A Review on Different Image Super-resolution methods for Satellite Images

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***Abstract*: Super-resolution imaging (SR) is a technique that enhance the resolution of an imaging system. Single image super resolution is the process of converting a low resolution (LR) image into high resolution (HR). There are various fields where we can apply this technique. It emphasizes or enhance the quality of image. Here input will be a low resolution image that is used to convert into high resolution one. Now super resolution has become a popular topic in image processing. Satellite images are mainly focused here and various methods are evaluated to increase its quality. Since satellite images are transmitted through air, probability of losing information is more. Using various super resolution methods we can improve the resolution of the received low resolution images. In this paper an overview of various papers has been presented.**

***Index Terms*: image super-resolution, satellite imagery, selective patch processing, difference curvature.**

I. INTRODUCTION

Nowadays various HR digital cameras are available but still many computer vision applications such as satellite imaging, forensic, target detection, medical imaging and many more still had a strong need for higher resolution imagery which exceeded the capabilities of these HR digital cameras. We focus on low quality images to upgrade it. Satellite imagery is used in many areas of research. Resolution is the key issue in these types of images. The resolution is an important feature of the image.

Fig. 1. blurred image and high resolution image

Super-Resolution image reconstruction is a promising technique of digital imaging which attempts to reconstruct HR imagery by fusing the partial information contained within a number of under-sampled low-resolution (LR) images of that scene during the image reconstruction process. Super- resolution image reconstruction involves up-sampling of under-sampled images thereby filtering out distortions such as noise and blur[1]. Image degradation can occur due to many reasons such as weak capture devices and limited environmental resources. Photo reconstruction is applied in many areas such as satellite images, medical fields, forensic evidence and other natural images. Many applications are used such as astronomy, geological studies, meteorology and satellite images.

Satellite imagery (also Earth observation imagery or space- borne photography) are images of Earth or other planets collected by imaging satellites operated by governments and businesses around the world. The resolution of satellite images varies depending on the instrument used and the altitude of the satellite’s orbit. Satellite imagery is sometimes altered with aerial photography, that has higher resolution, but is more expensive. Various satellite enhancement methods are evaluated here.

II. LITERATURE SURVEY

This section includes various methods used for image super- resolution in satellite images. Here we are evaluating different papers and estimating its efficiency using PSNR(Peak Signal to Noise Ratio).

$$\mathrm{PSNR} = 10 log_{10}[R^2 / MSE],$$

where R is the maximum fluctuation in the input image,

$$\mathrm{MSE} = \Sigma_{(}m, n)[I1(m, n) - I2(m, n)]^2 / (M*N),$$

where I1 is the input image and I2 is the proposed enhanced image, M and N are the size of the images.

A. *Discrete Wavelet Transform and Threshold Decomposition Driven Morphological Filter:*

In [2] enhancement technique uses DWT to decompose image into different subbands. The effort on edge enhancement has been focused mostly on improving the visual perception of images that are unclear because of blur. DWT separates the input image into different sub band images, namely LL, LH, HL, and HH. In order to preserve the high-frequency components of the image DWT has been employed . The low contrast input color image is decomposed into R,G,B color space. DWT is applied to each color(R,G,B) separately for betterment . The LL sub band of each color component of the image is decomposed into a series of binary levels. Each of the binary levels may be processed separately. These binary levels obtained can be then recombined to produce the final gray scale image with pixel values identical to those produced by gray scale processing. The success of threshold decomposition, gradient-based operators is used to detect the locations of the edges, by detecting the positions of the edges and then applying a class of morphological filtering. A morphological filter is used to sharpen these detected edges.

B. *Adaptive Band Specific Image Enhancement Scheme:*

In [3] illustrates the enhancement technique of all the frequency bands used in satellite images depending upon the area of application. The image is segmented in nine regions known as 'Top Left (TL)','Top Middle (TM)','Top Right (TR)', 'Middle Left (ML)','Middle Middle (MM)', 'Middle Right (MR)','Bottom Left(BL)', 'Bottom Middle (BM)' and 'Bottom Right (BR)'.

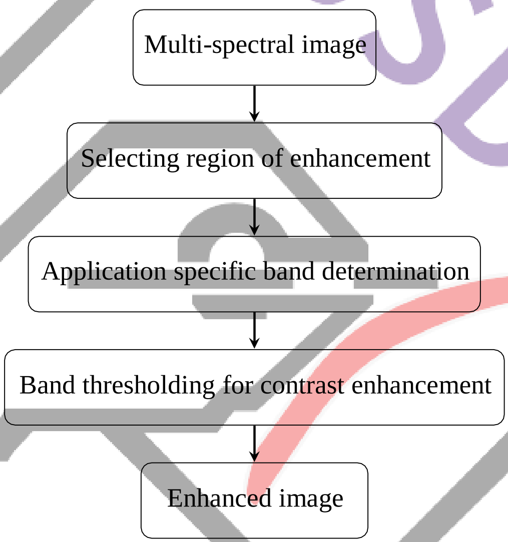


Fig.2 : System Model

After selecting the region of interest, the multi-spectral images are processed with the unique contrast enhancement code for each band. Operates on the principle of band thresholding, which offers the feature of setting contrast threshold for each particular band present in the image. The color contrast enhancement, sharpening and brightening techniques are used to make the particular selected region vivid. The resulting output shows an emphasis on the high frequency content of the image without changing the phase. Input image is a multispectral satellite image. Operates on all the bands that are defined for satellite imagery. Facilitates better observation of satellite images by selecting and enhancing the particular region of image of the image and resulting in contrast enhancement of the particular image section.

C. *Weiner filter and thresholding:*

In [4] median filter is selected as a preprocessing filter. As in an averaging filter, each output pixel is set to an average of the pixel values in the vicinity of the Corresponding input pixel. However, with median filtering, by calculating the median of the neighborhood pixels, an output pixel value is determined, rather than the mean. In the process of contrast enhancement, pixels with lower pixel value than a specific value are displayed as black, whereas the pixels having higher pixel value are displayed as white, and pixels having pixel value in between these two values are displayed as tint of gray. The outcome of this process is a linear mapping of a subset of pixel values to the full range of grays from black to white, creating an image of higher contrast.

D. *Discrete Wavelet Transform and Singular Value Decomposition:*

In [5] DWT decomposes the input image into four subbands and different operation is performed on different bands. Interpolation method is used here for the resolution enhancement of the satellite image whereas the Single wavelet decomposition technique enhances the contrast of the satellite image.

E. *Automatic Multi-Histogram Equalization for Satellite Images:*

In [6] the original image is converted into grayscale image. Calculate the mean brightness value (M) of the original image. Find the histogram of that image and calculate the number of valley points (n). Find the histogram thresholding value (T) by using $T = M/n$. Minimize the number of valley points by using histogram thresholding value. Rearrange the valley points from the histogram such that two valley points will not repeat within T. Name the resultant number of valley points as n Now select the resultant valley points as threshold points and divide the histogram into (n1+1) small parts . Equalize each histogram independently using Probability Density Function (PDF) and Cumulative Distribution Function (CDF).Normalize the image brightness .So, the resultant image after normalization will be the contrast enhanced image.

F. *DWT and high frequency subband image interpolation:*

In [7] Discrete Wavelet Transform is applied on the input image which decomposes the image into four sub- bands. Interpolation is performed on these four subbands. The low frequency subband contains less information as compared to the original input image. Hence original input image is used in the interpolation process. To preserve edge information interpolation on frequency subbands are performed.

The difference between the low resolution input image and interpolated LL subband image generates their high frequency components. This difference image and interpolated LH, HL and HH bands are added to estimate the respective high frequency components. Inverse DWT and bicubic interpolation is performed to obtain enhanced image.

G. *Multi-technology fusion:*

In [8] it first decomposes the original image into low frequency and high-frequency components using bi-dimensional empirical mode decomposition (BEMD). BEMD decomposes the original image into k IMF(intrinsic mode functions) and a Residue. The residue contains the edge information of the image. To enhance the low-frequency information, contrast limited adaptive histogram equalization is applied to IMF.

H. *Complex Wavelet Transform:*

In [9] it shows Dual-Tree Complex Wavelet Transform. The DT-CWT is a combination of two real-valued decimated DWTs. The ordinary decimated DWT is shift variant due to the decimation operation exploited in the transform. As a result, even if a small shift in the input signal can result in a very different set of wavelet coefficients. DT-CWT which exhibits shift-invariant property and improves directional resolution when compared with that of the decimated DWT. First create an initial estimate Y of the unknown HR image. The initial estimate Y is decomposed using the one-level DT- CWT to create one complex- valued low-pass subband and six complex-valued high-pass subbands. In the final step, the input LR image, together with the complex-valued high-pass subbands Y extracted from the one-level DT-CWT decomposition of Y, is used to create the HR image by employing IDT-CWT.

I. *Dual-Tree Complex Wavelet Transform and Non-local Means:*

In [11] DT-CWT-based nonlocal-means-based Resolution enhancement technique is proposed, using the DT-CWT, Lanczos interpolation, and Non local means filter. The NLM filter is based on the assumption that image content is likely to repeat itself within some neighborhood. Then, we apply the inverse DT-CWT to these filtered subbands along with the interpolated LR input image. And it is used to reconstruct the HR image.

J. *DWT with SWT*

In [12] Stationary Wavelet Transform (SWT) with Discrete Wavelet Transform (DWT) is performed on the input image. Both the wavelets use low resolution image as input image and produce high frequency sub band images .All the four sub band images are interpolated in DWT but not needed to interpolate in SWT. All the high frequency sub band images All the four sub band images are interpolated in DWT but not needed to interpolate in SWT. All the high frequency sub band images are added to each other, which is considered as an estimated high frequency sub band image.

K. *Deep memory connected network*

In [15] a deep memory connected network is used to enhance the image with large receptive field and better re- construction ability. To combine local detail as well as global information learned in different neural layers, DMCN is elaborately designed with local and global memory connections.

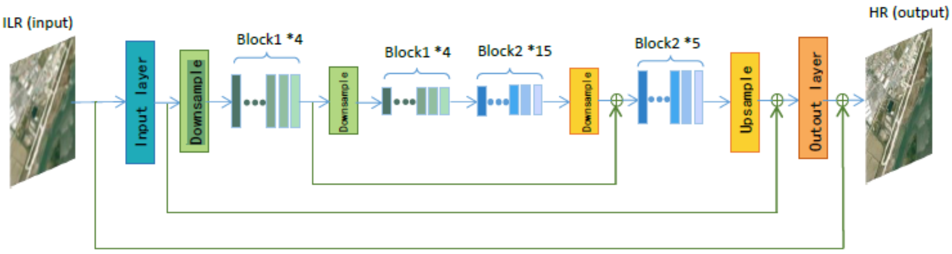
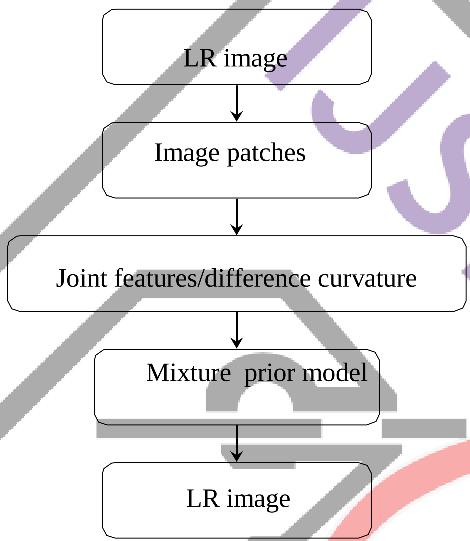


Fig 3:Deep memory connected network

III. PROPOSED WORK

The objective of single image super-resolution is to recon- struct a visually pleasing image from a low-resolution image after down-sampling and blurring. When we maximize the size of an image their quality degrades. To regain the quality is a challenge. Deep learning SR methods are all executed on GPU, which is limited in some mobile and ordinary devices with only CPU. Since PSNR rate with difference curvature introduced in [17] with various datasets is high we follow [17]. Its execution time is less compared to other methods.



Difference-Curvature based SPP[17]: Here the image is analysed in the form of patches. First the input LR image is divided into N patches. In the training phase we only have the HR image, then blur and down-sample it into LR size by bicubic interpolation. SPP(selective patch processing) strategy is used to select the patches with more edges and discard the patches with more ramps. Here difference curvature is considered since it preserves high frequency information, and distinguishes edges from flat, ramp region and isolated noise. Difference curvature can be calculated by,

$$C_i = \| f_i^{\epsilon} \| - \| f_i^{\eta} \|,$$

where f_i^{ϵ} and f_i^{η} are the second order derivatives in the direction of the gradient Δf_i and in the direction perpendicular to Δf_i respectively.
As the purpose of SPP is to select some informative patches by some special criterion, the median value over C_i in each patch is a right choice.

Learning mixture prior model[17]: Mixture prior model is a clustering model, and use it here for representing the patch prior well. A more convincing reason is that the distribution of each image patch generally has a multimodal landscape where any component could represent a special texture.

We define the joint features by concatenating x_i^h *and* x_i^l.

Now $x_i = \left| \begin{matrix} x_i^h \\ x_i^l \end{matrix} \right|$

where x_i^h- high resoluted patch

x_i^l- low resoluted patch

since we have both HR and LR during training phase. Then the N joint vectors are divided into T groups by sorting and segmenting the difference curvature of each image patch. Then they are mapped between the HR and LR features of each group.

Mixed Matching[17]: During testing phase we don't have high resoluted image to reconstruct. Inorder to improve the performance during reconstruction mixed matching is performed. Higher components are selected in mixed matching. The components of interpolated image with higher frequency values are matched with the obtained image and HR image is reconstructed.
The dataset using here is Landsat in USGS(United states geological survey).

IV. Comparative study of different papers:

Author	Ind:	Preprocessing	Contrast enhancement	Method	PSNR
R. Thriveni et al.	[2]	Morphological filter	Thresholding	Discrete avelet Transform and Inverse Wavelet Transform	36.2052
Pratibha Pandey et al.	[4]	Median filter	Thresholding	Contrast stretching	16.77
Aditi Sharmaet al.	[5]	DWT	Interpolation	Singular Value Decomposition	22.21
A. Pugazhenthi et al.	[6]	Average filter	Histogram equivalization	PDF and CDF	23.76
B. D. Jadhav et al.	[7]	DWT	Interpolation	Bicubic interpolation and IDWT	32.042
Lalit Mohan Satapathy et al.	[8]	Bi-dimensional empirical mode decomposition	Contrast limited adaptive histogram equalization	Multi-technology fusion	17.56
Hasan Demirel et al.	[9]	Gaussian low pass filter	Interpolation	DT-CWT	30.8993
Pooja Bidwai et al.	[10]	DWT	Interpolation	SVD and IDWT	41.267
Muhammad Zafar Iqbal et al.	[11]	DT-CWT	Lanczos interpolation	NLM filter and DT-CWT	17.5895
Mansing Rathod et al.	[12]	DWT	Bicubic interpolation	DWT with SWT	51.86
Shilpa Suresh et al.	[14]	DWT and SWT	Histogram equivalization	Singular value decomposition	24.6297
Wenjia Xu et al.	[15]	Low pass filter	Convolutional filter	DMCN	34.19

V. CONCLUSION

In most digital imaging applications, high resolution images or videos are usually desired for later image processing and analysis[18].The goal of single-image super-resolution is to obtain a high-resolution image from a single low-resolution image. Here we focused mainly on satellite images, since they are more prone to distortion. Here we surveyed different methods .Different Image improvement algorithms produce many different methodologies for image amendment to attain visually accepted images. The techniques of Contrast enrichment are utilized broadly for betterment of visual quality of low contrast images. Here we have used techniques like wavelet transform and morphological filtering, contrast enhancement, deep memory connected network, DWT-PCA based fusion technique and adaptive band enhancement technique.

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