Design of Hybrid Filter with Wavelet denoising and Anisotropic Diffusion Filter for Image Despeckling

Simranjit Kour
Department of Computer Science & Engineering, Chandigarh Engineering College, Landran Mohali, India

Bikrampal Kaur, Ph.D.
Department of Computer Science & Engineering, Chandigarh Engineering College, Landran, Mohali, India

ABSTRACT
Images are electronic snapshots of a scene or scanned from documents, photographs, manuscripts, printed texts, and artwork. Images when digitized are sampled and mapped as a grid of dots or picture elements (pixels). Different types of noises get introduced in the image, out of which speckle noise removal is considered fairly difficult. A lot of filters were created which basically worked on enhancing the quality parameters of the image, like Coefficient Of Correlation, Peak signal-to-noise ratio and Equivalent Number of Looks. Out of these models, Wavelet denoising, Lee, Frost and Kuan filters were quite famous. However, none were able to preserve the original image quality, as they required either removal of edges or over-smoothing for denoising the image. The objective of this paper is to work on the drawbacks of earlier models, and propose a modern approach to de-speckling an image by creating a hybrid filter which uses two different filtering techniques: wavelet denoising and anisotropic diffusion filter, to de-speckle the image without considerable removal of edges or causing over-smoothing.

General Terms
Noise filter, Speckle noise

Keywords
Digital image, despeckling, wavelet transform, anisotropic filter

1. INTRODUCTION
A digital image is a representation of a two-dimensional image as a finite set of digital values also termed as picture elements or pixels. Pixel values of an image represent the gray levels, colors, heights etc. Once an image is digitized, various operations can be applied on it for improving its quality. The unwanted particles or an electrical signal in image which degrade its quality form noise. Noise can be detected by the presence of dots formed due to the real signals getting corrupted by noise. Various methods were proposed in order to denoise the image. A good denoising model preserves edges while removing noise from the image. Models such as linear or 2nd order Partial Differential Equation model have been used traditionally which use Gaussian filter for noise removal. Linear model has a few drawbacks like it is not able to fully preserve edges which are present as discontinuities in the image. On the other hand, nonlinear models can handle edges in a better way while denoising. Out the various types of noises in a digital image, for example: impulse noise, Gaussian noise, shot noise, anisotropic noise etc., multiplicative noise is considered hardest to remove. It is present in the form of unwanted random signal that gets multiplied into some relevant signal during capture, transmission, or other processing therefore making it hard to detect. In the next section different types of noises have discussed.

2. TYPES OF NOISE
Noise is the one of the major problem in every imaging system. Noise may occur due to the following reasons:

- Physical nature of the system
- Due to image acquisition devices
- Due to the environment
- Image developing mechanism

There are basically three types of primary noises: random, fixed pattern and banding:

Random noise increases the intensity of the image. Intensity change occurs through color discrepancies. Random noise is hardest to get rid of because of its unpredictable nature.

Fixed pattern noise includes "hot pixels," which are formed when a pixel's intensity surpasses that of the random noise fluctuation. Fixed pattern noise is created during long exposures and is worsened by high temperature.

Banding noise is camera dependent noise which is introduced by camera while it reads the data from digital sensor. During the data processing steps, factors like shadows, photo brightening and high speeds also create banding noise.

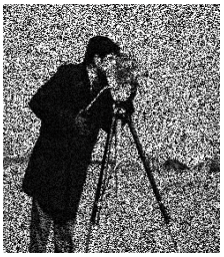
Speckle noise is a result of random fluctuations in return signal from an object in radars. Usually the object is not bigger than a single image-processing element. It is known to increase the mean grey level of local area in an image and is responsible for causing difficulty in image recognition.

In the following figure, a synthetic image is taken and speckle noise is introduced in the image with different deviations. The speckle noise as it can be seen is granular in nature and increases with increased deviation.

Original Image

Noisy image

(0.5 deviation)



Noisy image

(0.75 deviation)

3. SPECKLE FILTERING

Different methods are used to eliminate speckle noise. Multiple-look processing is one of the methods in which averaging of the speckle noise is done by taking several "looks" at a target in a single radar sweep. The other methods use adaptive and non-adaptive filters on the signal processing.

Adaptive filter is aimed at simultaneously suppressing speckle noise while preserving the subtle image detail of SAR images. A number of distinctive features are being possessed by adaptive filter such as use of local statistics, no change in valid values, no use of derived mean value and using only valid pixel. Adaptive speckle filtering is better at preserving edges and detail in high-texture areas (such as forests or urban areas).

Non-adaptive filtering is a new approach to filtering which is simpler to implement in comparison with adaptive filters and requires less computational power**.**

Speckle reduction filters can further be classified on the basis of whether they are window based or framed based.

3.1 Window based approach

Various filters which use window based approach are briefly explained as:

Lee filter: In this, the pixels to be filtered are replaced by a value which is calculated by using the surrounding pixels Its filtering quality depends on variance and is known for causing oversmoothing of images.

Kuan filter: This filter takes the pixels which are to be filtered and replaces with a value which is calculated based on local statistics. It is better than Lee filter as it is used to convert the multiplicative noise model in to additive linear form which makes despeckling easier. There is no estimation of noise variation in filter window. But the major disadvantage is that it depends on number of looks

Frost Filter: It uses the local image statistics in the filtering process. The limitation of this filter is that the parameters are adjusted according to variance in each area.

These techniques have similar disadvantages like, loss of edges during the despeckling and oversmoothing of the image.

3.2 Frame based approach

The above mentioned disadvantages of the window based approach were reduced by employing a more modern approach, frame based approach which is independent of the window size. In this approach, results are evaluated in terms of PSNR (peak signal to noise ratio), COC (coefficient of Correlation) and ENL(Equivalent No of looks) values. Two such filters are explained as below:

Wavelet denoising filter: In this approach, wavelet transform uses thresholding techniques to despeckle the image without causing considerable amount of oversmoothing or edge removal. Wavelets which are primarily used for filtering are actually localized waves. The term wavelet stands for a small "wave". It is independent on both space and time and is always periodic. Wavelet has become an essential tool for application domain and research.

Anisotropic diffusion filter: In anisotropic diffusion the main method is to smoothen within the region with preference to the smoothening across the edges without bias due to the filter window shape and size. this partial differential equation based removal approach allows the generation of image scales consisting of set of filtered images that vary from fine to coarse. Hence anisotropic diffusion is adaptive and it does not utilize the hard thresholds to alter performance in homogeneous areas or in region near edges and small features. It is quite edge sensitive. In anisotropic diffusion filter a conduction coefficient is set as one within the region and zero near the edges. It is applied in radar and medical imaging such as ultrasound.

4. LITERATURE SURVEY

Work done in the field of despeckling the image using different proposed filtering techniques are given as follows

Adib akl, Charles Yaacoub [1] proposed a model which produced better PSNR, COC and ENL values in comparison with earlier models such as Lee, Frost and Kuan filters individually. This filter is a hybrid of wavelet denoising filter and Kuan filter, which resulted in a gain with respect to speckle noise filters as well as simple denoising methods used earlier.

Yuan Gao and Zhengyao Bai 2008 [2] put forward a new method of speckle reduction of SAR images in curvelet domain. In this method, curvelet transform is integrated with wavelet filtering. The new method consists of five parts: preprocessing, curvelet transform (CT), curvelet coefficients processing and two inverse transforms. In the preprocessing step, Homomorphic transform is applied to convert multiplicative noise in SAR images to an additive noise which is suitable to be dealt with curvelet. After curvelet transform, curvelet coefficients are thresholded by using soft and hard thresholding functions with improved rules. In hard thresholding rule, noise variations are obtained by using noise parameter estimation. In soft thresholding rule, a classic soft thresholding function and thresholding rule used in wavelet domain is combined with curvelet. Finally, inverse CT and exponential transform are employed to reconstruct denoising image. It can be seen that the method presented in the paper is an effective one

S.Sudha et al [3] worked on wavelet-based thresholding scheme for noise reduction in ultrasound images. Comparison of the results obtained by the proposed method with the results achieved from the other speckle noise reduction techniques demonstrate its higher performance for speckle reduction in terms of peak signal to noise ratio.

Pierrick Coupe et al [4] developed a Bayesian thresholding and NL-means filter in Ultrasound images Quantitative results on synthetic images show the performances of the proposed method compared to well-established methods. Results on real Images shows that the proposed method gives better preserve accurately edges and structural details of the image.

Raman Maini and Himanshu Aggarwal [5] introduced and compared five different speckle reduction filters quantitatively using simulated imageries. The results have been presented by filtered images, statistical tables and diagrams. Filtering is one of the common methods which are used to reduce the speckle noises. Finally, the best filter has been recommended based on the statistical and experimental results in terms of PSNR.

Bibo Lu et al [6] proposed a novel SAR speckle reduction method base on nonlocal means (NLM) filter. NLM is applied to remove additive noise after taking the logarithm of the original speckle noise. The proposed method can preserve edges and protect more fine details. Results on real speckle SAR images are given and have also compared our method with some related methods.

Bala Prakash et al. [7] proposed a new technique which is independently select the filter for different types of images. In this technique a new independent filter will automatically check which filter gives better results in synthetic images, real time images, and photographic images. The results are computed through different parameters. The experimental results shows that proposed technique gives better results than other techniques.

5. PROPOSED MODEL

Hybrid filtering is a recent breakthrough in the field of despeckling images. Earlier one such model was proposed by Adibakl and Charles Yaacoub[1] in their research work on a hybrid model based on Kuan filter and wavelet denoising filter which produced better results than the earlier filters as it combined the filtering qualities of both the filters providing better Coefficient Of Correlation, Peak signal-to-noise ratio and Equivalent Number of Looks values. The proposed model uses new hybrid technique that combines wavelet based denoising and anisotropic diffusion filter. As wavelet is frame based approach, it is independent on both space and time, providing better resolution. Anisotropic diffusion filter is based on partial differential equation. It does not depend upon the window size and is based on Mean Square Error(MSME) approach. So it provides better filtering capability and enhances the edges

5.1 Proposed algorithm

The proposed algorithm can be briefly described in the following steps

1. First load the image using a MATLAB processing tool box.
2. Speckle noise is added into image and log transformation is applied.
3. Image is passed through wavelet denoising filter and Bayesian thresholding is applied.
4. Inverse wavelet transform will be applied on the threshold output, so as to extract the image. Hybrid of the anisotropic filter and wavelet will be formed.
5. Results are generated in the form of PSNR, COC and ENL.

The above steps used in the proposed algorithm can be explained in the following flowchart.

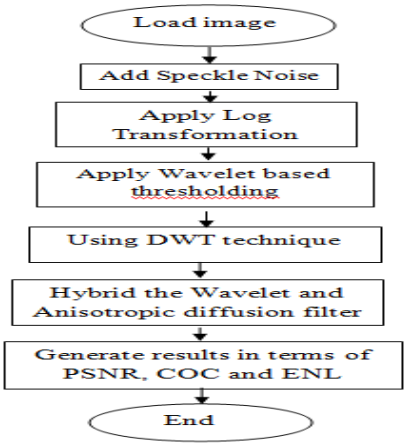


Figure 2 Basic flowchart depicting the despeckling of an image based on above algorithm

6. RESULTS

Coefficient Of Correlation, Peak signal-to-noise ratio and Equivalent Number of Looks values of different images which will be passed through the proposed filter are mentioned in the following table :

Table 1: Values of PSNR, ENL and COC for proposed model.

Cover Image	PSNR(db)	ENL	COC
Lena.png	**31**	**88.7047**	**0.351095**
Barbara.png	**31**	**46.9777**	**0.331526**
Hyderabad.png	**22**	**52.2195**	**0.13736**
Hous.jpg	**30**	**183.722**	**0.383953**
Boat.png	**30**	**118.878**	**0.472813**

7. CONCLUSION

The proposed technique will help in improving the errors which were not worked in previous models. The results show that the previous filters could not provide fully denoised images as their Coefficient Of Correlation, Peak signal-to-noise ratio and Equivalent Number of Looks values were quite low when compared to the proposed model. This model will be independent of the window size, thus avoiding oversmoothing of the image which was a major drawback in the previous models. So, an effort has been made to change from an old approach of window based filtering to a more efficient frame based approach along with the anistropic diffusion filter, based on Mean Square Error approach. The basic concept of creating a hybrid filter is to improve the overall results of both the filters which otherwise can have a few drawbacks if compared independently.

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