolation and bilinear interpolation techniques for two reasons: (1) Bicubic interpolation utilizes information from a bigger number of pixels. (2) Bicubic interpolation utilizes a Bicubic figuring that is more advanced than the estimations of the past interpolation methods [6]. Bicubic interpolation is fit for creating photo quality results and is likely the system most ordinarily utilized. This is the most advanced, as it takes information from the original pixel and 16 encompassing pixels to make the color of another pixel. Bicubic figuring is much more progressive than the other two routines, and it is fit for delivering print quality pictures. Bicubic interpolation likewise offers the two variations of "Smoother" and "Sharper" for finely tuned results.

D. *Hybrid Approach of Interpolation*

Another hybrid interpolation method in which the interpolation at edges is completed utilizing the co variance based method and interpolation at smooth range is carried out by utilizing iterative curvature based method. In the wake of discovering edges and smooth zone utilizing data from the neighbourhood pixels edge is interpolated utilizing co variance based method. The co variance coefficient of HR image is getting utilizing co variance parameter of LR image. In smooth are a curvature interpolation is completed by first performing bilinear interpolation along the bearing where the second derivative is lower and in corner to corner case the distinction between inclining is computed and use bilinear interpolation where the intensity contrast is less. This method has noteworthy point of interest regarding the processing time, crest sign to noise degree and visual quality compared to bilinear, bicubic and nearest neighbour.

E. *Projection onto convex sets*

Low resolution images usually suffer from blurring caused by a sensor's point spread function (PSF) and also from aliasing caused by under-sampling [6]. The POCS technique describes an option iterative approach to consolidate earlier learning about the solution into the reconstruction process. This algorithm simultaneously solves the restoration and interpolation issue to estimate the SR image. An estimate of the high-resolution version of the reference image is resolved iteratively starting from some subjective initialization. Successive iterations are acquired by anticipating the previous estimate onto the consistency set with a sufficiency constraint set that restricts the light black levels of the estimate to the extent [0, 255] [6]. The point of interest of POCS is that it is simple, and it utilizes the effective spatial domain observation model. It also allows an advantageous inclusion of from the earlier information. These methods have the disadvantages of slow convergence, on uniqueness of solution and a high computational cost.

F. *Iterative Back-Projection Algorithm*

In Iterative Back-Projection algorithm, process starts with the beginning guess of the HR image. Iterative Back-Projection algorithm is based on a similar thought as the computer-aided tomography where a 2-D article is reconstructed from its 1-D projections. The strategy involves a registration method, an iterative refinement for displacement estimation, and a simulation of the imaging process (the blurring impact) using a PSF [8]. This beginning HR image can be created from the info LR image. The starting HR image is down sampled to simulate the observed LR image. The simulated LR image is subtracted from the observed LR image. In the event that the starting HR image is same as the observed HR image then the simulated LR image and observed LR image are indistinguishable and their difference is zero the HR image is estimated by back anticipating the blunder (difference) between simulated LR image by means of imaging smudge and the observed LR image [9]. This process is rehashed iteratively to minimize the energy of the mistake. This iterative process of SR does iterations until the minimization of the cost function is attained to or some predefined iterations. Iterative Back-Projection algorithm is instinctive subsequently easy to understand. On the other hand, its ill-posed nature means that there is no novel solution. The decision of back-projection channel is discretionary. Block diagram of Iterative Back-Projection algorithm is shown in figure 2.

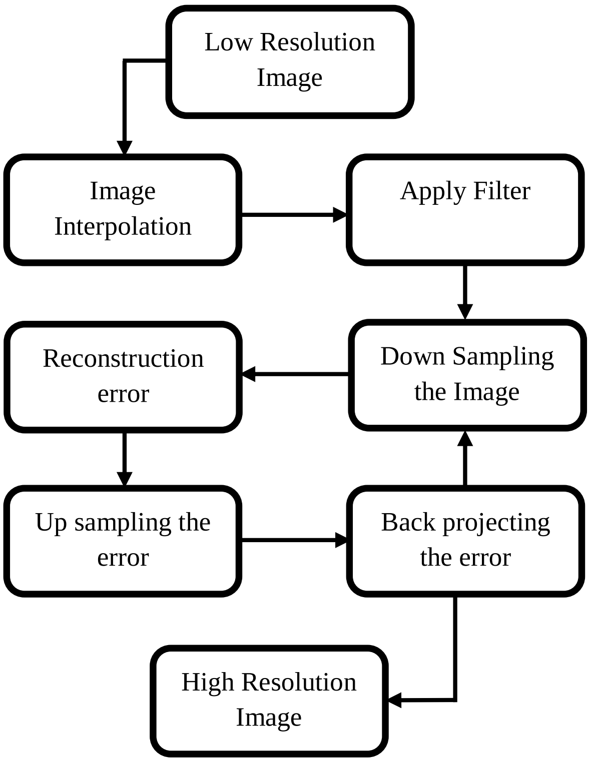
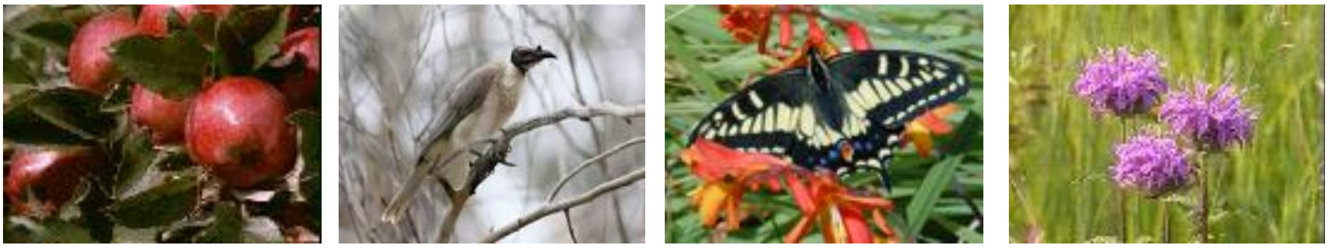


Figure 2. Block diagram of IBP algorithm

Table 1. Result of some algorithm based on PSNR

Image Quality Measure	**PSNR(dB)**		
Method	**NN Interpolation**	**Bi linear Interpolation**	**Bicubic Interpolation**
Apple	38.0720946	35.5812694	39.5507349
Bird	39.8560853	42.0843202	42.0843202
Butterfly	35.1895162	32.6302293	37.637012
Flower	37.3578395	34.4057338	38.0451516



Apple Bird Butterfly Flower

Figure 3. Sample of images

IV. Relation to other method

A. *Iterative Back-Projection (IBP) algorithm with canny edge detection*

In spite of the fact that IBP technique can minimize the restoration error significantly in iterative way and gives great impact, it projected the error back without edge guidance [1]. In this algorithm additional high recurrence information is included by canny edge detection and difference error of up sampled images from starting and simulated LR images thus that it works as edge preserving algorithm. Canny edge detection algorithm is used to recognize the extensive range of edges in images.

Steps of the canny edge detection algorithm:

- On LR image Gaussian filter is applied to remove noise and any speckles
- A gradient filter is applied on filtered image for obtaining gradient direction and intensity
- Apply edge thinning on image
- Tracing edges through image and apply thresholding.

Here the first step of algorithm is mathematically written as

$$\mathbf{X^{(1)} = X^{(0)} + X_e - X_H^{(0)}} \qquad \textbf{(1)}$$

Where $X^{(0)}$ is initial interpolated image, X_e is error correction and $X_H^{(0)}$ is high frequency estimation.

$$\mathbf{X_H = (X^{(0)} * H)} \qquad \textbf{(2)}$$

Where $X^{(0)}$ is the estimated initial interpolated image, H is the Canny edge detection as high pass filter.

The estimated HR image after n iterations,

$$\mathbf{X^{(n+1)} = X^{(n)} + X_e^{(n)} - X_H^{(n)}} \qquad \textbf{(3)}$$

The estimation of high frequency of images is,

$$\mathbf{X_H^{(n)} = X_H^{(0)} - \{((y)I^2{}_{BC}) - ((y^{(n)})U^2{}_S)\}} \qquad \textbf{(4)}$$

Where $X_h^{(n)}$ is high frequency component after nth iteration and I^2_{BC} is bicubic interpolation by factor 2.

Final equation of algorithm is,

$$\mathbf{X^{(n+1)} = X^{(n)} + (y - y^{(n)})U^2{}_S - \{X_H{}^{(0)} - \{((y)I^2{}_{BC}) - ((y^{\wedge(n)})U^2{}_S)\}\}} \quad \textbf{(5)}$$

Equation is for combination of Iterative Back Projection algorithm with canny edge detection and error difference between up sample HR images.

V. CONCLUSION

The SR imaging has been one of the fundamental image processing research areas. It can overcome or compensate the inherent hardware limitations of the imaging system to provide a clearer image with a richer and informative content. In this paper, we have presented a study of a survey of super resolution techniques. We classify image super resolution techniques into various categories. Here, we also present the result of some of these methods for comparison purpose. In this paper, our objective is to offer new perspectives and out looks of SR imaging research, besides giving an upgraded outline of existing SR algorithms. It is our trust that this work could inspire more image processing researchers attempting on this fascinating theme and creating more novel SR techniques along the way.

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