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An Unsharp Masking Algorithm Embedded With Bilateral Filter System for Enhancement of Aerial Photographs

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Abstract: Human visual system is more sensitive to edges and ridges in the images which composed of high spatial frequency components. Digital images having more spatial variations may contain informative content than their counterparts. Remote sensing images are one of those categories covering different aspects of land surface variations, aerial photographs are obtained on board image sensors on flying platform. Aerial photographs represent the land surfaces consists of textural and structural objects make more presence of edges. Interpolating information of aerial photographs become clumsy when the pixels are corrupted with noises at different density of levels. The kind of aerialphotographsare acquired in various way such as multi/hyper spectral sensors on board of satellites or the planes, by synthetic aperture radar (SAR) in remote sensing. The intelligence of the aerial photographs affected because of noises during image formation process and atmospheric factors. In this paper, unsharp masking (USM) algorithm based image denoising framework is proposed with Gaussian and bilateral filters. Structure similarity index(SSIM) and Image enhancement factor (IEF) based performance comparisons were studied for various noises on aerial photographs and the experimental results shown that the bilateral filter with USM system outperforms the Gaussian filter with USM. The simulation setup demonstrated using both additive and multiplicative noises with the different levels of noise density on aerial photographs.

Keywords, Unsharp masking, image denoising, Gaussian filter, Bilateral filter, Aerial photographs

I. INTRODUCTION

Aerial photographs are usually obtained from the flying objects such as on board satellite sensor, unmanned aerial vehicle(UAV) or drones used to be source of significant information of remote sensing applications [1]. Classification of intelligent information from the aerial photographs areinformative and require sophisticated algorithmic tools to do precise informative data processing[2]. Aerial photographs are indispensable in remote sensing applications such land use and change detection, forest inventory management, urban planning, natural disaster management and more[3].

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Valued image information is affected due to the noise generated in the electronic circuitry in the image sensor system [4], atmospheric turbulence, which effects the noisy and blurred aerial image [5].

It is essential to retain he pixels' value while removing noise in the image. Generally, image filtering makes blurring of abrupt intensity pixels' value into blurred which will be significant loss of information. It is necessary to have edge preserving ability algorithm to process the noise affected pixels to be edge retained after denoising step. Bilateral filter is a kind of non-linear edge preserving filter used widely for image denoising with edges preserved [6]. Contrast of the image will be not improved during denoising process, as all image denoising filtering algorithms do only noise removal process. To have improved contrast of the image, unsharp masking based methods will be a candidate among many algorithms. Contrast enhancement is achieved through retaining the high details of spatial variation in the image called image sharpness [7]. More works are prevalent for contrast enhancement with combination of unsharp masking algorithm to solve the contrast adjustment and denoising issues [8,9]. Authors proposed the integrated filter system based on combination of bilateral filter and unsharp masking in pipelined manner [10]. Image denoising and contrast enhancement are performed independently and pipelined by bilateral filter and unsharp masking filter respectively.

This paper is organized as follows: the section II presents the outline of bilateral filter and unsharp masking algorithms in the context of image denoising tool. Proposed system is illuminated in section III, experimental results are demonstrated in section IV and followed by conclusion of this work.

A. Bilateral filter

Bilateral filter is a non-linear smoothening filter used to preserve edges on the noisy pixels of images. Based on the Gaussian distribution, intensity value of every pixel under consideration will be replaced by the weighted average of intensity value of the nearest pixels. The estimated weight of the new intensity of pixel will be not only Euclidian distance among pixels, also range differences, i.e. it's a domain and range filtering of pixels on images [6]. It's an edge preserving, non-iterative smooth filter to remove noise in the few iterations, if needed to have cartoon like renditions more iteration of steps will be required. Bilateral filter denoises the corrupted pixels in the textural region of the image rather than the structural region at higher noise density [11], since textural regions are easily corrupted by noise highly.

The bilateral filter is implemented on local neighbourhood of pixels in an input image, filtering kernel is calculated by the weightage of average of spatial relationship and intensity similarity to other pixels under the filter window [6]. The simplified way to represent the bilateral filtering is given as,

$$BLF(I)_P = \frac{1}{W_p} \sum_{q \in S} G_{\sigma s}(\|p - q\|)\, G_{\sigma r}(|I_p - I_q|) I_q \quad (1)$$

Where $W_p = \sum_{q \in S} G_{\sigma s}(\|p - q\|)\, G_{\sigma r}(|I_p - I_q|) I_q$ is normalization factor

-I_p, $I_q$refer to the image pixel value at location of p and q respectively

- The set s and r refer the all possible pixel locations in the spatial domain and range domain respectively
- The $q \in S$ denotes the sum of all pixels indexed by q
- The operation $\|p - q\|$ refers to the L_2norm function on pixels considered and absolute value by the $|I_p - Iq|$operation on intensity values.
- The Letter G denotes the weighting function estimation based on the Gaussian function

Image inpainting is the field of image restoration, which is widely used in industries to have more visual understanding. Bilateral filter is used for rendering artistic effects, scratch removal effects and image inpainting applications[12, 13].

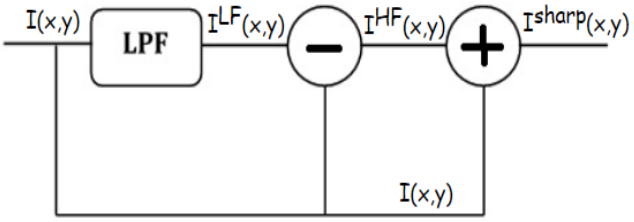

Fig.1. Unsharp Masking Filer

B. Unsharp masking algorithm

One of the ways to revealthe discernible details in the image by enhancing the overall sharpness of the original image by dealing the spatial frequencies. by separating them into low and high frequency components and manipulate them separately and combine together. Firstly, low pass filtering is applied on the input image, then the same subtracted from the input image to have high spatial frequency components. This is high frequency components yield the sharpened version of the image. The main drawback in this unsharp masking version of the image is halo effect around the edges. This unsharp masking is implemented as [10],

$$I^{HF}(x,y) = I(x,y) - I^{LF}(x,y) \qquad (2)$$

Where$I(x,y)$ is the input image to be filtered, $I^{LF}(x,y)$is the low pass filtered/blurred version of the input image and $I^{HF}(x,y)$ is the high frequency part of the input image.

$$I^{Sharp}(x,y) = I(x,y) + \alpha I^{HF}(x,y) \qquad (3)$$

Where $I^{Sharp}(x,y)$ is the sharpened version of the original input image

α is the weighting constant usually taken greater than zero. The degree of sharpening will be achieved depends on high value of α.

II. PROPOSED SYSTEM

As discussed earlier unsharp masking algorithms are generally implemented with low pass filter to make blurred of original image to highlights more fine details or increase the sharpness. Mostly Gaussian low pass filter is performed to have blurred version of original image and manipulated to sharpened level. As bilateral filter is known for edge preserving non-linear filter for noisy images, embedded into the unsharp masking step in the place of low pass filter. Bilateral filter is intended to supress noises in the aerial photographs at the same time to enhance the contrast of the same.

Schematic of the conventional unsharp masking system is given in Fig.1.

In the place of low pass filter, it is proposed to have bilateral filter as blurring filter and the comparison of performance made with the standard Gaussian low pass filter.In image processing, Gaussian filter is most prevalent function to smooth the noisy pixels, as the point spread function is very similar nature of Gaussian function.

There are several ways to enhance the sharpness of the image using the unsharp masking filter based on the smoothing/blurring techniques. They are histogram based, convolution mask based and conventional based methods. [14]. Authors in the work [10], used the convolutional based high pass kernel to obtain high pass component from the original image.

III. EXPERIMENTAL RESULTS

Simulation experiments of proposed system was performed on Matlab R2018a, 64bit version of windows 10 platform with 2.3GHz, 8GB RAM. The aerial image used in this experiment is available from [15]. Actual size of image is 3387×4663 with 24bit resolution to each pixel. For easy of processing image is resized to 512×512 level and converted to gray image.Performance measurement is necessary to evaluate the image processing algorithms; the following quantitative parameters are taken into performance comparison of different unsharp masking based denoising algorithms. They are mean, Structural similarity index measurement (SSIM), Entropy and Image enhancement factor (IEF) of the images concerned in the experiment.

Image enhancement factor is the ratio obtained between mean square error before and mean square error after image filtering. The expression for the IEF is given as bellow:

$$IEF = \frac{\sum_i \sum_j \left(\eta(i,j) - \overline{y(\iota,\jmath)}\right)^2}{\sum_i \sum_j \left(y(i,j) - \overline{y(\iota,\jmath)}\right)^2}$$

Where η denotes the noisy image.

Structural similarity index measurement (SSIM) is primarily used to examine the similarity between two images [16]. The higher the value of SSIM is, more the similarity of the image content is. Structural similarity index measurement is defined as:

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

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μ_x, μ_y-Mean of the two images
σ_{xy}- Co-variance of the image
σ_x^2, σ_y^2 variance of the images
C_1 and C_2 are the stability constant
Entropy can be defined as the statistical property of any data to measure the average information in it, higher the entropy value would represent the high information content in the data. It is measured by the following expression:

$$H(i) = \sum_{i=0} p(i) log_2 p(i)$$

For the sake of understanding the implementation of unsharp masking based on Gaussian and bilateral filters on noisy pixels of the image, the row of pixels before and after denoising step is shown. In the size of 512×512 input image, the line of pixel of x (50, 400) and y (150, 150) co-ordinates are selected to highlight the filtering process. The following figures shows that the input image, noisy version of the same and unsharp masking inbuilt with the Gaussian and bilateral filters.

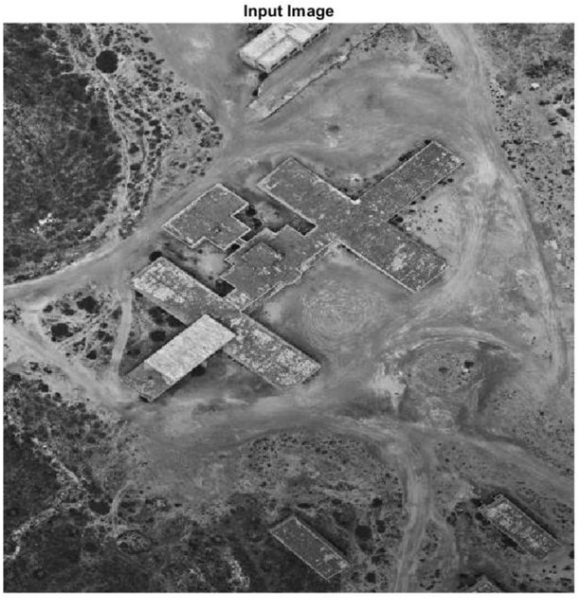

Fig.2. Input aerial photograph image

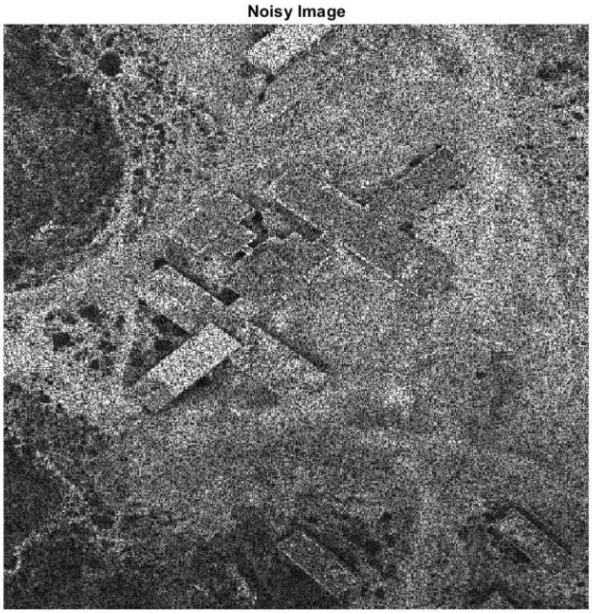

Fig.3. Speckle (0.2%) noised image

Fig.4. Unsharp masking with gaussian filters

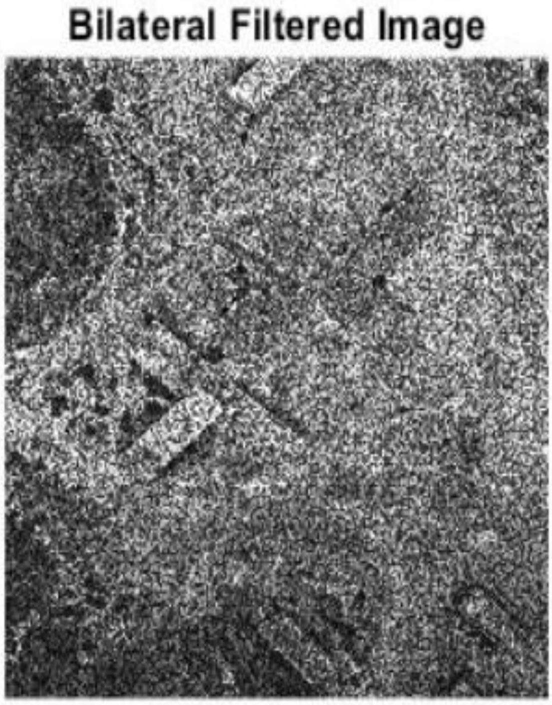

Fig.5. Unsharp masking with bilateral filters

Fig.1. shows the aerial photograph Table I represents the results of mean value for the noises mentioned at different levels. Speckle noise, salt and pepper noise and Gaussian noise are applied on the input aerial photograph at different noise density levels, unsharp masking embedded with Gaussian and bilateral filters are used to restore the image.Table II, Table IV are listed with the values of filtering for three noises in the image for different noise levels.

Table-I: Mean Value of Unsharp Images for Various Noises

Noise Type	Speckle		Salt & Pepper		Gaussian	
Noise Level	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*
0.2	0.1799	0.1872	0.1375	0.1467	0.0502	0.0549
0.4	0.1108	0.152	0.0601	0.0658	0.0341	0.0359
0.6	0.0845	0.0878	0.0300	0.0322	0.0267	0.0273
0.8	0.0712	0.0740	0.0124	0.0139	0.0209	0.0233

Table-II:SSIM Value of Unsharp Images for Various Noises

Noise Type	Speckle		Salt & Pepper		Gaussian	
Noise Level	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*
0.2	110.429	112.991	111.087	111.400	117.225	119.733
0.4	109.870	112.661	114.963	115.333	119.404	121.442
0.6	110.286	112.974	119.084	119.519	120.589	122.380
0.8	110.814	113.332	123.147	123.420	111.230	122.832

Table-III:Entropy Value of Unsharp Images for Various Noises

Noise Type	Speckle		Salt & Pepper		Gaussian	
Noise Level	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*
0.2	7.7131	7.6371	6.7039	6.7565	6.4235	6.2286
0.4	7.5319	7.3832	5.7002	5.7466	5.4690	5.2644
0.6	6.9885	6.8066	4.4551	4.4865	4.9183	4.7216
0.8	6.5603	6.3641	2.9638	2.9800	4.5433	4.3512

Table-IV:IEF Value of Unsharp Images for Various Noises

Noise Type	Speckle		Salt & Pepper		Gaussian	
Noise Level	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*	*Gaussian Filter*	*Bilateral filter*
0.2	0.6636	0.743	0.9885	0.9933	0.8095	0.8566
0.4	0.7416	0.8055	0.996	0.9982	0.872	0.9061
0.6	0.7793	0.8337	0.9982	0.9994	0.8994	0.9278
0.8	0.8029	0.851	0.9993	0.9998	0.9157	0.9402

IV. DISCUSSIONS

This proposed unsharp masking based on Gaussian and bilateral filters are evaluated with the aerial image under various noises with different noise levels. In this context, four quantitative metrics were used to compare the performance of the filters and listed in the above tables. IEF, SSIM and mean should be high if the denoising algorithm is better in removal of noises in the image whereas lower the value of entropy represents the better would be the filtering on noises. Table I shows the evaluated mean values of the denoised image for noises mentioned. For noise level of 0.2 through 0.8, mean values for the bilateral filtering is observed in performance than the Gaussian filtering in the unsharp masking framework. Table II represents the SSIM values for the three noises considered, the performance of bilateral and Gaussian filtering observed and prior method achieves good in position. Against the noises, the entropy measurement shows the bilateral filter with unsharp masking as forerunner to Gaussian filtering in the unsharp masking from the table III. The same continued in the table IV which depicts the calculation of IEF for the techniques discussed and bilateral filtering in the unsharp masking framework outperforms the Gaussian based one.

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V. CONCLUSIONS

In this article, Bilateral filtering based unsharp masking system is put forwarded to denoise the aerial photograph with different noise levels. Three different types of noises considered to study the performance of the restoration algorithms in the experiments. Unsharp masking embedded with Gaussian and bilateral filters are compared to evaluate the denoising performance for these noises. Though many recent versions in modified bilateral filtering proposed to tackle the noises in image denoising applications, it is an attempt to study the performance of standard smoothening models into theunsharp framework with bilateral filter. In the performance measurement metrics, in the view of comparison, mean, entropy, Image enhancement factor (IEF) and structural similarity index (SSIM) values of noisy and denoised images calculated. Unsharp masking embedded with bilateral based image smoothening claims better results than the Gaussian based unsharp masking framework. All these simulationstests conducted with weighting function of 0.5 in unsharp masking step. Contrast level of image may be improved on this weighting function by varying to maximum of 1. To further improve the proposed system, it can be extended to remote sensing images with different restoration algorithms, also hardware implementation wise performance need to be analysed for VLSI based platforms.

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