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Image Filtering Noise Removal with Speckle Noise

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***Abstract*— The main purpose of this paper is a brief study about the cause of the noise in the image and the removal technique of the noise from the noisy image. Images are often degraded by the noises. Noise removal is an important task in digital image processing technique. In general noise removal technique has a strong influence on the improvement of the image quality. In the field of noise reduction several linear and non-linear techniques are proposed. Linear filtering technique has a disadvantage because it is not able to effectively eliminate impulse noise as they have a tendency to blur the edges of the image. But non-linear techniques are effectively able to handle the impulse noise.**

***Index Terms*—Noise, formatting, image, Liner filtering, non-liner filtering.**

I. INTRODUCTION

Image enhancement is very important field in image processing. It is important to reduce noises from the images before extracting some features. There is no general theory of image enhancement.[2] When an image is processed for visual interpretation, then the viewer is the best judge of how well a particular method works.[3] A certain amount of trial and error is required before a particular image enhancement approach is selected.

Medical images, Satellite images are usually degraded by noise. Noise is the error which is caused in the image acquisition process, effects on image pixel and results an output distorted image. Noise reduction is the process of removing noise from the signal. Sensor device capture images and undergoes filtering by different smoothing filters and gives processed resultant image. All recording device may suspect to noise. The main fundamental problem is to reduce the noises from the color images.[4] The image analysis process can be broken into three parts which are preprocessing, data reduction, and features analysis. There may introduce noise in the image pixel mainly for three types, such as- i) Impulsive Noise ii) Additive Noise(Gaussian Noise) iii) Multiplicative Noise(Speckle Noise).[14]

Noise removal is an important task in Image Processing. This section offers some ideas about various noise reduction techniques. Depending on nature of noise, such as Additive or Multiplicative Noise, there are several approaches for removal of noise from an image. Multiplicative noise is generally more difficult to remove from the images than additive noise because the intensity of the noise varies from the signal intensity (e.g. Speckle Noise). Traditionally this is achieved by Linear Processing such as Wiener Filtering.[1] Synthetic Aperture Radar (SAR) imagery uses microwave radiation so that it can illuminate the surface earth. It provides its own illumination technique. It is not affected by the cloud cover or radiation in solar illumination.[3]

II. SOURCES OF NOISE IN DIGITAL IMAGES

The main source of noise in digital image processing arises during the image acquisition process (sampling and digitization) or image transmission. Noise is usually measured by the percentage of the corrupted image pixel. There are several reasons to add noise in the original image depending on how the image has been created. The reasons are:

I. If the image is scanned from a photograph made on film, the film grain is a source of noise. Noise may also be the result of damage to the film, or be introduced by the scanner itself.
II. If the image is captured in a digital format directly, then the mechanism for gathering (the data) may introduce noise.
III. Electronic transmission of image data can make noise.
IV. If the device sensor is not properly opened, then the emitted light from the object cannot enter into the device lenses and that's why noise is introduced into the image. Sensor temperature and light levels are major factors in making a noise.[13]
V. Dynamic range is a parameter which is used in mapping a 3D view in the image plane. If this range is high then the light intensity is scattered into a wide region which makes the picture noisy and if the dynamic range is small then more intensity is gathered on the pixels which also make the picture noisy.

III. MATHEMATICAL MODEL OF SPECKLE NOISY IMAGE

Mathematically noisy image can be represented as

$$V(x,y) = g[f(x,y)] + \eta(x,y) \dots \dots (1)$$

$$g[f(x,y)] = \iint h(x,y;x',y')f'(x',y')dx'dy' \dots \dots (2)$$

$$\eta(x,y) = u[g(f(x,y))]\eta 1(x,y) + \eta 2(x,y) \dots \dots (3)$$

Here $f(x,y)$ represents captured original image (object pixel) $V(x,y)$ is the observed degraded image, $h(x,y;x',y')$ represents the impulse noise of the image acquiring process and $\eta(x, y)$ represents input additive noise which has an image dependent random components $\eta 1(x, y)$ and an image independent random component $\eta 2(x, y)$. A different type of noise in the coherent imaging of objects is called Speckle Noise. Speckle Noise can be modeled as:

$$V(x, y) = f(x, y)s(x, y) + \eta(x, y) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where speckle noise intensity can be represented as $s(x, y)$.

Noise in Ultrasound Images: Ultrasound imaging systems are widely used mainly in the modern medical diagnostic tool to visualize the muscles, internal organs of the human body, size and structure and injuries properly. In an ultrasound imaging speckle noise shows its presence in the visualization process.

Noise in Synthetic Apertures Radar (SAR) images:

Synthetic Aperture Radar (SAR) technique is very much popular because of its ability to penetrate through clouds and soils under various weather conditions. Speckle noise is referred as the difference between a measurement and the true mean value. Degraded image can be mathematically expressed as $d(X, Y) = I(X, Y) * S(X, Y)$

Where $d(X, Y)$ is the degraded image, $I(X, Y)$ is the original image, $S(X, Y)$ is the speckle noise. (X, Y) represents the particular pixel location. The multiplicative nature of the speckle complicates more the noise reduction process.

Speckle Noise (Multiplicative Noise):

Some random values are multiplied with the image pixel value in the Speckle Noise. Speckle Noise is a major problem in some radar application. One of the main shortcomings is the poor quality of the image and affects the tasks of individual interpretation and diagnosis. Speckle noise can be expressed as J=I + n*I where J is the distribution speckle noise image, I is the input image, n is the uniform noise image by mean σ and variance v.

Many filters have been developed to improve the image quality by conserving the intrinsic scene features and texture.[13] Existing filtering technique such as mean, median filtering techniques remove the Speckle noise to some extends.[5]

A median filter mainly used in the photographic application which changes the image intensity mean value if the spatial noise distribution in the image is not symmetrical within the window. It follows some basic steps-

1. Consider each pixel in the image.
2. Sort the neighboring pixel value based upon their intensities.
3. Calculate the median value of the neighboring pixels. If the neighboring pixel of image which is to be consider contain an even numbers of pixel, then the average of the two middle pixel value is used to replace.
4. Replace the original value of the pixel with the median value from the list.

Functioning of median filter is similar to the averaging filter. It is used to reduce the amount of intensity variation between one pixel and the other pixel. Each pixel values are replaced with the median value of the neighborhood pixels. The response of the mask of the median filter is determined by a value that divides the pixel-values into two equal sorted parts, each part may contain some groups of equal values too.[9] As speckle noise is produced by the interference of the received radar waves, it may not comply with this phenomenon, rather it may like that the actual value of the noisy pixel should have the value nearer to some values those are closer to each other surrounding the center of the mask. That's why it does not reach satisfactory level.[11]

To remove these difficulties different variations of median filters have been developed for the better results. Wiener Filter was adopted for filtering purpose. It is appropriate in the Spectral domain. The wiener function applies a Wiener filter (a type of linear filter) to an image adaptively.[2] If the variance is large, wiener performs little smoothing and if it is small then it performs more smoothing. Wiener works best when the noise is constant power additive noise. But in the classical domain Wiener Filter is not adequate as it is designed primarily for the supression of the additive noise. It enhances the Signal-to-noise ratio while conserving the edges and lines in the image. Speckle noise is a high frequency component of the image. It appears in wavelet coefficients. [7]Therefore, a new technique is necessary which reduce Speckle by observing the neighbor pixel values. Recently many modern technologies are developed in reducing the Speckle noise using the wavelet transform as a multi-resolution image processing tool.

Speckle Noise Reduction and Enhancement of SAR and Ultrasound Imaging:

- Noise Reduction in Speckle Noise: Speckle noise reduction in SAR images can be reduced in the following steps which are described as below:

1) Do the modeling of the original image $f(m, n)$ with the probability density function

$$\frac{P(f(m,n))}{f'(m-x, n-y)} = e^{\left(-\log\left(1+\eta^2(f(m,n), f')\right)\right)}$$

$$e^{\left(-\log\left(1+\eta^2(f(m,n), f')\right)\right)} = \left(\frac{1}{\rho^2}\right)\sum_{(x,y)}\left(f(m,n) - f'(m-x, n-y)\right)^2$$

Where

2) Do the estimation of the mean μ and variance σ^2 using the mathematical model.

$$\mu = \frac{\sum_{l=1}^{\infty} \omega^l z^l}{\sum_{l=1}^{\infty} \omega^l} \quad \text{and} \quad \sigma^2 = \frac{\sum_{l=1}^{\infty} \omega^l (z^l - \mu) * (z^l - \mu)}{\sum_{l=1}^{\infty} \omega^l}$$

where

$$\omega^l = \frac{(p(z^l))}{(q(z^l))},$$

p(z) is the estimation of non-Gaussian Probability Density Function, q(z) is the sampler PDF that includes non-zero support of target PDF. Infinity (∞) is the samples drawn from

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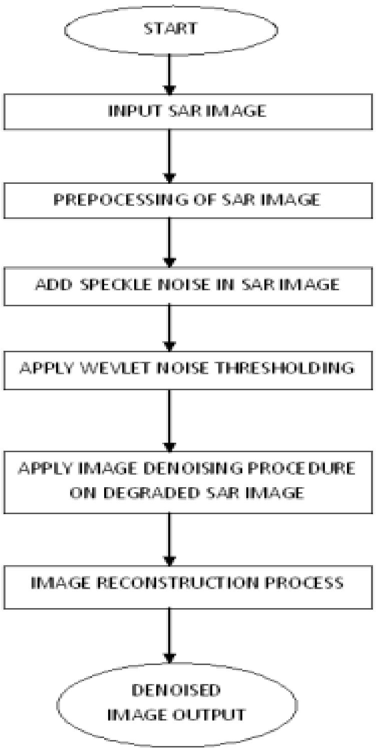
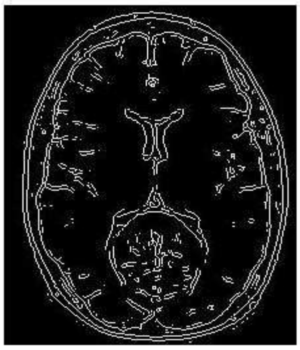
the sample PDF "q" which concentrate on the points where $p \geq q$. When $q \geq p$ we can use samples from q to determine estimation under p.

3) Incorporate the observed noise model as: $\frac{X(m,n)}{(m,n-1)} = [\mu, 1]^T$ and $\frac{P(m,n)}{(m,n-1)} = [\sigma^2]$
4) Calculate sigma points as: $\frac{Y(m,n)}{(m,n-1)} = X^x \frac{(m,n)}{(m,n-1)} * (m,n-1)$
5) Apply the measurement model on each and every sigma points.

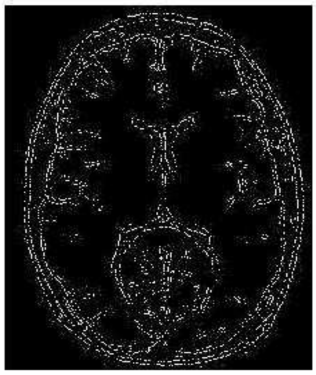
- Noise Reduction in Ultra Sound Images: Steps for the speckle noise reduction in ultra sound images are carried out as below:
  a. Construct Multiplicative Noise Model.
  b. Do the transformation of Multiplicative Noise Model.
  c. Do Wavelet transform of noisy image.
  d. Calculate variance of noise.
  e. Calculate weighted variance of signal.
  f. Calculate threshold value of all pixels and sub band coefficient.
  g. Take inverse DWT to do the despeckling of Ultrasound images.
  h. Calculate PSNR (peak signal to noise ratio) for the evaluation of the algorithm.



Original Image



Speckle Noise Image



IV. PROPOSED ALGORITHM

In this proposed algorithm, the pixel values within the mask should be in ascending order. Then calculate the average of the pixel values in the mask. [10]Then we have to select the higher or lower priority of the pixel and normalized by the corresponding distance between the computed average value and the highest or lowest value of the pixels. The mask response depends on the higher priority of the pixel value. In general, the noisy pixels have higher value, so it gets higher priority and then remove the noise from those pixels by using the filtering technique. [8]

Step 1: Sort the pixel value in the ascending order by using the mask operation.

Step 2: Calculate the average pixel value within the mask (Aavg).

Step 3: Calculate the difference between each pixel and the calculated average value. Dl represents the difference between the average value and the lowest pixel value. Dh is the difference between the higher pixel value and the average value.

Step 4: For each value of the mask,

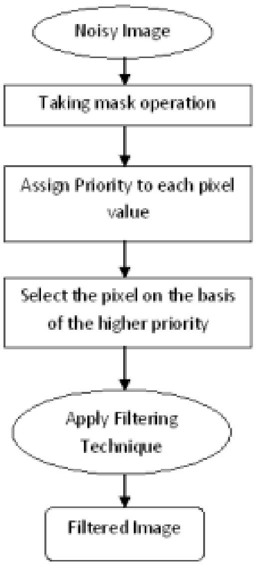
If the present pixel value Gc is less than the average value then the priority will be calculated as $\frac{G_c - G_{min}}{D_l}$.

If the present pixel value Gc is less than the average value then the priority will be calculated as $\frac{G_{max} - G_c}{D_h}$.

Step 5: Make the priority table and choose the higher priority.

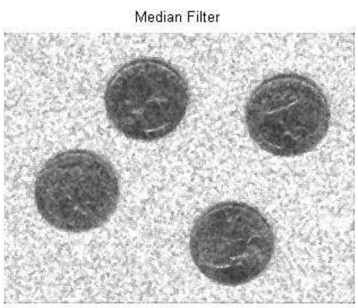
Step 6: The response of he filter with filter mask is the pixel value corresponding to the higher priority.

V. FLOWCHART OF THE PROPOSED ALGORITHM



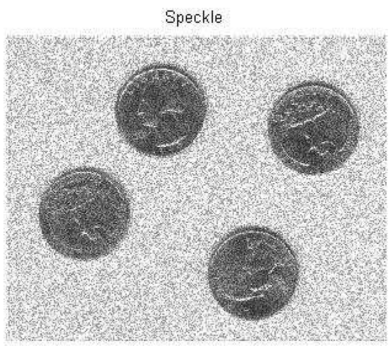
VI. REMOVING SPECKLE NOISE FROM IMAGES BY FILTERING

Constructive or destructive light or dark pixels known as Speckle noise can be observed in the Radar Waves (microwave or millimeter wave).[5]Speckle noise may appear in the remotely sensing image such as a light emitted from the laser, an active sensor, and passes in phase and reach their target area interacting with other obstacles in their way. If the light travels in out of phase condition then the light or bright pixels are appeared. These pixels are Speckle noisy image. Ideally speckle noise should be completely removed from the remote sensing image. But complete reduction is not possible.[2] Idle Speckle filtering technique is an appropriate method that can be used to reduce the speckle noise and to preserve the radiometric information and to enhance the signal-to-noise ratio while preserving the edges and the lines in the image between different areas and spatial signal variability, i.e. textural information. Generally Speckle noise can be reduced by using the multi-look processing or spatial filtering. Spatial filters can be divided into two parts: a) Non-Adaptive b) Adaptive. Non-adaptive filter takes the parameters the whole image signal into consideration and leaves out the local properties of the terrain backscatter or the nature of the sensor.[3] Fast Fourier Transformation (FFT) is an example of such filtering technique. On the other hand, adaptive filters accommodate changes in the local properties of the terrain backscatter as well as the nature of the sensor. Speckle noise is a high-frequency component of an image and appears in Wavelet transform as a multi-resolution image processing tool. Recently many techniques have been proposed to reduce the speckle noise.[1] Jain developed Wavelet Shrinkage Filtering method, a homomorphic approach, comparative study between wavelet coefficient shrinkage filter and several standard speckle filters that are being largely used for speckle noise suppression. It has several steps: a) Firstly take logarithm of an image. b) Translates the multiplicative noise into additive noise. c) Consequently apply Wiener Filtering Technique.



Speckle filtering technique is based on mathematical approach and applied on the image pixel by using the mask operation. In the mask based technique, the mask is applied on the centered pixel value and is shifted along the image by only one pixel at a time until the whole image is covered. By applying these filtering techniques,[4] smoothing effect and speckle noise reducing is achieved to a certain extent.

Median Filter: A median filter is a kind of powerful non-linear filter mainly used in the photographic application which changes the image intensity mean value if the spatial noise distribution in the image is not symmetrical within the window and also removes the pulse or spike noise.[5] Functioning of median filter is similar to the averaging filter.



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Matlab Code:

```
I1=imread('coin.jpg');
figure, imshow(I);
title('Original');
I=rgb2gray(I1);
J=imnoise(I,'speckle',0.02);
figure, imshow(J); title('Speckle');
L=medfilt2(J);
figure, imshow(L);title('Median Filter');
```

Lee Filter: Lee filter is mainly used to reduce the speckle noise basis on the assumption that the mean and variance of the local pixel is equal to the local mean and variance value. The formula for the Lee filter for speckle noise reduction is given as:

$$R'(t) = I(t)W(t) + I'(t)\left(1 - W(t)\right)$$

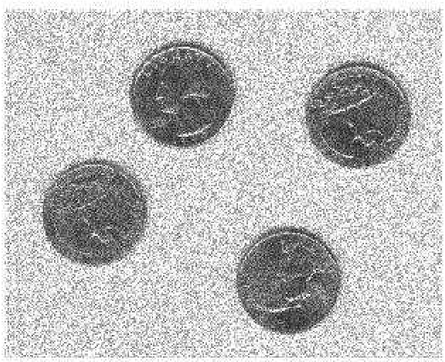
Where $W(t) = 1 - \frac{C_u^2}{C_I^2(t)}$ is the weighted function and $c_u = \frac{\sigma_u}{u}$, $c_I(t) = \frac{\sigma_I(t)}{I(t)}$

Kaun Filter: Kaun filter is much better than the Lee filter because of transformation of multiplicative noise model into single dependent additive noise model.[14] It has the same form of the Lee filter but there is a difference of weighting function which is given as:

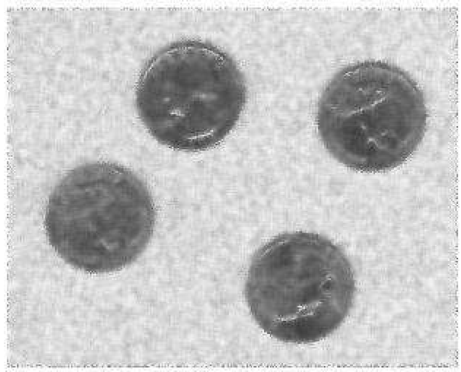
$$W(t) = \frac{1 - \frac{c_u^2}{c_I^2(t)}}{1 + c_u^2}$$

Wiener Filter: Wiener filtering technique is proposed by N.Wiener in 1942. It is a linear filter applied to an image adaptively using the local image variance.[5] If the variance is large then it works little smoothing and when the variance is small then it works well. Wiener filter technique has more time to compute than linear filtering technique.

Speckle



Wiener filter



VII. PERFORMANCE PARAMETER

For comparing original image and uncompressed image, we calculate following parameters:

A. Mean Square Error (MSE): The MSE is the cumulative square error between the encoded and the original image defined by:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left\|f(i,j) - g(i,j)\right\|^2$$

Where f is the original image and g is the uncompressed image. The dimension of image is m X n. Thus MSE should be as low as possible for effective compression.

B. Peak Signal to Noise Ratio (PSNR): PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined as:

$$PSNR = 20\log_{10}\left(\frac{MAXf}{\sqrt{MSE}}\right)$$

Where MAXf is the maximum signal value that exists in our original "known to be good" image.

C. Bit Per Pixel: It is defined as number of the bits required to compress each pixel. It should be low to reduce storage requirement.

D. Signal to Noise Ratio(SNR): It is defined as the ratio between a signal and the background image. SNR=Psignal/Pnoise , where P is the average power. Both noise and power must be measured at the same points in a system and within system with same bandwidth.

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