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A Survey of 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.***

Keywords: ***Super resolution, Frequency domain, Spatial domain, single image and multiimage Super Resolution techniques***

1. Introduction

The Super-Resolution (SR) is a technique for generating a higher resolution image from several number of low resolution images. The details contained in an image will be described by image resolution .The pixel density will be high in high resolution images and we get more details about the original image or scene. Super resolution combines non redundant data in the low resolution images (LR) and generate high resolution image .This non redundant information introduced by sub pixel shifts .Uncontrolled motions between imaging system and scene will results this sub pixel shifts. The combined LR image must contain some information which is unique to that image .This is the main requirement for super resolution.

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, Medical Image Processing, Ultrasound Imaging, Line-Fitting , Automated Mosaicking , 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 .

Many super resolution approaches are introduced for better performance and results .One of the earlier approach was frequency domain approach introduced by Tsai and Huang [2].But it faces some difficulties during performing stages .Then many special domain techniques are introduced for overcoming the difficulties which are faced in the frequency domain approach. Some of these are Deterministic regularization approaches are ,non uniform interpolation, projection onto convex sets, iterative back projection, and adaptive filtering.

The paper presents the later sections as follows. Section 2 described basics of processing and formulation of SR images. Section 3 presents various approaches and methods used in SR reconstruction and fourth section conclude this paper .

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 combining 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 resulting from resampling 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 degrade image quality .In super resolution processing it convert 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] .

An observed set of low resolution images could be taken from one or multiple cameras or could be frames of a video sequence .The SR reconstruction algorithm receive this corrupted images as inputs .The these LR images need to be mapped to a common reference frame. This process is done 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. 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. Super-resolution 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.

3. Super Resolution Techniques

Super Resolution techniques can be classified into mainly two classes of methods the classical multi-image super-resolution and Example-Based super-resolution .In multi-image SR [7][8][9] a high resolution image construct by combining an observed set of low-resolution images of the same scene are taken .Example-based SR, low and high resolution image patches are learned from a database .This database contain low and high resolution image pairs which are usually with a relative scale factor of 2 .Then it is applied to a new low-resolution image for recovering its most likely high-resolution version of image. Repeated applications of this process results higher SR factors .In classical multi image super resolution the image will be reconstructed using reconstruction algorithms .but in case of example based SR there is no guaranty of exact image reconstruction.

Before going to the SR algorithms let us discuss some hardware approaches for increasing pixels per unit area .These are decreasing the pixel size and increasing the sensor size [10], [11]. First specified method is a useful solution but we can't reduce the pixel size beyond a specific threshold and it will decreases the amount of light which reaches the associated cell of the pixel on the sensor .Also increase shot noise in the results .The second solution will increases the capacitance but the charge transfer rate reduced .For large scale imaging this hardware-based solutions will be highly expensive .So we are going to the algorithmic based solutions.

Super Resolution algorithms can be broadly classified into two classes based on domain representation Frequency domain and special domain .Frequency domain has two classes' wavelet transform and Fourier transform. Special domain algorithms are again classified into two classes' single image reconstructing algorithms and multi image reconstructing algorithms.

3.1 Frequency domain Methods

The first derived work done on the basis of relationship between low resolution images and establishing High resolution image from the relative motion between this LR image as Tsai and Huang [12] .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 .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 super-resolved 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 Fourier-Wavelet Regularized Deconvolution [17].

3.2 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.

3.2.1 *Single Image 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

SR algorithms and Reconstruction Based Single Image SR Algorithms.

Learning based Single Image SR algorithms are also known as learning based or Hallucination Algorithms .These algorithms were first introduced(1985) for generating high resolution fingerprint images using neural network .These algorithms developed with a training step .During this stage the relationship between HR images and their LR counterparts will learn. Image reconstructed later with this learned knowledge. Proper generalization capability is very essential in the training database of learning based SR algorithms .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. Next method is a Belief Network, this is explained in papers [20] and [21]**.**Here using belief network such as Markove model or tree structures .Manifold method is an another set of algorithms. HR and LR images form manifolds

These manifolds having similar local geometries in two distinct feature [22]. Reconstruction Based Single Image SR Algorithms are try to address the aliasing artifacts that is present in the LR input image. These algorithms can be classified into three groups[1].In this groups first we consider Primal Sketches .The main Idea used in this group is a class-based a priori .This concept used in most of the hallucination-based algorithms .The key concept here using is the hallucination algorithm is applied only to the primitives (ridges, corners, T-junctions, and terminations)but not to the non-primitive parts of the image[1].Second group is Gradient Profile. The shape statistics in natural images the gradient profiles are robust against changes in image resolution [23] [26].Next method is Fields of Experts(FoE).This is actually an a priori for learning the heavy non-Gaussian statistics of natural images [24] [25].

3.2.2 Single Image Super Resolution Techniques

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].

3.2.3 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 reconstruct HR image 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]**.**

4. Conclusion

Super resolution is an emerging researching area. This paper discuss 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 all of these algorithms are not applicable for all applications. It also faces some difficulties in optimal camera sensor designing , high dynamic range image super resolution etc .So in these field these are some future researching areas.

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