Design and Analysis of Denoising Framework for Overcoming Speckle Noise Footprints

Anand B. Deshmukh[a], Dr. Sanjay V. Dudul[b]

[a] Dept. of Information Technology, Sipna College of Engineering and Technology, Amravati, India
[b] Prof. & Head, Dept. of Applied Electronics, Sant Gadge Baba Amravati University, Amravati, India

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Abstract: Sudden change in the brightness and color values in the images causes introduction of noise in image and frames of the video stream. Such random variation of the brightness and color values doesn't carry any intelligence in fact, it deteriorates the quality of the image and frames in video stream. To nullify the effect of such meaningless information, denoising frameworks are designed. In this research paper we have proposed denoising framework for speckle noise, this approach is sometimes also called as de-speckling algorithm. For performance evaluation we are critically analyzing the de-speckling techniques with respect to the PSNR, MAE, and MSSIM.

Keywords: MAE, MSSIM, PSNR, Speckle Noise.

1. Introduction

The undesirable and random variation of the signal quantity in the pixels is the noise in an image. Such random variations of the pixel values are measured with respect to its neighbouring pixels. More the amount of random variation in the pixel value more is the noise added to the pixel and in fact to the image. There are different possible sources through which this noise can be added to the image. The noise may be added to the image at the time of image capturing, image enhancing and may be at the time of transmission via wireless media like wi-fi, Bluetooth or through wired media. While the image is being captured, introduction of noise is may be due to switching elements, sensor shake or camera shake, sensor misalignments and due to many other similar reasons. At the time of image enhancement, the noise gets added due to changing the ISO factors and unusual or uncalibrated use of the automated functions. On the other hand, channel interference, random variations in the environmental conditions may the possible reasons of addition of noise into an image. Same is the story about the video streams, because video stream is nothing but collection of frames and frames are images only. In order to nullify the effect of such unwelcomed factors in an image and restore the image into its equivalent normal form, certain algorithms are designed which are called as denoising frameworks.

Based on, in which pattern the noise is introduced in the image defines the type of noise. There exist different noises as Gaussian Noise, Impulse Noise, Mixed Noise, Speckle Noise and many more. In this research paper we are about to disclose the study done for introduction of the Speckle Noise in an image and in the lateral section, methodology is proposed to nullify the effect of Speckle Noise which is also termed as de-speckling.

The speckle noise is mainly observed in the synthetic images which are generated by the RADAR imaging and airborne images. So, it is obvious like it is introduced due to the random interferences caused due to the multiple return waves collected in return, after collision, from the object. It generally looks like deployment of white and black/ gray spots in an image. Through the present research work, an extensive survey is carried out to understand the previously reported technology and a new technology is proposed for de-speckling an image infected with speckle noise. For implementing the said approach, Lena, Airplane and Pepper images are used. For performance analysis, different factors like PSNR, MAE and MSSIM are used in the result and discussion section.

2. Previously Cited Technology

The process of removing the noise from the images also called as restoring or denoising or image enhancement, in case of removing the noise from image, it is also called as De-speckling. The quality of de-speckling depends on multiple factors like quality of the original image, how harshly the noise infected the image and the type and characteristics of filter which is used for denoising.

Elimination of noise in images is a growing technology in the field of digital image processing. Many noise removal algorithms are available to remove random noises which corrupt the images during processing. In digital images, the most common types of noises that frequently occur are Gaussian noise, impulsive noise and speckle noise. Different linear and non-linear algorithms are developed by the researchers to eliminate such kinds of noises. The proposed technique **(Tufan Sadhukhan et. al., 2019)** in, is able to reduce the square mean error by splitting the real picture into hue, saturation and intensity components. The modified median filtering technique further eliminates the noisy components and increases the peak signal to noise ratio and signal to noise ratio for the noise free images.

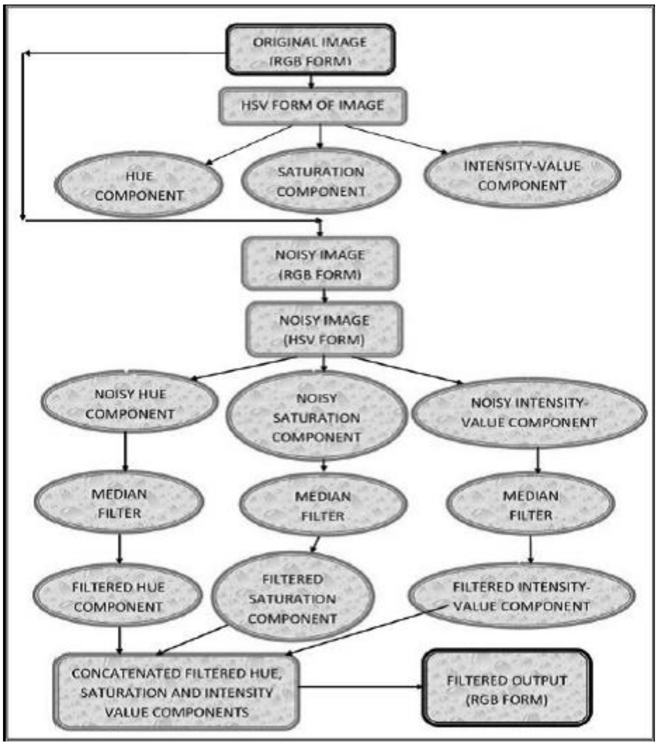

Figure 1: Flowchart of filtering technique

Any indiscriminate dissimilarities of information in pictures are defined as noise. Noise may appear due to a random increase or decrease in brightness and darkness in a picture. Bhawna Dhruv et. al. analysed the performance and effectiveness of different filtering methods such as median filter, average filter and adaptive wiener filter based on processing speed and entropy **(Bhawna Dhruv et. al., 2017)**. Each filtering method is applied on the image corrupted by four different types of noises like Gaussian, salt and pepper, Poisson and speckle noise for the elimination of noise. The results show that filtering methods act differently for individual noise. It is analysed that; median and Wiener filters processing speed is fast when compared with average filter. Also, for all the three-filtering methods speckle noise shows the best entropy.

Maryam Mohammadi and Reza Mokhtari proposed an equation for nullifying the effect of the speckle noise using region indicator. For better reproduction of the image, particularly the edges of the image, innovatively, gaussian convolution is used in the indicator. For removing noise, non-linear filter is used this helps to remove noise at better level while preserving the original contents of the image. **(Yi Zhou et. al., 2021)** experienced that the images generated from optical coherence tomography that is OCT are poor in quality and are challenging for analysis. This is because of introduction of speckle noise in the image due to coherence effect. In this research paper authors **(Y. Zhou et al., 2021)** are improved model of Conditional Generative Adversarial Network (cGAN), which was previously developed by the same authors. The said model works in two steps. In the first step, the CycleGan is trained to examine the change of pattern in two OCT images and in the second stage, authors train the mini-cGAN model following the PatchGAN mechanism to nullify the speckle noise components.

(Xiaoyue Sang et. al.,2020) observed the importance of the pure image representation in the OCT technique for proper analysis and interpretations and for proper diagnosis. OCT signals are most prone to the speckle noise.

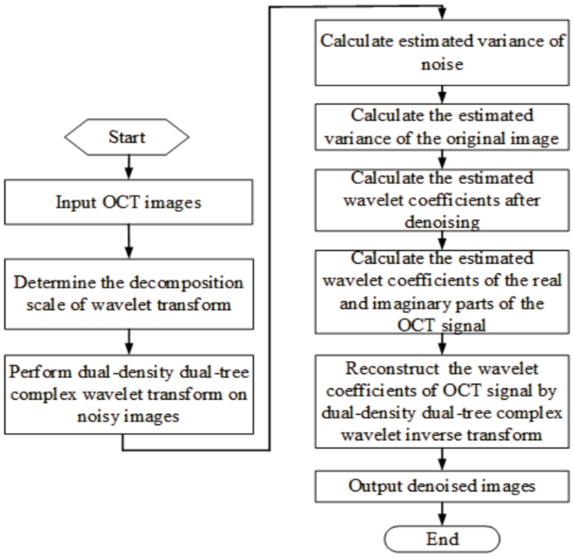

Figure 2: De-speckling by DDDT complex wavelet transform

Authors **(Xiaoyue Sang et. al.,2020)**dedicated their research work for de-speckling and also attempted critical analysis with the outcomes of varies wavelet transform based methods. In this dedicated work research scholars have disclosed dual density dual tree complex wavelet method which works with local variance estimation based bivariate contraction model for overcoming the effect of speckle noise. For implementation of the proposed work, retina, swine eye and human dental images are used as data set. As an outcome, effective de-speckling is observed while retaining the significant edge information of the OCT images.

(Yan Hu et. al., 2020) OCT is widely used for ophthalmology for diagnosis of issues related to the retina. However, introduction of speckle noise in such imaging makes the diagnosis process challenging. To resolve this issue, authors **(Yan Hu et. al., 2020)**have proposed an novel approach for 3D OCT images. This works in two steps: variance stabilizing transformation is applied to redistribute the speckle noise in to the gaussian noise and then the transformed data is decomposed and filtered in 3D Shearlet domain. Authors observed highest edge contrasts as compared to the previously reported de-speckling algorithms.

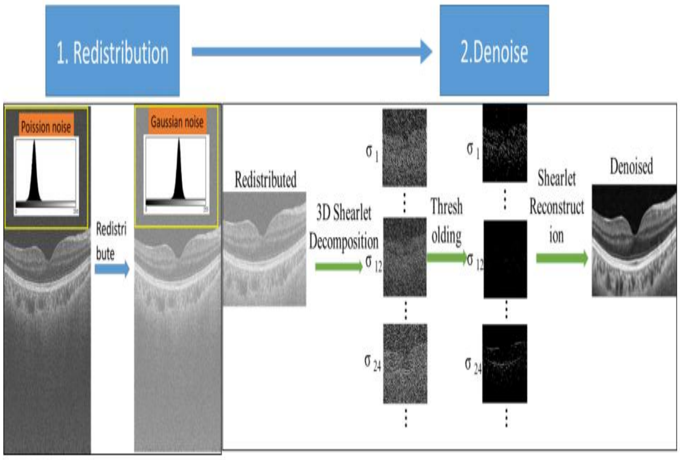

Figure 3: Proposed Denoising Framework

It is known that, the traditional filtering system can not be deployed for overcoming the effects of the mixed noise from the Color Doppler Ultrasound images, since their performance is not stable. To come out of this, authors **(M. Kumar et. al., 2020)** have proposed novel Multi-Channel Functional Link Artificial Neural Network (M-FLAN) to overcome the impact of the speckle noise from the color doppler ultrasound images. Further, performance of the proposed M-FLAN is compared with the other filters like Mean, Median, Weiner and MLP, where, better performance was observed.

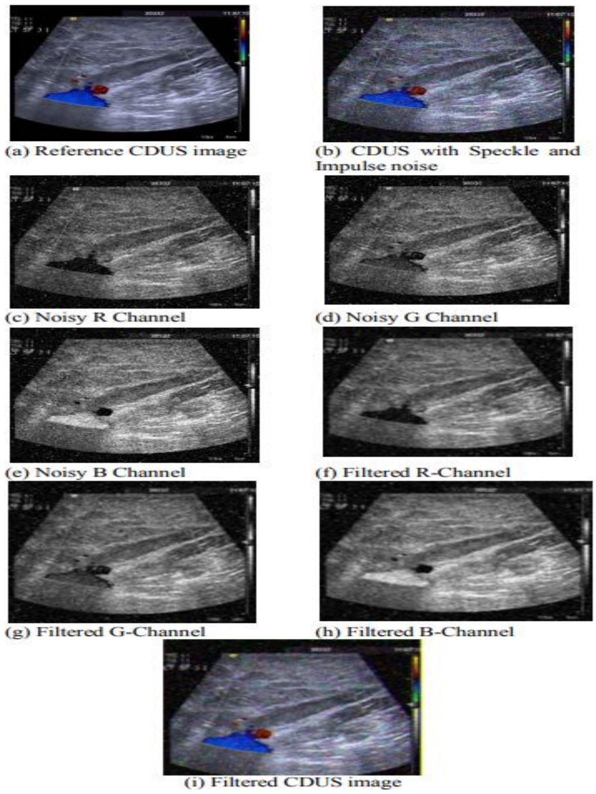

Figure 4: Denoised CDUS Images

In ultrasound images which are used in medical imaging for diagnosis of the different diseases easily get infected by the speckle noise, which upon enhancing, using different image processing algorithms, degrades the quality of the image, making the diagnosis process more challenging. **(C. A. Duarte-Salazar et. al., 2020)** discloses 27 different effective techniques for smoothing the processing of de-speckling by preserving the important information in the ultrasound image like edge and extensions.

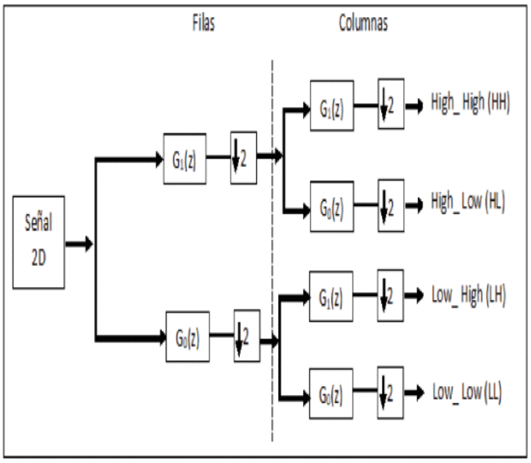

Figure 5: Wavelet Decomposition

Initially, the authors considered traditional methods like spatial filtering, diffusion filtering and wavelet filtering technique. Further, the study is enhanced by considering machine learning and deep learning fundamentals. Finally, full reference and non-reference metrics are considered for removing the speckle noise in the images.

Medical imaging and analysis is the most popular tools for diagnosis of the different diseases in the human body. During image acquisition the medical image generally gets acquainted by additional unwanted signals like speckle noise, gaussian noise, impulse noise and many other unwanted factors.

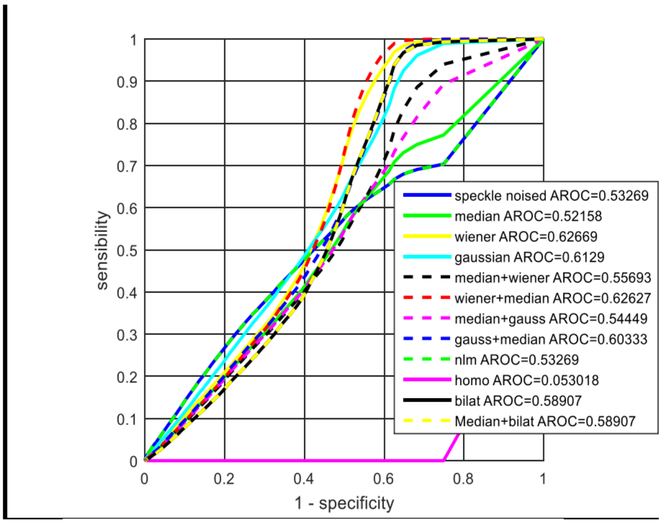

Figure 6:ROC Graph of the Proposed Scheme

This introduction of noise is due to different possibilities like, patient body position, fatness or it may be due to the sensor elements like electrical noise and sensor noise. Such additional mis-leading information in the medical image causes proper diagnosis of the disease challenging process. To overcome this situation, **(Kavitha G. and Chetana Prakash, 2020)** have proposed multi-level hybrid filtering technique for removing speckle noise. Authors used Median, Filter, Wiener Filter, NLM Filter, Homorphic Filter, Bilateral Filter and Hybrid Filter are applied for overcoming the effect of speckle noise. Further the performance is critically analyzed using PSNR, MSE, SSIM and ROC parameters.

Ultrasound imaging is the most popularly used as a source for proper diagnosis of the diseases in the human body. Such medical images get easily infected by the different noises like speckle noise. So far, professionals have reported use of different denoising algorithms using different filters and compounding techniques. **(Ahmed F. Elnokrashy, 2019)** have proposed use of motion compounding technique for de-speckling of the ultrasound images. In this process, motion estimation and compensation take place and Optimized adaptive Rood Pattern search (O-ARPS) is proposed to be used based on the original ARPS. O-ARPS Optimized for the ultrasound images and multicore processing platform.

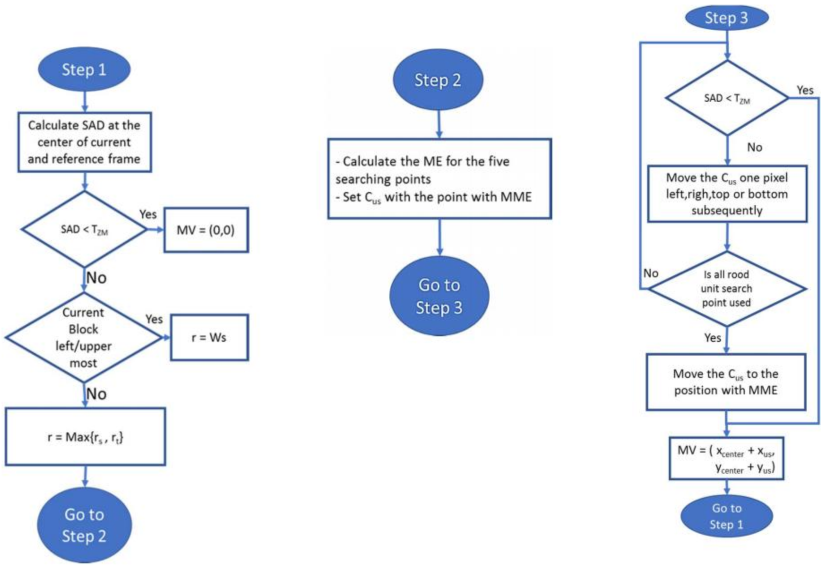

Figure 7: Flowchart Indicating the Denoising Process

Speckle noise appears as granular spots in an image, this is observed frequently in medical imaging due to the wave impendence.**(Azrah Rubanee et. al., 2019)** proposed a novel technique which gives effective filtering mechanism which destroy the noise components from the dim scale images. This method also deals with the other noises also by joining mean filter and middle filter.

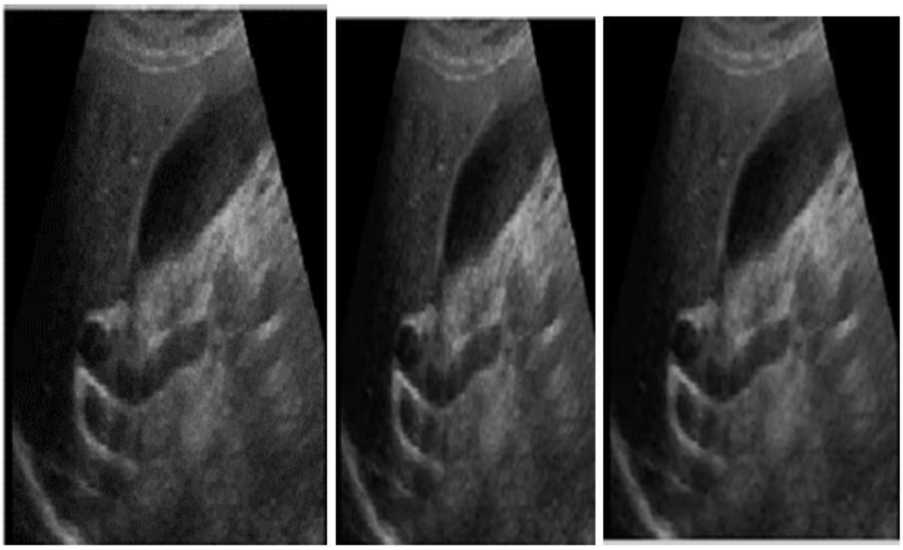

Figure 8: Input, Noised and Denoised Image

3.Proposed Methodology

The proposed technique for denoising the speckle noise is explained with the help of the figure 9 below.

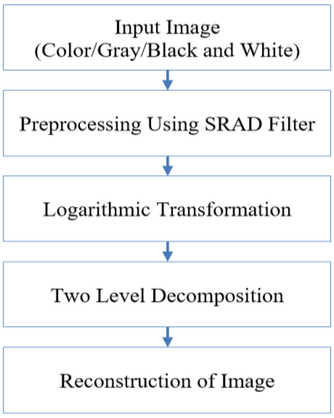

Figure 9: Flowchart for denoising impulse effect in imge

To begin with, the pure image is feed to the system. This image can be either colour image or Gray scale image or it can be black and white image. We carried out the demonstration using colour image of Lena image, Mandrill image and Airplane image in .jpg image file format as shown belowin figure 10.

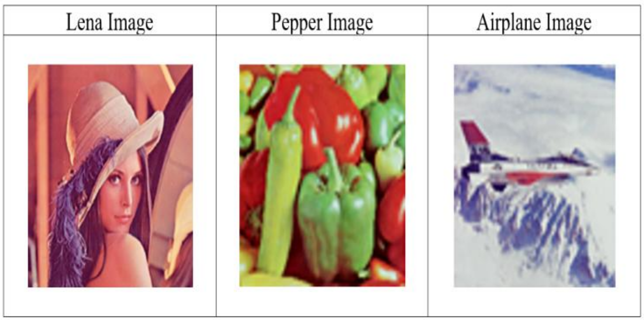

Figure 10: Input Images for De-Speckling

To observe the effect of speckle noise in image, we are adding the speckle noise in the above images with variance from 0.01 to 0.1. To realize an ability of speckle noise removal and edge information preservation, we have used speckle reducing anisotropic diffusion (SRAD) filter as a preprocessing filter. As the wavelet domain has the advantage of eliminating additive noise, we used logarithmic transform to convert multiplicative noise present in SRAD image into additive noise as shown in the subsequent figure 11.

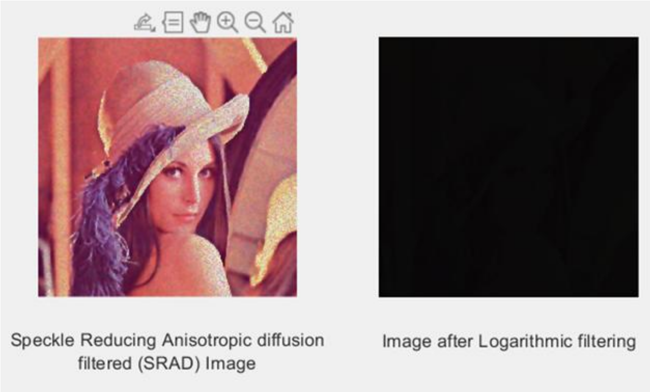

Figure 11: Effect of Multiplicative and Additive Noise

A two-level DWT decomposition producing high-frequency sub-band images and a low-frequency sub-band image for each of the RGB framer resulting from the SRAD image are shown in the subsequent figures.

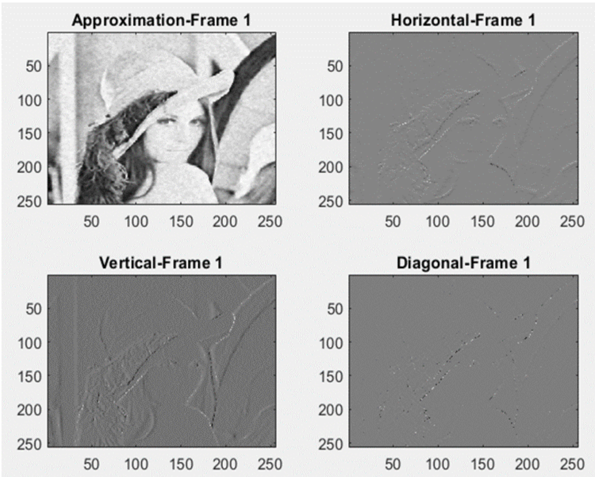

Figure 12: Level-1 Wavelet Decomposition for Frame-1

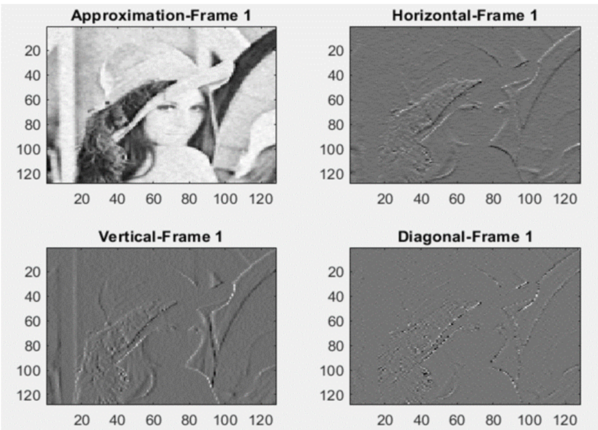

Figure 13: Level-2 Wavelet Decomposition for Frame-1

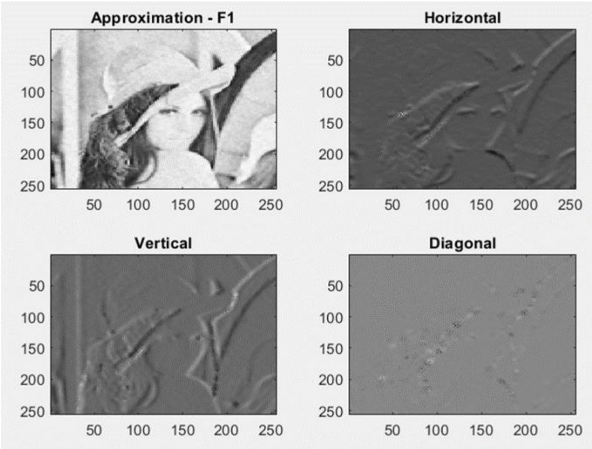

Figure 14:GDGIF for Frame-1

To retain each of the wavelet coefficient and remove the noise, combination of WGIF and GDGIF is used, which is shown in the subsequent figures.

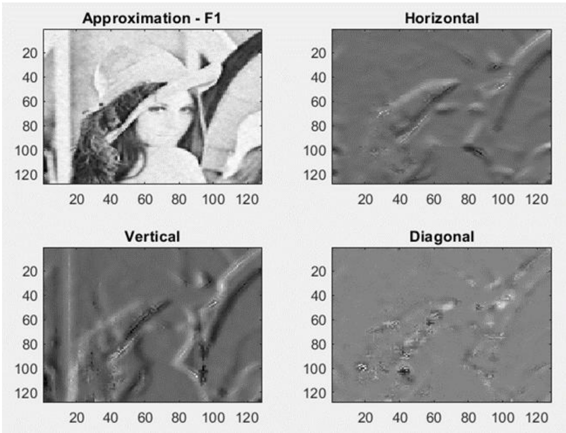

Figure 15:WGIF + GDGIF for Frame-1

Finally, a noise free image is obtained using IDWT and Exponential Transform as shown in following figure.

Figure 16: Reconstructed Image and Oroginal Image

4.Result and Discussion

The effect of the proposed de-speckling algorithm is depicted through the following figures of lena image, airplane image and pepper image.

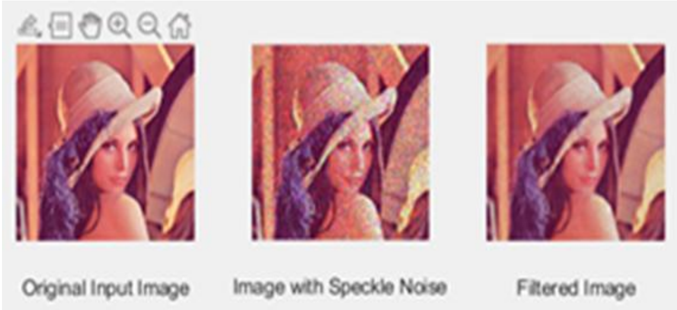

Figure 17: Despeckling Algorithm Effect on Lena Image

Figure 18: Despeckling Algorithm Effect on Airplane Image

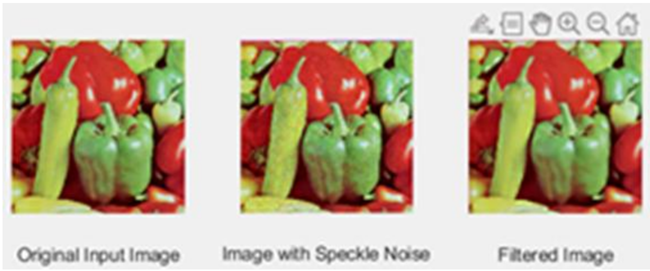

Figure 19: Despeckling Algorithm Effect on Pepper Image

Statistical analysis of the speckle noise based on Variance, PSNR and SSIM is disclosed through following table, respectively, for lena image, airplane image and pepper image.

Table 1: Analysis on Lena Image

Image	**Variance**	**PSNR**	**SSIM**
Lena	0.01	27.4008	0.95887
	0.02	27.0921	0.95595
	0.03	26.7904	0.95302
	0.04	26.5253	0.94944
	0.05	26.2204	0.94598
	0.06	25.9097	0.94294
	0.07	25.6473	0.93989
	0.08	25.3228	0.93611
	0.09	25.1242	0.93265
	0.1	24.8185	0.92922

Table 2: Analysis on Airplane Image

Image	Variance	PSNR	SSIM
Airplane	0.01	24.4795	0.80005
	0.02	24.3272	0.77942
	0.03	24.1323	0.76359
	0.04	23.973	0.73895
	0.05	23.7654	0.72365
	0.06	23.5467	0.70383
	0.07	23.343	0.69887
	0.08	23.1355	0.6813
	0.09	22.9039	0.67346
	0.1	22.6432	0.67534

Table 3: Analysis on Pepper Image

Image	Variance	PSNR	SSIM
Pepper	0.01	24.7218	0.94577
	0.02	24.6486	0.94355
	0.03	24.5748	0.9418
	0.04	24.4795	0.93958
	0.05	24.3432	0.93684
	0.06	24.298	0.93528
	0.07	24.0873	0.93194
	0.08	24.1109	0.93152
	0.09	23.94	0.929
	0.1	23.8568	0.92675

5.Conclusion

In this research paper, an effective algorithm is proposed for removing speckle noise from the different images. For demonstration of the effectiveness of the proposed algorithm, three different images like Lena Image, Airplane Image and Pepper Image are considered in jpg file format. Speckle noise is added in all three images from 0.01 to 0.1 variance. First, speckle reducing anisotropic diffusion (SRAD) filter is deployed as a pre-processing filter. Subsequently, logarithmic filter is applied for converting the multiplicative noise into additive noise. Then, to retain each of the wavelet coefficient and remove the noise, combination of WGIF and GDGIF is used. Finally, the performance evaluation is carried out using Variance, PSNR and SSIM variables.

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