A Comparative Study on Approaches to Speckle Noise Reduction in Images

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Abstract **- Noise refers to the random variation of intensity of a pixel, which modifies the actual information of the image. As a result, pixels which appear in the image are not the actual pixels. Addition of extraneous values to the image causes the occurrence of noise. Noise is categorized into impulse (salt-and-pepper) noise, uniform noise, Gaussian noise, exponential noise, Erlang (gamma) noise, photon noise, speckle noise, etc. Speckle noise is the noise that arises due to the effect of environmental conditions on the imaging sensor during image acquisition. Speckle noise is mostly detected in case of medical images, active Radar images and Synthetic Aperture Radar (SAR) images. Various researchers have performed experiments to overcome this kind of noise using different filtering techniques based on soft computing approaches, such as Fuzzy Filter, Genetic Algorithm, Particle Swarm Optimization, Artificial Bee Colony Optimization, Neural Networks, etc. In this paper, we present a brief analysis of different techniques used for speckle noise reduction, along with their advantages and disadvantages, in a comparative manner.**

Keywords – Image Processing; Speckle Noise; Filtering; Soft Computing.

I. INTRODUCTION

Image is the preservation of visual evidence either by traditional methods or digital methods. In digital views, it is the representation of intensity matrix. Each element of the matrix represents the intensity value of the pixel in the corresponding position. In a gray scale image, the intensity value varies from 0 to 255. 0 indicates black (minimal intensity) and 255 indicates white (maximum intensity), giving a total of $256 = 2^8$ different levels of gray. Image processing refers to a digital image in general. Noise is introduced in an image during the image acquisition or transmission. It degrades the quality of the image, which creates problems for further operations. Noise is a random variation of image intensity. That means, the pixels in the image show different intensity values instead of their true values. Noise is mathematically defined as the process (n) which affects the actual image (s) to produce the final noisy image (f) at the time of image acquisition.

$$f(p,q) = s(p,q) + n(p,q) \quad (1)$$

Degree of noise in an image is defined by the number of pixels corrupted in it [1]. Basic factors for noise are as follows.

- Image sensor may be affected by environmental conditions during image acquisition.
- Inadequate light levels and sensor temperature may introduce noise in the image.
- Conflict in the transmission channel may also corrupt the image.
- Dust particles on the scanner screen can also introduce noise in the image.

According to different sources of noise, noise can be classified into Erlang (gamma) noise, uniform noise, speckle noise, salt and pepper (Impulse) noise, photon noise, exponential noise, etc.

Speckle is a small spot, just like natural dots of color on a skin. So, speckle noise refers to random generation of numerous small spots in the image. Such type of noise is generated in SAR and ultrasound images. In Ultrasound and SAR images, it reduces the ability of human observation to make a decision based on the diagnostic examination. Thus, an image with speckle noise has low contrast, and that makes it difficult to perform further steps of image processing.

For better performance and proper analysis of image, noise-free original quality image is required, that's why the concept of de-noising arises. Image de-noising is an essential step in image processing. It helps to restore an original image from a noisy image by improving the visual qualities of the image. Several techniques are used to remove the different types of noises. In case of speckle noise, researchers have so far focused on filtering methodology. Filtering is the technique that removes unwanted components or features. For speckle noise reduction, various type of filtering techniques have been introduced, such as Gaussian filter, Median filter [4], Mean filter, Wiener filter, MAP, AD, SRAD [5], R-ML, First Order linear filter, Geometric filter, Adaptive filter, etc.

Soft Computing is the process of finding inexact solutions to computationally hard tasks, such as solutions to NP-complete problems, for which no known precise algorithm has been designed till date. Soft computing approaches can be subdivided into three basic categories, i.e. Fuzzy Logic, Evolutionary Algorithms and Neural Networks. In speckle noise reduction, these technologies were implemented by different researchers to get a better converging result in various aspects, like time, quality etc. Many Membership Functions

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(MFs) are used, like triangular MF, Gaussian MF, Trapezoidal MF, etc. in fuzzy logic based approach, which give better results according to their use and the respective problem statements.

In speckle noise removal, triangular MF has been implemented using Fuzzy Logic [28]. Evolutionary Algorithm (EA) is a generic population-based meta-heuristic optimization algorithm. EA uses the concepts of biological evolution, like reproduction, mutation, recombination, and selection. Till date many EA techniques have been evolved, such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Cat Swarm Optimization (CSO), Fish School Search (FSS), Ant Colony Optimization (ACO), Artificial Bee Colony Optimization (ABC), etc. In speckle noise, almost all the techniques are implemented and tested for better solutions. Many researchers are still working on it to get better and efficient solutions for speckle noise removal.

Neural network is an information processing model based on the biological neuron. Neural networks are organized in layers of a large number of interconnected processing elements (nodes).In neural networks, three layers are present, namely input layer, hidden layer and output layer. Patterns are presented in a network via input layer. Input layer communicates with one or more hidden layers where the actual processing is done using weighted connections. Hidden layers link to the output layers which give the output result. Most neural networks contain some learning rules which modify the weights of the connections according to input patterns. Neural network in speckle noise reduction gives better results as compared to other mechanisms.

This paper takes a bird's eye view on various techniques used for Speckle Noise removal and classifies them, with their dissimilarities, advantages, disadvantages and characteristics to analyze clearly for better understanding of different techniques of de-noising a speckle noise.

II. SPECKLE NOISE

Speckle noise is a multiplicative noise. It occurs in all coherent imaging systems, such as SAR (Synthetic Aperture Radar) and medical ultrasonic images. This noise can be modeled by random value multiplications with pixel values of the image and can be expressed as

$$J = I + n * I \quad (2)$$

where, J refers to speckle noise distribution image, I is the input image and n is the uniform noise image having mean o and variance v [1]. Speckle noise is generated in various ways in different type of images. In case of ultrasound images, speckle noise arises when a sound wave beat arbitrarily interferes with little particles or on a scale equivalent to sound wavelength [2]. In case of conventional radar images, it arises due to random variation in return signal. As an example, the standard image Lena is taken and introduced with a speckle noise of variation 0.4, as seen in Fig 1.

Speckle Noise is random in nature. Many researchers have applied noise removal techniques for speckle noise reduction. Such methodologies are described in the next section.

Fig 1: Original Image Speckle Noisy Image

III. SPECKLE NOISE REDUCTION METHODOLOGY

Speckle noise degrades the quality of the medical and SAR images. It reduces the effectiveness of human observation to discern the details of the diagnostic examination. Speckle noise reduces the contrast of the images, which makes it difficult to perform further image processing operations like segmentation, edge detection, etc. To overcome this problem, different filtering techniques are used.

A. Filtering

Filtering is a technique to remove the unwanted information from an image, so as to make it more appropriate for the next step of the image processing. Various types of filters are used to remove the speckle noise from images. We discuss some special filters which are used for de-speckling the image. The different types of filters used are as follows.

Mean Filter: It is a window based linear class filter. It is known as average filter. It is applied to remove the speckle noise using a square kernel (i.e. 3x3, 5x5, or 7x7) of grey-level values. In median filter, the noisy pixel is replaced by the mean (average) of the neighbouring pixel values. This filter potentially blurs the speckled image [12].

*Median Filter***:** Median filter is normally used for de-noising the image. It is similar to the mean filter but better, because it preserves the useful details of the image [16]. The median filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings. In median filter the noisy pixel is replaced by the median of the neighboring pixel values. It is generally used for reduction of speckle noise in ultrasound images.

Low-pass Gaussian Filter: This filter is introduced to remove the speckle noise in ultra sound images. In this filter, noisy pixel is replaced by the average value of the surrounding pixel based on Gaussian distribution.

Wiener Filter: Wiener filter is a linear filter. It is known as least mean square filter [2]. It minimizes the overall mean square error in the de-noising process of the image. If the variance is small, it performs smoothly. If the variance is large then it performs less smoother.

Adaptive filter: **:** In ultrasound images, adaptive filters are widely used. The implementation of the filter is very simple and easy to control. Commonly used adaptive filters for removal of speckle noise are Lee filter, Frost filter and Kaun's filter [11].

SRAD filter: It is known as Speckle Reducing Anisotropic Diffusion [10]. It removes the speckle noise without destroying the edges of the image. This filter has a better performance due to preservation of the edges and features of the image.

B. Speckle noise reduction in SAR images

SAR (Synthetic Aperture Radar) images are generally satellite images. SAR provides the high resolution images of large areas under all weather and lighting conditions. It is a powerful tool of remote sensing. It takes the advantages of radar signal and complex information processing capability of modern digital electronics to provide high resolution images.

The formation of radar images are done by coherent interaction of the transmitted microwave. Targets are also considered with this formation technique. This causes to the addition of speckle noise in images. This noises due to the coherent addition of the signal which are scattered from ground scatterers within each pixel . In general a radar image looks more noisy than an optical image.

There are several techniques to remove speckle noise from the SAR images. F. Qiu, J. Berglund, J. R. Jensen, P. Thakkar, and D. Ren (2004) [9] uses local statistics to detect speckle noise SAR images and replaces pixel values with a local median value by implementing a local adaptive median filter. Mansourpour M, Rajabi MA, Blais (2006) [6] applied adaptive filter and compared six different speckle reduction filters quantitatively using both simulated and real imageries. Md. Robiul Hoque, Md. Rashed-Al-Mahfuz (2011) [7] applied spatial filtering technique which selects response of mask based on priority, that keeps coefficient of variation among the masks closer. This technique made signal-to-noise ratio high and standard deviation of the whole image was reduced to get a great result. Luis Gomez, Cristian Munteanu, Julio Jacobo-Berlles, and Marta Mejail (2011) [10] proposed an interactive SRAD filter to de-speckle the Speckle nose. K.Bala Prakash, R.Venu Babu, B. Venu Gopal(2011) [11] analyzed that R-ML and AD gives better result than other filtering techniques. Ashkan Masoomi, Roozbeh Hamzehyan, and Najmeh Cheraghi Shirazi (2012) [8] proposed a tours algorithm using Gaussian low pass filter to decompose the image. Then, to un-blur the image a Kohonen Self-Organizing Map (SOM) is performed directly on the de-noised image. Simrat and Anil Sagar (2014)[2] analyzed various filtering techniques for SAR image and concluded that Wiener filter gives better result than most existing filters. The following table gives a brief idea about different research techniques used in speckle noise reduction in SAR images, their characteristics and advantages.

TABLE I. SPECKLE NOISE REDUCTION FOR SAR IMAGES

Authors	Methods	Characteristics	Advantages
Qiu, J.Berglund, J. R.Jensen, Pathik Thakkar andDianwei Ren (2004)	Adaptive median filter for speckle noise detection and reduction	Computes the statistics of a moving window and determines speckle noise based on local mean and standard deviation information and use adaptive local median function to replace the central speckle noise, while valid pixels keep their original values.	Uses local statistical rather than the global statistical, replace only speckle noisy pixel without changing valid pixel values, uses original local median value rather than the derived mean value to replace the noisy pixel, preserves the edges and other information of the image.
Mansourpour M, Rajabi MA, Blais (2006)	Comparative study of different filter to remove thee speckle noise from SAR images	The speckle noise reduction methods and among all studies the effect of mean, median, Lee sigma, local region, Lee, Gamma-MAP, and Frost filters with different kernel sizes on the SAR imageries.	Gamma MAP, Lee and Frost filter with 5x5 window are better for speckle noise reduction compare to others.
Md. Robiul Hoque, Md.Rashed-Al-Mahfuz (2011)	Spatial filter technique approach to reduce speckle noise	The proposed filtering technique selects response of mask based on priority that keeps coefficient of variation among the masks closer.	This technique made signal to noise ratio is high and standard deviation of whole image was reduced to get a great result.
Luis Gomez, Cristian Munteanu, Julio Jacobo-Berlles, and Marta Mejail (2011)	SARD filter design using evolutionary computing method	SARD filter is combined with interactive genetic algorithm.	A compact tool for SAR image filtering, not limited for only SRAD filter but also implimented on other parameterized filter.
K.Bala Prakash, R.Venu Babu, B. Venu Gopal (2011)	Performance analysis of various filters in various image to remove sreckle noise	Comparison of various filter for various type of image	AD filter for synthetic image. SRAD and AD for photographic image. AD and R-ML filter has better performance in SAR data.
Ashkan Masoomi, Roozbeh Hamzehyan, and Najmeh Cheraghi Shirazi (2012)	Tour algorithm based Gaussian low pass filter	Use SOM neural based algorithm for de-bluring the images	Provides better result than such well known learning based method taking the learning rate, width of the window and iteration constant.
Simrat and Anil Sagar (2014)	Comparison of different filtering methodology for speckle noise reduction	Apply different filtering approches on the SAR image for reduce the speckle noise and compare their performance	Wiener filter gives better result than the various existing filters. It minimizes the overall means square error in the denoising process of the image.

C. Speckle noise reduction in Medical images

Medical image processing is very important to obtain the correct images, which facilitates the accurate observations for the given application. Medical images are corrupted by different types of noises. Generally medical images are corrupted by speckle noise. It reduces the quality of the images which makes it difficult for the feature extraction, recognition, analysis and quantitative measurement. So noise reduction in medical images is necessary. Removing noise from the medical images is a challenging area now a days. Several noise removal techniques are developed to remove speckle noise from medical images, which have been discussed here.

S.Kalaivani Narayanan and R.S.D. Wahidabanu (2009) [12] developed an efficient and robust denoising method for ultrasound images. Pierrick Coupé, Pierre Hellier, Charles Kervrann, and Christian Barillot (2009) [13] proposed to use a Bayesian framework to derive a NL-means filter adapted to a relevant ultrasound noise model. Raman Maini, Himanshu Aggarwal (2009) [14] simulated imageries through five different speckle removal filters. Diffusion and Frost filters gave the best results. Due to its nonlinear nature and adaptive anisotropy the diffusion filter has excellent speckle reduction and detail preserving properties. R. Sivakumar, D. Nedumaran (2010) [15] combined the Wiener filtering and thresholding methods in the wavelet transform domain for getting better results to reduce the speckle noise from ultrasound B-scan image. Hitesh H. Vandra and H.N.Pandya(2010) [16] compared different speckle reduction filters and presented the performance analysis for reducing speckle noise in computed topographic images, in terms of the assessment parameters PSNR and MSE. M. N. Nobi and M. A. Yousuf (2011) [17] presented a simple and efficient technique to reduce noise from the medical images, which combined both median filtering and mean filtering to determine the pixel value in the noiseless image. Suganya Devi S, Suganya Devi D (2012) [18] proposed the comparative study of various filtering techniques like Wiener filter, Bayes wavelet filtering and Morphological filtering method for de-noising the medical images. Faten A. Dawood, Rahmita W. Rahmat, Suhaini B. Kadiman, Lili N. Abdullah, Mohd D. Zamrin (2012) [19] proposed a comparative study of various filters, like Mean, Gaussian, Median and Laplacian filters to reduce speckle noise from 2D-Echocardigraphic Images. Gnanambal Ilango, B.Shanthi Gowri (2012) [20] proposed different filtering techniques for the removal of speckle noise from CT medical images by topological approach. R. Eveline Pregitha, V.Jegathesan and C.Ebbie Selvakumar (2012) [21] proposed Adaptive Shock filter that gave desirable results in terms of MSE and PSNR, better than other existing filters for removing the speckle noise from ultrasound images. Reeta Soni, Lalit P Bhaiya (2012) [22] proposed wavelet filtering and compared with other filters to reduce speckle noise from ultrasound images and MRI images. Vivek Venugopal, Amanpreet Kaur (2013) [23] proposed comparative study of various filters to reduce the speckle noise using the parameters MSE and PSNR from the MRI images. Mehedi Hasan Talukder, Md. Aminul Islam, Md. Masudur Rahman, Md. Azmal Absar (2013) [24] proposed new methodology of SRAD filter than the traditional SRAD filter to de-noise the speckle noise from ultrasound images. Navjot Kaur, Sunil Khullar(2013) [25] introduced an enhanced stick filtering technique to reduce speckle noise from ultrasound images. Nishtha Attlas , Dr. Sheifali Gupta (2014) [26] proposed various filtering techniques using DWT, like DWT with wiener filtering, DWT with median filtering and DWT with both wiener and median filtering. Kinita B Vandara (2014) [27] proposed the Modified Anisotropic Diffusion (MAD) filter for removing the speckle noise from the ultrasound image and analysed its performance. The various techniques and their advantages and characteristics are discussed in Table II.

TABLE II. SPECKLE NOISE REDUCTION FOR MEDICAL IMAGES

Authors	Methods	Characteristics	Advantages
Pierrick Coupé, Pierre Hellier, Charles Kervrann, and Christian Barillot(2009)	Bayesian NL-means filter	Noisy pixel is replaced by the weighted average of other pixels with weights reflecting the similarity between local neighbourhood pixel and other pixels.	NL-means filter is more suitable for US imaging. This method is very efficient for smoothing homogeneous areas while preserving edges
Raman Maini,Himanshu Aggarwal(2009)	Comparative study of five different filter like Mean,Median,Local Region,Frost, Diffusion	Performance analysis of five different filter with the parameter SNR,PSNR,MSE	Diffusion and Frost filters have the best results Due to its nonlinear nature and adaptive anisotropy the Diffusion filter has excellent both speckle reduction and detail preserving properties. The Frost filter also strikes a balance between averaging and the all-pass filter.
R.Sivakumar, D. Nedumaran(2010)	Wavelet based threshold technique	Combine Wiener filter with wavelet based threshold technique	Reduce speckle noise smoothly, increase SNR and preserve some details of the images.
Hitesh H. Vandra and H.N. Pandya(2010)	Comparison of different filtering technique to reduce speckle noise in CT image	Performance analysis of Median, Wiener, Maximum a Posterior filter	Median filter is better compared to other two filters.

M. N. Nobi and M. A. Yousuf(2011)	New filtering technique by combine mean and median filter	Combine both median filter and mead filter for determine the more accurate value of pixel of noisy image.	Perform better than other filters and preserve structural details of the images.
Suganya Devi S, Suganya Devi D(2012)	Wavelet filtering techniques	wavelet filters are well performed by using wavelet thresholding functions	Bayes wavelet filters gives better performance than the wiener filters Morphological filter gives better performance than Bayes .
F.A.Dawood, R.W. Rahmat, S.B. Kadiman, L. N. Abdullah, M.D. Zamrin(2012)	Comparative study of filters eg. Mean, Gaussian, Median , Laplacian filter	Performance calculation is done by RMSE, PSNR SNR parameters	Gaussian has better performance over Mean and Median . Laplacian gives the best solution among these
Gnanambal Ilango ,B.Shanthi Gowri(2012)	Topological approach	Analyzing six different filters	LT1 median filter performance is better than all other filters.
R. Eveline Pregitha, V. Jegathesan and C. Ebbie Selvakumar(2012)	Adaptive Shock filter(ASF)	Continuous class of filters based on PDEs	ASF produce better result than that of Kaun , Lee, Frost Gabour Filter
Reeta Soni, Lalit P Bhaiya(2012)	Wavelet filtering	Finding the DWT coefficient and suppressing it by various technique	Wavelet filter is better for the high level noise
Vivek Venugopal, Amanpreet Kaur(2013)	Comparison between filters	Performance analysis by MSE, PSNR, NAE	Geometric Filter , First order liner filter gives better result than others
Mehedi Hasan Talukder, Md. Aminul Islam, Md. Masudur Rahman, Md. Azmal Absar(2013)	SRAD filter	New methodology for SRAD filter	Better than traditional SRAD filter
Navjot Kaur, Sunil Khullar(2013)	Stick filtering technique	Remove noise without losing edge details	Remove speckle noise completely and produce better result than mean, Median , Lee, Lee-sigma filters etc.
Nishtha Attlas, Dr. Sheifali Gupta(2014)	DWT Technique	DWT applied on Median , wiener and both separately	Hybrid filter (Median and wiener) gives better solution than individuals.
Kinita B Vandara(2014)	Modified anisotropic diffusion(MAD) filter	Partial differential equation (PDE) based speckle removal approach	MAD Filter removes the speckle noise very efficiently and edges preservation and feature extraction are also here

D. Soft computing approaches for speckle noise reduction

Soft computing is an approximation model. It is used to solve the real world problems. It is tolerant of imprecision, uncertainty, partial truth, and approximation for decision making. The principal of soft computing is that it tolerates uncertainty and imprecision to achieve the best solutions. Basic methodologies of the soft computing are Fuzzy Logic, Neural Networks and Evolutionary computing. Soft computing techniques are used in different areas but now they are widely used in SAR images and medical images to remove speckle noise.

1) Fuzzy Logic approaches:

Fuzzy set theory is a useful tool for decision making. It handles uncertainties. Fuzzy logic is based on human knowledge, which is expressed in term of linguistic variables. If-then rules in the fuzzy logic play a role in approximation of the variable. By using fuzzy logic and fuzzy sets, various problems can be approximated closer to the actual solutions. Different fuzzy filters are defined to remove the speckle noise. Several techniques have been proposed to reduce the speckle noise using fuzzy logic. Yilun Chen, Fuyue Huang, Jian Yang (2006) [34] introduced a fuzzy filter based on the fuzzy window to reduce speckle noise from SAR images. Hua Cheng, Jinwen Tian (2009) [35] proposed a filtering technique based on fuzzy logic for speckle noise reduction from SAR images. Md. Aminul Islam, Mehedi Hasan Talukder, Md. Mosaddik Hasan (2013) [36] proposed modified binning method and fuzzy inference system to reduce the speckle noise from ultrasound images. Nagashettappa Biradar, M.L.Dewal, Manoj Kumar Rohit (2014) [28] proposed a triangular membership function based fuzzy filter with integration of Wiener filters.

2) Neural Network Approach

Inspiring by the biological neuron, the artificial neural network was designed. Neural networks are good for solving the engineering, mathematical problems, as well as financial, medical and business problems. Faster computers and faster algorithms are designed using neural networks. By neural network approach many techniques have been introduced to remove the speckle noise. Alper Basturk, M. Emin Yuksel (2007) [29] proposed a new technique based on ANFIS to reduce speckle noise from SAR data. Torali Saikia and Kandarpa Kumar Sarma (2014) [37] introduced a de-noising technique by combining the features of multilevel Discrete Wavelet Transform (DWT) and Feed Forward Artificial Neural Network (FF-ANN).

3) Evolutionary Computing Approach

Evolutionary computing approach is based on the natural selection principle. It is a population based technique. This technique chooses the best individual from a population which is used in the next step for obtaining the best solution in a certain problem. It helps to search the best solution from a large and complex space. In this approach different techniques are used, like Genetic Algorithm (GA), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), Ant Colony

Optimization (ACO), Fish School Search, Bacterial Foraging Optimization (BFO) etc. Some of the evolutionary approaches have been applied for removal of speckle noise. Ali Rafiee, Mohammad Hasan Moradi, Mohammad Reza Farzaneh (2004) [30] proposed a new filter by using Genetic-Neuro-Fuzzy technique for reduction of speckle noise from sonography images. S.Mohamed Mansoor Roomi, R.B Jayanthirajee (2011) [31] introduced a modified hybrid median filter using Particle Swarm Optimization technique. Mathur U, Gill Sandeep S, Dr. Rattan Munish (2011) [32] introduced a new approach by using BFO techniques with homomorphic Wiener filter to attain improved PSNR of eye images highly corrupted by speckle noise. Fatma Latifoglu (2013) [33] proposed a new 2D FIR filter using Artificial Bee Colony (ABC) optimization.

The below table describes the various soft computing approaches to speckle noise reduction in a comprehensive manner.

TABLE III. SPECKLE NOISE REDUCTION BASED ON SOFT COMPUTING APPROACH

Authors	Methods	Characteristics	Advantages
Yilun Chen, Fuyue Huang, Jian Yang (2006)	Fuzzy Filtering technique	A fuzzy window based filter is introduced ,where neighbor pixels of the window contribute to find local statics according to the desired membership function	Fuzzy window evalute the uniform properties of pixels of SAR image, where more focus on high membership grade pixels.
Hua Cheng, Jinwen Tian (2009)	Fuzzy logic based filter	Two stages- First stage compute a fuzzy edge for each pixel in the filter windows Second stages uses the fuzzy edge to wait the contribution of neighboring pixel values and performs fuzzy filtering	Reduce the speckle noise iteratively in homogeneous area. It also preserved the edge ot the image
Md. Aminul Islam, Mehedi Hasan Talukder, Md. Mosaddik Hasan (2013)	Modified binning method and fuzzy inference system	Fuzzy inference system for speckle noise detection and modified binning method for speckle noise reduction without blurring the edges of the image.	Remove the noise very smoothly and restores the fine details efficiently and provide better results
Nagashettappa Biradar, M.L.Dewal, Manoj Kumar Rohit (2014)	Fuzzy filter with integration of wiener filter	TriangularMembership Function based fuzzy filter enhance with integration of wiener filter to get the better result	It has the edge and structure preservation capability also remove the high amount of speckle noise
Alper Basturk, M. Emin Yuksel (2007)	Adaptive Neuro-Fuzzy Inference System(ANFIS)	Combines the advantages of ANN (Artificial Neural Network) and FIS (Fuzzy Inference System)	This technique remove the speckle noise more effectively by preserving details and texture of the images.
Torali Saikia and Kandarpa Kumar Sarma (2014)	Multi level DWT based on FFANN	Combining the features of multi level DWT and Feed Forward ANN	More efficient to de-noise the image do not blurring the edges of the image
Ali Rafiee, Mohammad Hasan Moradi, Mohammad Reza Farzaneh (2004)	Genetic-Neuro-Fuzzy technique	Combine the advantages of genetic, neural and fuzzy paradigm	Using Genetic-Neuro-Fuzzy approach this technique effictively remove the speckle noise from the highly corrupted images also preserves the details of the images
S.Mohamed Mansoor Roomi,R.B Jayanthirajee (2011)	Modified hybrid median filter using Particle Swarm Optimization technique	PSO has been used as a tool to optimally select weighting factors of the neighborhoods of each corrupted pixel so that it minimizes the variance in thesample uniform area of the given image	Perform better in high noisy level
Mathur U, Gill Sandeep S, Dr. Rattan Munish (2011)	BFO techniques with homomorphic wiener filter	BFO technique is applied with homomorphic wiener filter to improve PSNR of highly corrupted images	Robust approach to get the better PSNR
Fatma Latifoglu (2013)	ABC technique with 2D FIR filter	Filter coefficient of 2D FIR filter is optimised by the ABC optimization technique	Based on the population based computation. It is easy to implement and gives the better result to reduce the speckle noise

IV. PERFORMANCE EVALUATION

This section describes the performance comparison of different type of filters for speckle noise reduction in image. Use Lena image as a test image in ".png" format as an original image. This image is corrupted by the speckle noise with variance 0.04. De-noising the image using different filter and their performance comparison are carried out. Quantitative analysis is done by using seven parameters like MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio), SNR (Signal To Noise Ratio), SC (Structural Content), AD (Average Difference), MD (Maximum Difference), NAE (Normalized Absolute Error) for test image with speckle noisy image with variance 0.04 which is shown in the Table IV and the comparison of performance different filters vs. (MSE,PSNR,SNR,SC,AD,MD,NAE) Objective Metrics is shown in the Fig 2.

TABLE IV. PERFORMANCE METRICS OF DIFFERENT FILTERS FORTEST IMAGE WITH SPECKLE NOISE WITH VARIANCE 0.04

	MSE	PSNR	SNR	SC	AD	MD	NAE
Average Filter	158.0284	26.1435	46.6813	1.0164	0.7438	101	0.0737
Median Filter	235.641	24.4083	44.8032	1.0129	1.1482	157	0.0957
Gaussian Filter	291.6639	23.4820	50.2603	0.9938	0.3299	72	0.1112
Wiener Filter	172.5834	25.7608	53.2488	1.0023	0.1651	78	0.0799

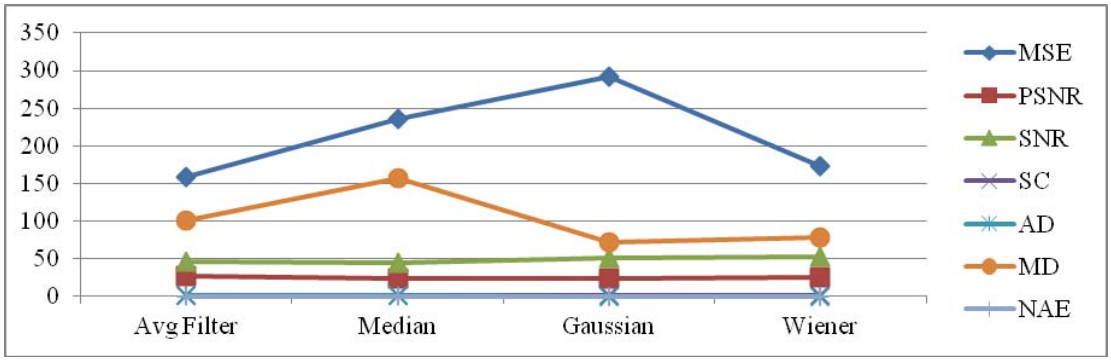

Fig 2: Comparison of performance of different filters vs. (MSE,PSNR,SNR,SC,AD,MD,NAE) Objective Metrics

V. SCOPE FOR FURTHER RESEARCH

Noise reduction is an essential step in digital image processing. Noise reduction means removing the unwanted information from the images for the better quality of the images and further processing like segmentation and restoration. Various researches are going on to remove the speckle noise from various images. Filtering is the most important process to reduce speckle noise. Several mechanisms are used in the filtering technique. Recent work is going on for applying soft computing approaches with different filters to improve the performance of the filters. The main aim of the future research is to discover a new optimized filtering technique which effectively removes the speckle noise without destroying any features of the images like edges, structure of the image, etc. This technique will be easy to implement and will be faster in removing any type of speckle noise.

VI. CONCLUSION

In this paper, various filtering techniques have been reviewed to remove the speckle noise from various images. Selecting the best technique for a particular image to remove speckle noise is a challenging task. So a good judgment is required to select the suitable method as per the image to remove speckle noise. This paper provides the proper techniques for specific speckled noisy images. It was found that Average and Wiener filter provides better performance than other filtering techniques in SAR images. Due to the vastness of the field, this paper is unable to describe more details of the individual methods and their comparison, which is planned to be dealt with in more details in future survey papers.

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