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Empirical Study of Various Speckle Noise Removal Methods

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Abstract: In restorative picture transforming, picture denoising has turn into an exceptionally vital practice all through the diagnose. Lessening commotion from the restorative pictures, a satellite picture and so on is a test for the analysts in advanced picture transforming. A few methodologies are there for clamour decrease. By and large dot clamour is generally found in manufactured opening radar pictures, satellite pictures and medicinal pictures. In this paper a review on different speckle noise removal techniques is done.

Keywords: Speckle, SAR, Frost, Lee, Wavelet

I. Introduction

The field of picture preparing concentrates on mechanizing the procedure of social affair and transforming visual data. While transforming or acquiring the images, the quality of the image gets degraded by noise. The performances of imaging sensors are affected by variety of factors such as environmental conditions during image acquisition and by quality of the sensing elements themselves. Image restoration attempts to reconstruct or recover an image that has been degraded by noise or the photometric reasons.

Noise can be multiplicative and additive. Additive noise is systematic in nature and can be easily modeled and hence removed or reduced easily. Whereas multiplicative noise is image dependent, complex to model and hence difficult to reduce. Additive noise is the noise which adds up in the original image. Multiplicative noise is the noise which multiplies with the original image. Different types of noises are Gaussian noise, Salt & Pepper noise, Speckle noise and Poisson noise.

II. Speckle Noise

Speckle noise happens when a sound wave beat haphazardly interferes with little particles or protests on a scale tantamount to sound wavelength. Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images.

Speckle noise in conventional radar results from random fluctuations in the return signal from an object that is no bigger than a single image-processing element. It increases the mean grey level of a local area. Speckle noise in SAR is generally more serious, causing difficulties for image interpretation. It is caused by coherent processing of backscattered signals from multiple distributed targets.

Features of Speckle Noise:

- i) Speckle noise in SAR is a multiplicative noise, i.e. it is in direct proportion to the local grey level in any area.
- ii) The signal and the noise are statistically independent of each other.
- iii) The sample mean and variance of a single pixel are equal to the mean and variance of the local area that is centred on that pixel. [1],[2],[6].

III. Need for filtering

Speckle noise degrades the quality of Ultrasound (US), Synthetic aperture radar (SAR), scanned and photographic images and thereby in Ultrasound and SAR images reducing the ability of a human observer to discriminate the fine details of diagnostic examination. Hence images with speckle noise will results in reducing the contrast of image and difficult to perform image processing operations like edge detection.

IV. Filtration techniques

Several different methods are used to eliminate speckle noise, based upon different mathematical models of the phenomenon. One method, for example, employs multiple-look processing, averaging out the speckle noise by taking several "looks" at a target in a single radar sweep. The average is the incoherent average of the looks.

A second method involves using adaptive and non-adaptive filters on the signal processing (where adaptive filters adapt their weightings across the image to the speckle level, and non-adaptive filters apply the same weightings uniformly across the entire image). Such filtering also eliminates actual image information as well, in particular high-frequency information, and the applicability of filtering and the choice of filter type involves tradeoffs. Adaptive speckle filtering is better at preserving edges and detail in high-texture areas (such as forests or urban areas). Non-adaptive filtering is simpler to implement, and requires less computational power.

There are two forms of non-adaptive speckle filtering: one based on the mean and other based upon the median (within a given rectangular area of pixels in the image). The later is better at preserving edges whilst eliminating noise spikes, than the former is. There are many forms of adaptive speckle filtering including the Weiner filter, the Lee filter and the Frost filter. [1],[2],[6].

A. Median Filter:

The best-known order-statistics filter is the median filter, which, as its name implies, replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel. The original value of the pixel is included in the computation of the median. Median filters are quite popular because, for certain types of random noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Median filters are particularly effective in the presence of both bipolar and unipolar impulse noise. A major advantage of the median filter is that the median filter can eliminate the effect of input noise values with extremely large magnitudes. The output y of the median filter at the moment t is calculated as the median of the input values corresponding to the moments adjacent to t .

$$y(t) = \text{median} \left(x \left(t - \frac{T}{2} \right), x(t - T_1 + 1), \dots, x(t), \dots, x \left(t + \frac{T}{2} \right) \right).$$

where t is the size of the window of the median filter. [6]

B. Wiener filter:

Wiener filter also known as least mean square filter. Wiener filter proposed in the year of 1942 is adaptively applied on the image according to the local image variance. It minimizes the overall mean square error in the process of inverse filtering and noise smoothing. It is the linear estimation of the original image. If the variance is small, wiener performs smoothly; if the variance is large then the wiener performs less smoothly. It works best both in additive and multiplicative noise.

Wiener Filter in Fourier Domain:

$$G(u, v) = \frac{H^*(u, v)P_s(u, v)}{|H(u, v)|^2P_s(u, v) + P_n(u, v)}$$

where

$H(u, v)$ = Degradation function

$H^*(u, v)$ = Complex conjugate of degradation function

$P_n(u, v)$ = Power Spectral Density of Noise

$P_s(u, v)$ = Power Spectral Density of un-degraded image

The term P_n/P_s can be interpreted as the reciprocal of the signal to noise ratio. [6]

C. Frost Filter:

The Frost filter is an adaptive filter that uses a negative exponential distribution for the speckle noise and local image statistics for filtering process. This filter gives weights for each cell by using local image statistics i.e. calculated locally for each filter window. The weight for a cell depends on the distance from the center cell. Weighting factor decreases with distance from pixel of interest and increases as variance with kernel increases. In order to minimize the mean square error of the signal estimate this filter performs a weighted average of the

cell values in the filter window, with the weights for each cell. It replaces the pixel of interest with a weighted sum of all values within $n \times n$ moving kernel. The filter therefore smoothes more in homogeneous areas because the center cells are heavily weighted as the variance in filter window increases, but provides a signal estimate closer to the observed value of the center cell in heterogeneous areas. The formula used for Lee filter is:

$$DN_{out} = [Mean] + k[DN_{in} - Mean]$$

Where Mean = Average of pixels in moving window

$$K = \frac{Var(x)}{[Mean]^2 \sigma^2 + Var(x)}$$

and

$$Var(x) = \left(\frac{[Variance\ within\ window] + [Mean\ within\ window]^2}{[Sigma]^2 + 1} \right) - [Mean\ within\ window]^2$$

D. Lee filter:

Unlike Frost filter the Lee filter uses a least-squares approach to estimate the true signal strength of the center cell in the filter window from the measured value in that cell, the local mean brightness of all cells in the window, and a gain factor is calculated from the local variance and the noise standard deviation and assumes a Gaussian (normal) distribution for the noise values, and calculates the local noise standard deviation for each filter window. In general term it replaces the pixel of interest with average of all Digital Number values falling within that range. The Lee filter calculation produces an output value close to the original input value in higher contrast regions and a value close to the local mean for uniform areas. In uniform areas more smoothing occurs. The formula used for Lee filter is:

$$Dn = \sum_{m \times n} k \alpha e^{-\alpha |t|}$$

$$\alpha = \left(\frac{4}{n \sigma^{-2}} \right) \left(\frac{\sigma^2}{I^{-2}} \right)$$

Where

V. Applications

The speckle effect is used in Astronomy, Medical, Radar data, Satellite images and many more.

VI. Conclusion

After studying the above Speckle Noise reduction techniques researches show that Wiener filter is best suited for removal of Speckle Noise. In future work we will propose and implement a novel filter after working on the disadvantages and advantages of the existing techniques.

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