© 2018 IJSRST | Volume 4 | Issue 5| Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Scienceand Technology

Satellite Image Restoration Using Bilateral and Guided Filters

C.VamsiKrishna[1], S.Narayana Reddy[2], P.Jagadamba[3]
[1]Department of ECE, S.V.University College of Engineering, Tirupati, Andhra Pradesh, India
[2]Professor of ECE, S.V.University College of Engineering, Tirupati, Andhra Pradesh, India
[3]Assistant Professor of ECE, SKIT College of Engineering, Sri Kalahasthi, Andhra Pradesh, India

ABSTRACT

While capturing and transmitting of satellite images, due to channel effects or uncertain conditions the received images are highly degraded. These effects introduce different noise such as, Additive White Gaussian Noise, Salt & Pepper Noise and Mixed Noise. To remove these noise different types of filters are used. In the previous methods, these noise patterns are removed by using Recursive Least Square (RLS) adaptive algorithm. The implementation of this methodology is being carried out by estimating the noise patterns of unknown noise and noise patterns are eliminated by configuring Signal Enhancement with RLS algorithm. The restored images are functioned for further denoising and enhancement techniques. The performance is evaluated by means of quantitative measures in terms of MSE, RMSE & PSNR. In proposed methodology we are using the bilateral and guided filters which is used for removal of noise more effectively than the previous methods. These filters will smoothen the images while preserving edges. In blateral filtering each pixel is replaced by the weighted average of its neighbor pixels, but in guided filter the behaviour at edges will be more efficient than the bilateral filter. The performance of the proposed method is measured by means of image parameters as seen in previous methods. By comparing these values and output images, proposed method shows the efficient restoration of noisy images.

Keywords: Guided filter, Bilateral filter, Mean square error(MSE),Root mean square error(RMSE), and Peak signal to noise ratio(PSNR)

I. INTRODUCTION

Filtering is perhaps the most fundamental operation of image processing and computer vision. Most of images are affected due to noise upto some extent, image analysis is often simplified if this noise can be filtered out. In image processing image extraction and restoration plays a major role in retrieving original or input image. There are different types of noises which degrades the image while transferring and restoring. Noise represents unwanted information which deteriorates the image quality. Due to this noise we may loose the data or gain the unwanted data that cause effect to our image. Noise means pixels within the image having different pixel values rather than original pixels. There are different types of noise that effects the images, some of them are salt and pepper noise, Gaussian noise, gamma noise, mixed noise etc.,. The noise may add at any satge of transmission or receiving, due to the environmental effects also the image will be degraded. If the image is transmitted at high temperature it will get more lightened and cause Gaussian noise effect.To restore the images different types of filters are used. These filters are applied on the image pixels to retrieve the original image. If we take Gaussian low-pass filtering it computes a weighted average of pixel values in the neighborhood, in which, the weights decrease with distance from the neighborhoodcenter. so near pixels are likely to have similar values, and it is therefore appropriate to average them together. The noise values that corrupt these nearby pixels are mutually less correlated than the signal values, so noise is averaged away while signal is preserved. The assumption of slow spatial variations fails at edges, which are consequently blurred by low-pass filtering. Many efforts have been devoted for reducing this undesired effect. In the previous methods noise is removed by using RLS adaptive algorithm, which is used for the restoration of images from the unknown noise. This unknown noise is found by using channel noise estimation patterns and image denoising method and then the image is retrieved by using image processing techniques. In this paper we are using bilateral and guided filters to get the more accurate images and results. These filters will perform smoothing and edge preserving techniques. Finally the performance is measured by comparing the two methods using image processing parameters.

II. DIFFERENT TYPES OF FILTERS USED TO REMOVE NOISE FROM AN IMAGE

An image can be degraded with different types of noises. In these there are mainly four noises that will frequently degrade the image. Those are salt and pepper noise, Gaussian noise, speckle noise and uniform noise. To remove these noises different types of filters are used. In that RLS adaptive filter, median filter, average filter and laplacian filters are considered and their operations are performed. RLS adaptive algorithm is a non linear one used for image restoration from the noise, in this method we are using two-Dimentional image and applying Additive white Gaussian noise (AWGN) to that image. Now by adding AWGN to the input image it will be degraded and noise corrupted image acquisition is formed. In the rls algorithm to estimate the unknown channel noise adaptive filter is used. This adaptive filter has ability to track variations in the signal or parameters of time varying system to meet the performance factors. The channel noise estimation consists of two parts which are (a) channel estimation by means of system identification and the second (b) image denoiosing by signal enhancement.

(a) channel noise estimation by system identification:
In a wireless channel the conditions changes rapidly with time.we need to estimate the noise patterns in the desired signal. The filter coefficients of RLS adaptive filter are synchronized iteratively in order to decrease the error. When object function is minimized, then coefficients of adaptive filter are matched with that noise patterns.

(b) Image denoising by signal enhancement:
After achieving estimated noise patterns, image denoising is done by signal enhancement configured with RLS algorithm. The embedded noise patterns are successfully removed by correlating with estimated noise patterns.

By estimating noise patterns the RLS algorithm will remove the noise by comparing with noise corrupted image. As the image restoration is done by using rls adaptive algorithm, the retrieved image will be embedded with different noises. In which salt and pepper noise is the major one. Due to some environmental conditions the image becomes blurr, contrast and brightness problem may occur. Due to these problem the image quality will be reduced. So by using some image processing techniques we are retrieving image upto the mark. The image processing techniques involve Meadian filter, Average filter, Laplacian filter, and histogram equilisation. The brief explanation of these filters are given below.

Median filter is a non linear filter, mainly used for the removal of salt and pepper noise, it is done by categorizing all the pixel values from the neighbours into numerically assending order and then replacing the pixels by considering with the middle pixel value.

Average filter is also called mean filter, in which each pixel value of an image is replaced with mean value of its neighbours, including itself. This has the effect of eliminating pixel values which are deceiving of their surroundings. It will reduce the amount of intensity variation between one pixel and the other. This filter is used for smoothing images.

If the output from the moving average filter is subtracted from the originl image, on a pixel by pixel basis then it is called laplacian filter. This filter is also called second order derivative filter used to detect the edges in images. This filter does not take out edges in any particular direction, but it take out edges in two classification process. Positive laplacain operator, B) Negative laplacian operator. In positive laplacain the center element of mask should be negative and corner elements of mask is zero. If this operator is used then resultant should be subtracted from original image. In negative laplacian the center element of mask should be positive and corner elements of mask is zero and rest of all elements should be -1. If this operator is used then resultant should be added to the original image. Histogram equilisatoin is used to adjust the intensities of an image and to enhance contrast. By using these image processing techniques the image is restored and the performance of these filters is evaluated by means of quantitative measures in terms of MSE, RMSE and PSNR. In the proposed method to improve the image quality and decrease the noise in image we are going for bilateral and guided filters.

III. PROPOSED METHODOLOGY

In proposed method we are using bilateral and guided filters to reconstuct the image by reducing the noise and increase in PSNR value. This can be shown by comparing the outputs of different image processing parameters. The analysis of proposed method is shown in the below flow chart.

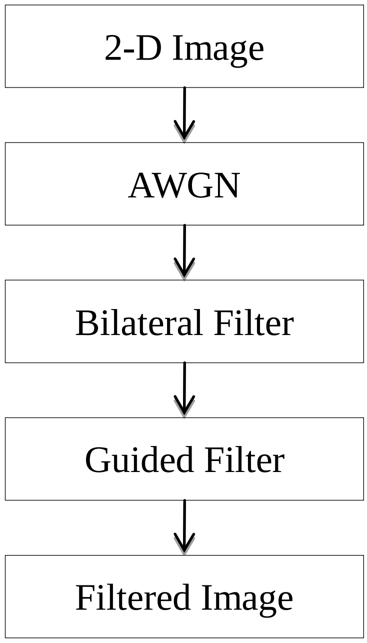


Figure1. Flow chart of proposed methodology

A. Bilateral Filter

It is a non-linear filter which smoothen the images while preserving edges. The working principle of bilateral filter is that each pixel value in an image is replaced with the weighted average of its neighbouring pixels. This filter mainly depends on two factors that indicate size and contrast features to preserve. This filter is widely used in noise reduction, multiscale detail disintegration and image generalization. Gaussian convolution is very similar to Bilateral filter, but it doesnot preserve edges. Gaussian convolution states that each pixel of output image is a weighted sum of its neighbour pixels in the input image.

The simplest way to smoothen image is blurring. An image filtered by gaussian convolution X is given as[3]

$$X[I]_p = \sum_{q \in s} G_\sigma(\| p - q \|) I_q \quad (1)$$

Where $G_\sigma(x)$ denotes Gaussain kernal

$$G_{\sigma}(x)=\frac{1}{2\pi\sigma^{2}}\exp(\frac{-x^{2}}{2\sigma^{2}}) \quad (2)$$

I_p is the image value at pixel position P

I_q is the image value at pixel position q

S be the set of image locations of spatial domain

R be the set of pixel values of range domain

||p-q|| is the eucledean distance between pixel locations p and q

Gaussian filtering is a weighted average of intensity of the adjacent positions with a weight decreasing with the spatial distance to the center position p.

The main process of bilateral filter is that for a pixel to influence the another pixel, it not only occupy near by location pixel but also have similar value.

The bilateral filter is denoted by

$$BF[I]_{p}=\frac{1}{\omega_{p}}\sum_{q\in s}G_{\sigma_{s}}(\|p-q\|)G_{\sigma_{r}}(|I_{p}-I_{q}|)I_{q} \quad (3)$$

ω_p is the normalization factor

$$\omega_{p}=\sum_{q\in s}G_{\sigma_{s}}(\|p-q\|)G_{\sigma_{r}}(|I_{p}-I_{q}|) \quad (4)$$

Where σ_s and σ_r are spacial and range parameters

As the range parameter σ_r increases, bilateral filter gradually approximates gaussain convolution more closely. Increase in the spatial parameter σ_s smooths larger features.

Consider a pixel located at (i,j) that is to be denoised in image using its neighbouring pixels and one of its neighbouring pixel be (k,l), then the weight of the pixel (k,l) to denoise (i,j) is given by

$$\omega(i,j,k,l)=\exp(-\frac{(i-k)^{2}+(j-l)^{2}}{2\sigma_{d}^{2}}-\frac{\|I(i,j)-I(k,l)\|^{2}}{2\sigma_{r}^{2}}) \quad (5)$$

where σ_d *and* σ_r are smoothing parameters and I(i,j) and I(k,l) are the intensity of pixels (i,j) and (k,l) respectively.

After calculating the weights the normalized form is given as

$$I_{d}(i,j)=\frac{\sum_{k,l}I(k,l)\omega(i,j,k,l)}{\sum_{k,l}\omega(i,j,k,l)} \quad (6)$$

I_d is the denoised intensity pixel of (i,j)

This bilateral filter has unwanted gradient reversal artifacts near edges, and its fast implementation is also a challenging problem. So we are using gradient filter to overcome these problems.

B. Guided Filter

Guided filter Performs edge-preserving smoothing operation like bilateral filter, but it has better behaviour while preserving edges. It is fast and non approximate, linear time algorithm, whose computational complexity is independent of filtering kernal size. It doess not suffer from the gradient reversal artifacts. This filter performs very well in terms of both quality and efficiency in various applications, such as noise reduction, digital smoothing, image matting, haze removal.

A general linear translation varient filtering process is considered. At a pixel i the filtering output is expressed as a weighted average.[13]

The weighted average is given as

$$b_{i}=\sum_{j}W_{ij}(I)a_{j} \quad (7)$$

where i and j are pixel indexes. a and b are the input and output images respectively. I is the guidance image, W_{ij} is a filter kernal of guidance image and independent of a.

Now we define the guided filter and its kernel. The main assumption is that guided filter is a local linear model between the guidance I and the filter output b. Assume that b is a linear transformation of I in a window ω_k centered at pixel k

$$b_{i}=p_{k}I_{i}+q_{k} \quad \forall\ i\in\omega_{k} \quad (8)$$

The solution for linear regression is given by p_k, q_k

$$p_k = \frac{\frac{1}{\omega}\sum_{i\in\omega_k} I_i a_i - \mu_k \hat{a}_k}{\sigma_k^2 + \in} \quad (9)$$

$$q_k = \hat{a}_k - p_k.\mu_k \quad (10)$$

Here, μ_k and σ_k^2 are the mean and variance of I in ω_k, $|\omega|$ is the number of pixels in ω_k, and $\hat{a}_k$ = 1, a_i is the mean of a in ω_k , $\in$ is the regularisation parameter, preventing p_k from being too large

The guided filter output is given by

$$b_i = \frac{1}{|\omega|}\sum_{k:i\in\omega_k} p_k I_i + q_k \quad (11)$$

$$b_i = \hat{p}_i I_i + \hat{q}_i \quad (12)$$

Finally the kernel weights can be explicitly expressed as

$$W_{ij}(i,j) = \frac{1}{|\omega|^2}\sum_{k(i,j)\in\omega_k}\left(1+\frac{(I_i-\mu_k)(I_j-\mu_k)}{\sigma_k^2+\in}\right) \quad (13)$$

Where I_i and I_j are guideance image at pixel index i,j.

IV. PERFORMANCE EVALUATION

The objective measure is computed quantitatively by means of Mean Square Error, Root Mean Square Error and Peak Signal toNoise Ratio parameters.

Mean square error (MSE) is defined as the cumulative squared error between the original and restored image.

$$MSE = \frac{1}{MN}\sum_{X=1}^{M}\sum_{Y=1}^{N}[f(x,y)-\hat{f}(x,y)]^2 \quad (14)$$

Where f(x,y) is original image and $\hat{f}(x,y)$ is the restored image, x and y are the descrete coordinates of image and M*N represents image size.

Root mean square (RMSE) is defined as

$$RMSE = [\sum_{X=0}^{M-1}\sum_{Y=0}^{N-1}[f(x,y)-\hat{f}(x,y)]^2]^{\frac{1}{2}} \quad (15)$$

RMSE is frequently used to measure the difference between original image and the restored image.

Peak signal to noise ratio (PSNR) is defined as the ratio between maximum power of a signal to the power of humiliating noise that affects the fedility of its representation.

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (16)$$

Where 255 is the maximum possible pixel value of an 8 bit image. PSNR is used to measure the quality of reconstructed image. If the PSNR value is high, then the reconstructed image is said to be a quality image.

V. RESULTS AND ANALYSIS

In this paper, the proposed methodology for the image restoration, its denoising and enhancement is tested and implemented in MATLAB R2016b. By calculating the above image parameters, we are comparing previous method and proposed method. The below satellite image-1 and satellite image-2 represents the comparision between the filters used in the previous and proposed methods.

From the observation of the below images, the restoration of images using previous methods are less effective than the proposed images. The edge preservation and smoothing for the images is done more effectively in proposed method. Gradient reversal artifacts are removed succussfully using Guided filter. The tabular columns shows the comparision of previous and proposed methods using quantitative image parameters.

1) Input Image

2) Noise Image

3) Median Filter Image

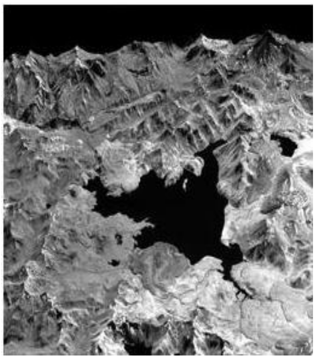
4) Average Filter Image

5) RLS Adaptive Image

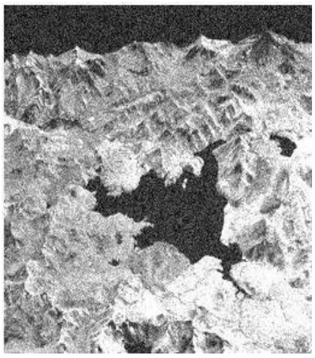
6)Bilateral Filter Image

7) Guided Filter Image

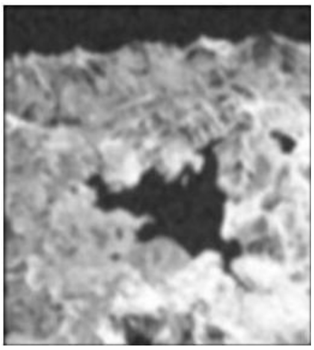
Figure2. Satellite image-1 Restoration using Bilateral and Guided filetrs



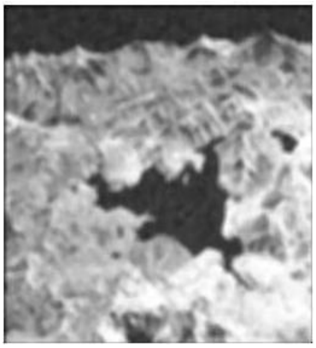
A) Input Image



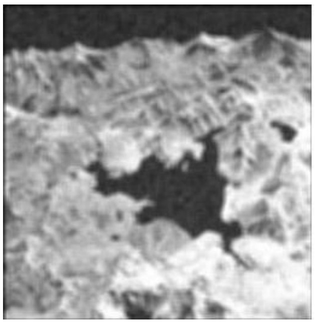
B) Noise Image



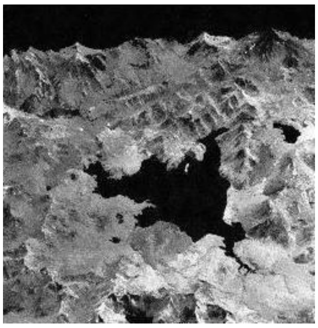
C) Median Filter Image



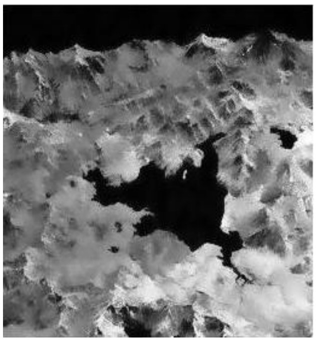
D) Average Filter Image



E) RLS Adaptive Image



F) Bilateral Filter Image



G) Guided Filter Image

Figure3. Satellite image-2 Restoration using Bilateral and Guided filters

Table1. Comparing Proposed method with previous method for Satellite Image-1

FILTERS USED	MSE	RMSE	PSNR(dB)
GUIDED FILTER (Proposed Method)	0.546	0.731	60.895
BILATERAL FILTER (Proposed Method)	0.606	0.778	58.731
RLS ADAPTIVE FILTER	1.976	1.405	56.127
MEDIAN FILTER	2.785	1.668	47.033
AVERAGE FILTER	3.654	1.911	36.387

Table2. Comparing proposed method with previous method for Satellite Image-2

FILTERS USED	MSE	RMSE	PSNR(dB)
GUIDED FILTER (Proposed Method)	0.397	0.630	79.808
BILATERAL FILTER (Proposed Method)	0.514	0.716	73.547
RLS ADAPTIVE FILTER	2.976	1.725	68.123
MEDIAN FILTER	4.555	2.134	57.030
AVERAGE FILTER	4.654	2.157	46.387

VI. CONCLUSION

In this study, the removal of gaussian noise from the satellite images is implemented by using bilateral filter and guided filter. Comparing with the previous methods the proposed method shows better performance. After denoising, the resultant images have shown better visual effects and preserve sharp edges. The bilateral and guided filters are exposed to achieve the improved value of Peak Signal to Noise Ratio(PSNR) and reduced value of Mean Square Error(MSE).

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