A Survey on Image Inpainting for Remotely Sensed Images

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***Abstract*— Image inpainting is the process of reconstructing an image or to fill the missed region by using the surrounding pixels so that it looks reasonable to human eye. Sometimes, while capturing the image dead pixels will exists in the image which results in degraded image. In this paper, various algorithms are discussed by using which we can get a smoothed and undegraded image.**

***Keywords*— Inpainting, MAP algorithm, Exemplar based inpainting, RBFNN method, MNLTV model Bandelet Based Inpainting.**

I. INTRODUCTION

Inpainting is a technique by which you can recover your image from a degraded image i.e. whether it is corrupted by noise or you want to remove some unwanted things from an image, inpainting techniques are now very much popular now a days especially in remotely sensed images where there is very difficult to remove portions or to remove noises such as speckle noise. SAR images are mostly affected by speckle noise which is very difficult to remove. Adaptive filters can be used to reduce the speckle noise however the use of adaptive filters require more amount of computational power. To overcome this problem we can use denoising filter known as NL-means .

After that, non local methods can also be used in which NLTV(non local total variation)model can preserve both edge and texture details. Dead pixels are unwanted pixels in the image which results in degraded image. Maximum a posteriori(MAP) method is very much capable of removing the dead pixels from an image and also used for image destripping. MAP algorithm make use of neighbors a periori constraint and give the desired results.

The simple method of destripping is the use of low pass filter in frequency domain. But the disadvantage of this method is that it doesn't remove all the stripes from the image and hence cause blurring. According to researchers wavelet method can also be used for destripping which can easily detect and eliminate stripes in an image but in this method some blurness also occurs. To overcome this problem we have finite impulse response filter.

II. INPAINTING METHODS

Basically there are two methods of image inpainting [8]

i. Structural inpainting
ii. Textural inpainting

Structural inpainting make use of geometric information for filling the missed region in an image

Textural inpainting filled the missed regions by similar neighborhoods of damaged pixels.

More image inpainting techniques are described as follows:

A. Diffusion Based Inpainting:

In diffusion based inpainting technique missed region in the images are recovered by using the neighboring known pixels. But its disadvantage is, it cause blurness while filling the missed region [8].

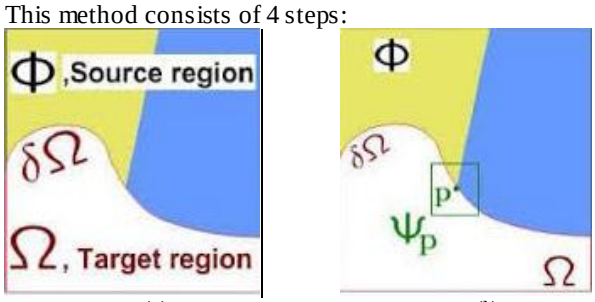
B. Partial Differential (PDE) based Inpainting:

This method is useful only when the missed region is small. It can be applied to large regions but the results will not be too good.

C. Exemplar Based Inpainting:

In Exemplar based inpainting, Criminisi algorithm is used which is the combination of inpainting process and texture synthesis based technique .In this algorithm there is no such blurness like in inpainting process and loss of linear details like in texture synthesis.

This method consists of 4 steps:



(a) (b)

Fig1:Exemplar Based Texture Synthesis[3]

Where target region is denoted by 'Ω', source region is 'Φ'

i. Initialize the targeted region
ii. Compute the filling priorities
iii. Search for Example and compositing
iv. Updating image information

D. *Wavelet Transform Based Inpainting:*

Strength of this method is, it separates the actual signal from noise and its weakness is, it does not depends upon geometic aspects. when wavelet method is compared with diffusion method, Strength of diffusion method is that it is geometry-driven & its Weakness is that it is localized model. By using wavelet method, we can decompose an incomplete image and obtain its wavelet coefficients but we have to apply the mask manually[9].

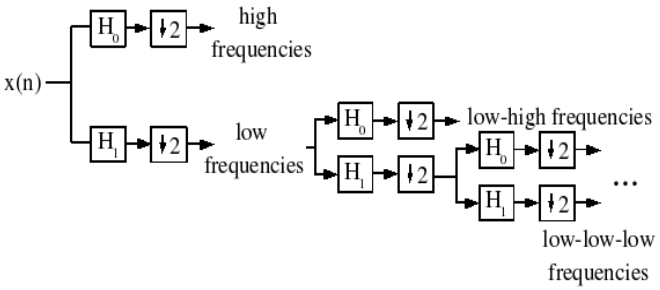


Fig2:Wavelet decomposition. of image

x(n)-original image
HF,LF,LHF, LLLF are wavelet coefficients

TABLE I
Advantage and Disadvantage of Inpainting Methods[9]

Methods	**Adv.**	**Disadv.**
PDE(partial Differ.=n)	Preserves structural & linear details	Blurness occurs for large regions
Texture synthesis based	Results do not display/blur/arti-facts	Not for Curved structure
Exemplar based Texture Syn.	Preserves textural and structural info.	For large affected regions then gives bad results
Diffusion based inpainting	Diffuse info. from surrounding pixels	Blurness occurs

NON-LOCAL INPAINTING METHODS

Remotely sensed images are also known as SAR images. Sometimes the images are distorted either by noise stripes or contaminated clouds. The solution of these problems are given by these methods. Techniques are described as follows:

A. Multichannel Nonlocal total variation(MNLTV)Model
B. RBFNN in shearlet domain
C. Modified Exemplar Based
D. Bendelet Based Inpainting
E. Maximum a posteriori (MAP)
F. Non-local means Algorithm

A. MNLTV Model:

When capturing an image from the satellite,sometimes dead pixels can exist in the image depending upon the condition, not always. To remove those dead pixels we use MNLV model as you can see in the Fig 3.

Regularization methods such as manifold, sparsity which are in the category of local methods i.e. that are very good at nonlocal methods are good at geometric structures such as edges.

(a) (b) (c)

Fig3:Removal of dead pixels[1]

(a)Original image
(b)Image contaminated by dead pixels
(c)Recovered image using MNLTV model

Quality of the image depends on parameters such as PSNR(peak signal to noise ratio), SSIM(Structural similarity index module), Q metric(quality metric).value of SSIM lies between 0-1.More the values of these parameters more good will be the quality. The future scope of this work is that weighting function which is used in this paper is within single band, the future work is extend it to multiple band.

B. RBFNN In Shearlet Domain:

RBFNN is a thin plate spline radial basis function based inpainting in Shearlet Domain to recover dead pixels from the image. This method take the features of Discrete Shearlet Transform which is good at textured and non textured images. In this method when multispectral satellite images are captured by air borne sensors. Multispectral image is a combination of monochrome images of same location taken by different sensors. For reducing the cost for memory and to increase the processing speed this proposed model is used in shearlet domain which combines the features of radial basis which have excellent performance when dealing with textured images.

Proposed scheme:

i. Degraded input image
ii. DST of input image
iii. Detect the missing areas using statistical measures
iv. Perform the inpainting process

C. Modified Exemplar Based:

This method behave very good at detection of clouds.So the aim of this method is to remove those clouds from the image and reconstruct it. Reconstruction of missing data in remotely

sensed images is a great challenge due to its complexity.Therefore for more accuracy and clearity in the image two methods were proposed for filling the missing regions First method uses recovering pixels from neighboring information whereas Exemplar method for reconstruction and other method uses Modified Elemplar method for inpainting process .

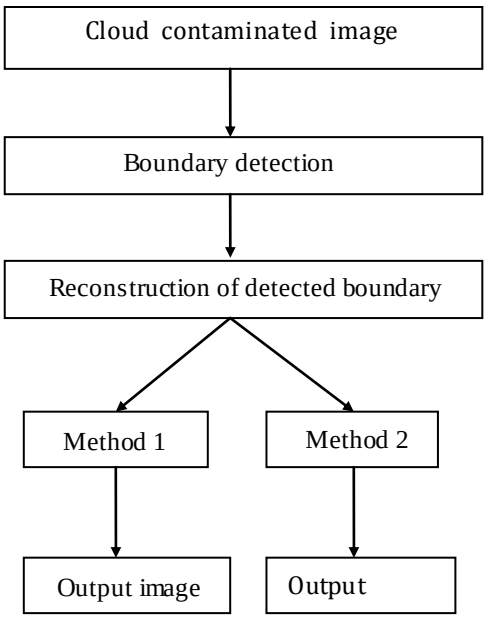
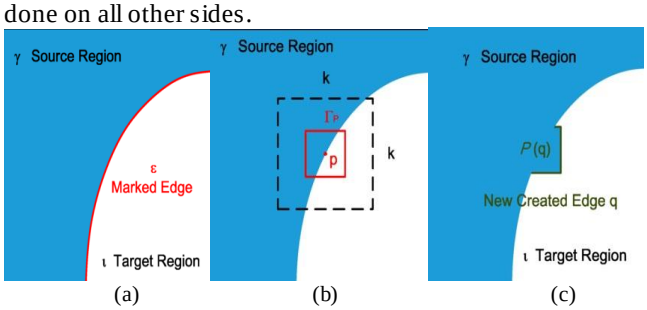


Fig4:Process diagram[7]

Method1-Exemplar based
Method2-Modified Exemplar based

In a modified exemplar method ,draw a bounding box which covers the edges of target region now the target is with in the box and the outer region is the source region then create the 9x9 patch outside the bounding box in Fig5.Select the source patch from one of the row which is free from the target region now the selected patch is then moved to target region Same is done on all other sides.



(a) (b) (c)

Fig5: Patch identification in hole padding process
(a)Edge marking
(b)Find range
(c)Patch pasting

In this, two different remotely sensed images are used and then the proposed algorithms are applied to those images. The cloud contamination Is done by edge detection and image fusion then the region which is missed in the image is recovered by using these proposed methods.

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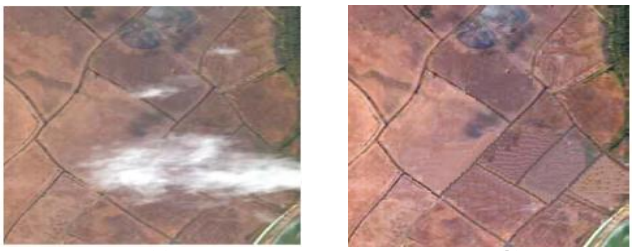
D. Bendelet Based Inpainting:

Sometimes images are obsecured by cloud shadows. To remove those shadows bendelet based inpainting is used. This proposed technique is based on Bandelet transform with multiscale grouping.



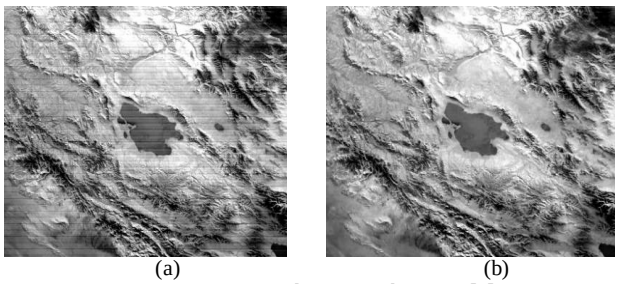
(a) (b)

Fig6: Cloud removal by Bendelet Transform Technique[4]

Another method is adaptive reconstruction technique which is proposed by Lee and Crawford for these kind of problems.But this method has high computational complexity hence not used.

E. Maximum A Posteriori (MAP):

Remotely sensed images sometimes suffers from noise stripes and dead pixels. There are different algorithm available for this method but it has been demonstrated that MAP algorithm is much better than any of the conventional destripping methods. Researchers have already been tested this algorithm on Terra and aqua MODIS images. Some researchers use wavelet method for destripping because of scaling and directional properties .



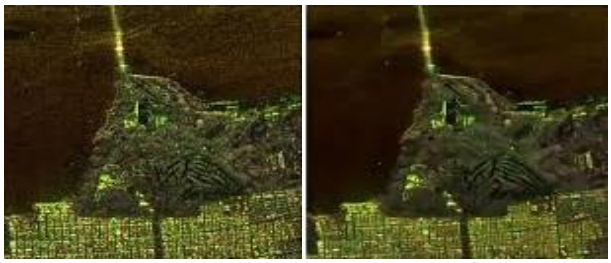
(a) (b)

Fig7: Image destripping by MAP [5]

F. NL(nonlocal)-means Algorithm:

Satellite images are usually affected by various types of noise. Various methods for the removal of noise are Gaussian method ,anisotropic method and Total variation minimization method. Many of the methods loose too many details from the image while removing the noise so to overcome this problem,NL- means algorithm was preserving the image details relating to structure. First, Gaussian filtering method was used which gives poor results while removing the noise from the image.

Then later, weiner filter was used which gives better results than the Gaussian method but still blurring exists. Then after that we have SUSAN filter which is more better than the other two filters. After using SUSAN filter we still have small noise in the image. Then at last we have NL-means filter which performs exceptional better than the existing filter.



(a) (b)

Fig8: Despeckling of SAR Image Using Generalized Guided Filter With Nonlocal Means

III. LITERATURE REVIEW

Qing Cheng, Huanfeng Shen [1], proposed a model i.e. MNLTV which is more robust than any other algorithm, the result of proposed model is then compared with results of other methods like NLTV model, MCA algorithm, Criminisi method, MTV model and NLM (nonlocal-means).

R.Gomathi, Vincent Antony Kumar [2], have presented RBFNN, a thin plate spline radial basis function based inpainting in Shearlet Domain to recover dead pixels from the image. This method takes the features of Discrete Shearlet Transform which is good at textured and non textured images.

D.Linett Sophia, K.Lalitha and J. Praveen Chandar [3],have presented a method for cloud detection and reconstruction technique. Reconstruction of missing data in remotely sensed images is a great challenge due to its complexity
.

Aldo Maalouf, Philippe Carre, Bertrand Augereau, and Christine Fernandez-Maloigne [4] have presented a technique which is used to improve the cloud contaminated images i.e while taking the image sometimes images are obsecured by cloud shadows. The proposed technique is based on Bandelet transform with multiscale grouping.

Huanfeng Shen and Liangpei Zhang [5], proposed a algorithm for image destripping. Remotely sensed images sometimes suffers from noise stripes and dead pixels. There are different algorithms available for this method but it has been demonstrated that MAP algorithm is much better than any of the conventional destripping method.

Buades, B. Coll and J.M.Morel [6] compare the early methods of denoising with the proposed algorithm. Various methods for the removal of noise are Gaussian method, anisotropic method and Total variation minimization method. Many of the methods loose too many details from the image while removing the noise so to overcome this problem, NL- means algorithm was preserving the image details relating to structure.

IV. CONCLUSION

In this paper, all the inpainting techniques either used for normal images or for remotely sensed imaged are discussed. Every technique is discussed with their working and limitations. The motive of this paper is to aware the readers who want to work on remotely sensed images. In this paper all the algorithms used for SAR image i.e. for destripping ,cloud contamination, noise removal are discussed. Overall study tells that all techniques trying to provide better result in terms of quality of the image.

V. FUTURE ASPECTS

According to Literature survey discussed in this paper ,limited amount of work has been done on MNLTV model, Modified Exemplar based ,Bendelet Transformation.So we can do a lot a work on these methods and it opens a new horizons for the researchers in the field of inpainting methods.

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