A Survey study on Single Image and Multi Image Super Resolution Techniques

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Abstract :Super resolution is a technique for constructing high quality images .The main idea behind this process is combining a set of low resolution images taken from the same image or scene. Nowadays Super resolution techniques used in many applications including medical imaging, Satellite imaging, digital imaging, Biometric representation etc. This paper presents the principle of super-resolution and makes a survey about various image reconstruction methods .Furthermore paper discuss some issues and challenges faced in this field.

Index Terms- Super resolution, Frequency domain, Spatial domain, single image and multiimage Super Resolution techniques

1 INTRODUCTION

A digital image's resolution can be categorized in a variety of ways, including by its pixel, spatial, spectral, temporal, and radiometric resolutions. Image resolution is defined as the smallest discernible or measurable detail in a visual presentation. Spatial resolution refers to the spacing of pixels in an image and is measured in pixels per inch (ppi). The higher the spatial resolution, the greater the number of pixels in the image and correspondingly, the smaller the size of individual pixels will be. This allows for more detail and subtle color transitions in an image. The spatial resolution of a display device is often expressed in terms of dots per inch (dpi) and it refers to the size of the individual spots created by the device. By increasing the density of sensor one can increase the resolution of the imaging device. When the size of sensors is reduced beyond a limit it causes shot noise in the captured images as reducing the size of sensor also reduces the amount of light incident on it. Hardware cost increases with the increase in the number of sensors. Therefore there is limitation with the hardware that restricts the spatial resolution of the image.

While spatial resolution is limited by sensor size, the image details (high frequency bands) are also limited by the optics due to lens blurs (associated with the sensor point spread function (PSF)), lens aberration effects, aperture diffractions and optical blurring due to motion. Constructing imaging chips and optical components to capture very high-resolution images is prohibitively expensive and not practical in most real applications, e.g., widely used surveillance cameras and cell phone built-in cameras. In some other scenarios such as satellite imagery, it is difficult to use high resolution sensors due to physical constraints.

Another way to address this problem is to accept the image degradations and use image processing to post process the captured images, to trade of computational cost with the hardware cost. These techniques are specifically referred as super-resolution (SR) reconstruction.

The idea of super-resolution (SR) techniques is to construct a high-resolution (HR) images from several input low-resolution (LR) images, thereby increasing the high frequency components and removing the degradations caused by limitations of low-resolution imaging device/system. The SR technique combines non redundant information contained in multiple low-resolution frames to get a high-resolution image. The combined LR image must contain some information which is unique to that image.This is the main requirement for super resolution .The broad classification of SR techniques is based on use of single low-resolution and multiple low-resolution images to generate a large size image.

High resolution images are very essential in many applications especially medical imaging, satellite imaging etc. So better performing SR techniques are also a need .The main application areas of SR imaging are[1]Satellite and Aerial imaging, Remote Sensing, Surveillance Video , Medical Image Processing, Infrared Imaging, Facial Image Improvement ,Text Images Improvement, Compressed Images and Video Enhancement, Sign and Number Plate Reading, Iris Recognition , Fingerprint Image Enhancement, Digital Holography and High Dynamic Range Imaging .

For better performance and outcomes, numerous super resolution methods are offered. Tsai and Huang's frequency domain approach was one of the earlier methods [2]. However, it encounters some issues while performing. The challenges that the frequency domain approach faces are then addressed via a variety of special domain techniques. Non-uniform interpolation, projection onto convex sets, iterative back projection, and adaptive filtering are a few examples of deterministic regularization techniques.

2 PROCESSING OF SUPER RESOLUTION

In super resolution the primary step is to take a set of low resolution images that result from the observation of the selected same image or scene .By using super resolution algorithm which combines the input LR images such that the final HR image results a high resolution image with high quality[4]. In generally we are considering the observed low resolution images as a resultant from resample of a high resolution image. The goal is then to recover the high resolution image which when resampled based on the

input images and the imaging model, will produce the low resolution observed images[5].So the accuracy of imaging model is very important for super-resolution. Any incorrect modeling or motion degrades image quality.

In super resolution processing it converts the temporal resolution in to spatial resolution and this approach can be used to perform any combination of the following image processing tasks Registration, Interpolation, De-blurring [3] . The broad classification of SR techniques is based on use of single low-resolution and multiple low-resolution images to generate a large size image. In the SR setting, however, multiple low-resolution observations are available for reconstruction, making the problem better constrained. The non-redundant information contained in these LR images is typically introduced by subpixel shifts between them. These subpixel shifts may occur due to uncontrolled motions between the imaging system and scene, e.g., movements of objects, or due to controlled motions, e.g., the satellite imaging system orbits the earth with predefined speed and path. An observed set of low resolution images could be taken from one or multiple cameras or could be frames of a video sequence .The basic steps involved in Superresolution is given in Figure 1The SR reconstruction algorithm receive this corrupted images as inputs .Then these LR images need to be mapped to a common reference frame. This process is done by registration stage. During this process it estimate the relative shifts between observed LR images compared to the reference LR image with a fraction of pixel accuracy. The accurate alignment is a key factor for the success of SR process .In this stage many types of transformations could be required for registration of images like affine transformations, biquadratic transformations or planar homographic transformations. The registered HR image results from the previous stage will not always match up to a uniformly spaced HR grid. Therefore non-uniform interpolation stage is necessary for obtain a uniformly spaced HR image from a composition of non-uniformly spaced LR images.

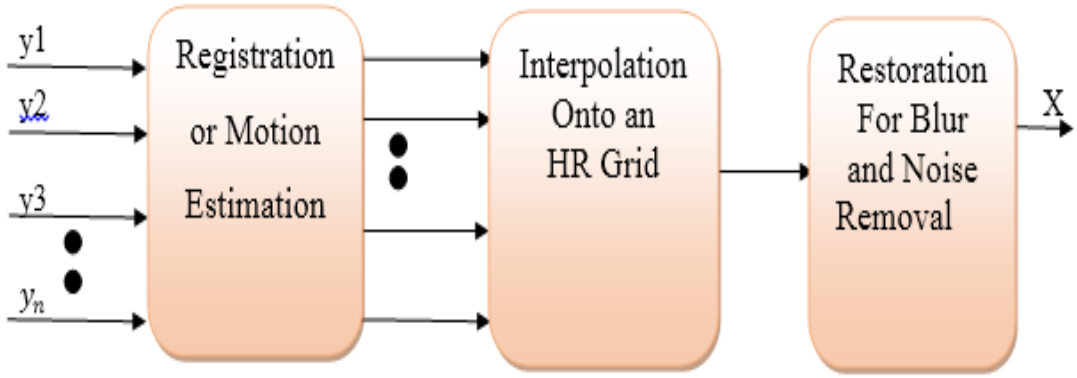

Figure 1 Steps in Super Resolution

In last stage (De-blurring) is applied to the up-sampled image for removing blurring and noise. A forward imaging model or an observation model is explained in reference [5][3]papers .Good Formulation of this imaging model will be one of the important aspects in super-resolution for the imaging and motion process. This model relates the original scene to the observed set of low resolution images. The available low-resolution input images are getting from the high-resolution original scene by warping, blurring and down sampling the scene. Superresolution image reconstruction is based on the theory of Analytic Continuation [6].In this method reconstruction of the whole analytic function based on its values in certain area.

2.1 Super Resolution Techniques

Super Resolution techniques different categorization is given in the figure 2. Super Resolution algorithms can be broadly classified into two classes based on domain representation Frequency domain and spatial domain .Frequency domain has two classes' wavelet transform and Fourier transform. Spatial domain algorithms are again classified into two classes' single image reconstructing algorithms and multi image reconstructing algorithms.

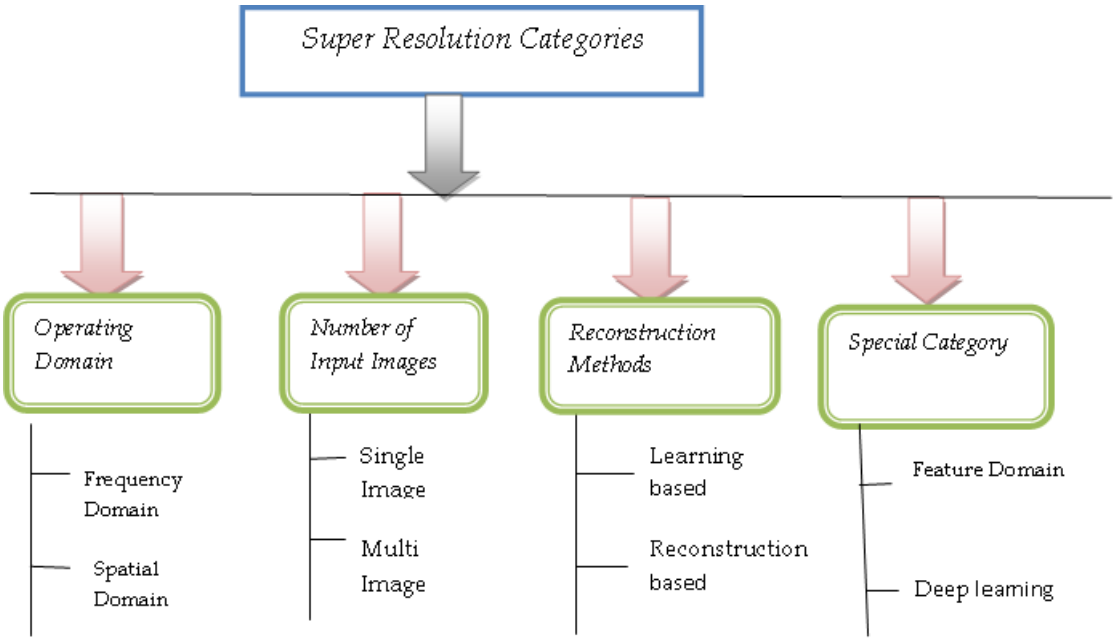

Figure2 Categorisation of different techniques in Super Resolution of Images

2.2 Frequency domain Methods

The basic frequency-domain super-resolution problem of Tsai and Huang or Kim et al. looks at the horizontal and vertical sampling periods in the digital image, and relates the continuous Fourier transform of the original scene to the discrete Fourier transforms of the observed low-resolution images. Both these methods rely on the motion being composed purely of horizontal and vertical displacements, but the main motivating problem of processing satellite imagery is amenable to this restriction

In this class of SR algorithm the input LR images are in the frequency domain and then estimate the HR image in this domain .Then the reconstructed HR image is transform back to the spatial.

The frequency domain approach described on the basis of three principles 1.First one is the shifting property of the Fourier transform .Second is the aliasing relationship between the continuous Fourier transform (CFT) of an original HR image and the discrete Fourier transform (DFT) of observed LR images .Third one is the assumption that an original HR image is band limited. Frequency domain based SR algorithms can be subdivide into two classes Fourier transform based and wavelet transform based .The first work done in frequency domain was Gerchberg [13] (1974) and then Santis and Gori [14] introduced the first SR algorithms .These introduced methods were iterative methods in the frequency domain. Which are based on the Fourier transform .Then later reintroduced in [15] in a non-iterative form, based on Singular Value Decomposition (SVD).But the first popular multiple-image SR algorithm in the frequency domain was Tsai and Huang's system [16] introduced in(1984).This developed algorithm was designed for working on LR images taken by Landsat 4 satellite.

Wavelet transform developed as an alternative to the Fourier transform SR algorithms. This is decomposing the input image into structurally correlated sub-images .This results the self-similarities between local neighboring regions. Stationary Wavelet Transform results from the high frequency sub bands are used to improve the interpolated sub bands .Combine all of these sub bands using an inverse Discrete Wavelet Transform (DWT).It will generate superresolved HR output. Wavelet based methods faced some difficulties during implementation while it can be done using Fourier transform method .By combining together these two methods a new method introduced in into the FourierWavelet Regularized Deconvolution [17].

2.3 Spatial domain methods

In this class of SR algorithms, the forwarded imaging model is formulated, and reconstruction is effected in the spatial domain. The linear spatial domain observation model can accommodate global and non-global motion, optical blur, motion blur, spatially varying PSF, non-ideal sampling, compression artifacts and more[3].Spatial domain algorithms can be classified into two classes single image based and multiple image based algorithms.

2.4 Reconstruction Based Algorithms

There algorithms are either reconstruction based or learning based[1].This method also gives a better solution for high frequency information lost during the sub-sampling or decimation of an image. Single image based algorithms are mainly based on two classes Learning based Single Image algorithms and Reconstruction Based Single Image SR Algorithms. Learning-based or Hallucination algorithms were first introduced in 1985 in which a neural network was used to improve the resolution of fingerprint images. This algorithm involves training a neural network which learns the relationship between HR and their LR counterparts. The acquired knowledge is used as the prior information for the construction of HR images. The training database must have good generalization capability helps in knowledge acquisition.

Sufficiency and predictability are two factors used for confirm above criteria .The various aspects used in this class are described below. First we consider Feature Pyramids [18][19].During training step each HR face image is first down-sampled and blurred

several times to produce a Gaussian resolution pyramid. From these Gaussian pyramids, Laplacian pyramids and then Feature pyramids are generated .After training step, for an LR test image the most similar LR image among the available LR images in all the pyramids is found.

In Reconstructed based approach, incorporate the prior knowledge to model a regularized cost function. The image priors include the gradient prior, non-local self-similarity and the sparsity priors. These prior characterize different and complementary aspects of natural image feature. Therefore combinational on of multiple image prior for SR model may be beneficial to improvement of performance.

2.5 Single Image Super Resolution Techniques

In Single-frame imaging performing the observed LR image from HR image is modeled by $y_k = DB_kM_k\,x + n_k \;\; k = 1,2..n$ Where M_k is a warp matrix, including the global or local translation, rotation etc., B_k represents a blur matrix, D is a sub sampling matrix, x is an original image and represents a noise vector. Figure 2 shows basic architecture for super resolution. It consist of steps like estimation of relative motion, i.e., registration, non-uniform interpolation, and de-blurring. In Registration step to the estimation of the relative shifts of each LR frame with respect to a reference LR image with sub-pixel accuracy, Non-uniform interpolation is to produce an improved resolution image and image restoration is applied to the up-sampled image to remove blurring and noise. Before apply any technique on image, preprocessing is carried out on image to remove noise or to convert image into gray scale image.

Many techniques exist for the super-resolution problem in the spatial domain. Among these solutions some are include interpolation, deterministic regularized techniques, stochastic methods, iterative back projection, and projection onto convex sets among others[3].In Interpolation of Non Uniformly Spaced Samples, first registering a set of LR observed images of a single image .From the non-uniformly spaced samples SR image may be reconstructed. But the results show this technique having poor performance because the camera sensors do not act as impulse functions. Deterministic Regularization is another technique which solves the inverse problem by using the prior information [27]. Projection Onto Convex Sets (POCS).This algorithm estimates registration parameters ,then simultaneously solves the restoration and interpolation problem to estimate the SR image .Iterative back projection is another method , by back projecting the difference between the simulated LR image and captured LR on interpolated image HR image is estimated. One modified method proposed in back projection by using canny edge detection is described in paper[3].

2.6 Multiple Image based SR Algorithms

Multiple image or classical SR algorithms are mainly reconstruction-based algorithms .Initial work in this field published based on Iterative back projection .The set of low resolution images were registered and HR image is reconstructed by averaging this images[28], [29].This iteration process repeated for getting better improved results .Iterative adaptive filtering methods are used for regenerating Super Resolution videos[31].Some direct methods are also described in paper[1].Select a set of LR images as input. Select one of the LR image was chosen as a reference image .The remaining other images were registered against it [32], [33].Select a scaling factor and scale up the reference image scaling factor .The remaining other LR images were warped into that using the registration information .The HR image is generated by combining all the images together .Finally for reducing noise level deblurring process applied to the HR image. Projection onto Convex Sets(POCS) [30] is another method. For solving the SR problem these algorithms define an implicit cost function [34].

3 CONCLUSION

Super resolution is an emerging researching area. This paper discusses some Super resolution algorithms and techniques used in single imaging and multi imaging . Single imaging algorithms are mostly application based and in case of multi imaging algorithms are designed for general applications .But the fact is each and every algorithms have their own advantages and disadvantages interms of convergence, computation which doesn't provides a tailored stitch solution to fit for all applications that demands Superresolution .In future the combination of these methods could be tried to arrive an optimize solution

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