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Denoising MRI images using NLM filter

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***Abstract*—** This paper discusses the medical imaging and the noise present in the images. Different denoising and filtering techniques are also discussed. The paper focuses on the NLM filter and further types used to denoise rician noise present in MRI images.NLM filter enhances the textures and edges of an image. NLM filter provides a feasible method or ways to get the least results by reduction of geometrical configuration.

Keywords— Image Denoising, Noise, Filters, MRI, NLM filter

I. INTRODUCTION

Medical imaging is the technique and process that is used for viewing and creating visual representations of the interior of a body for the purpose of clinical analysis and medical treatment and also gives a visual representation of the function of some inner organs or tissues. It, therefore, has an important role to improve public health for all population groups. Medical imaging actually helps to reveal internal structures hidden by the skin as well as the bones, so to diagnose and treat disease. It is a part of biological imaging and also establishes a database of normal anatomy and physiology to identify abnormalities. It incorporates the imaging technologies of X-ray radiography, magnetic resonance imaging, medical ultrasonography or ultrasound, endoscopy, elastography, thermography, tactile imaging, medical photography and positron emission tomography (PET), Single-photon emission computed tomography (SPECT) that are nuclear medicine functional imaging techniques. Since many repetitive patterns exist in natural and medical images, the NLM filter proposed by [1] has drawn the special attention in denoising particularly MR images [2]. The traditional MRI denoising techniques were first designed to remove Gaussian noise in an image but were not able to detect rician noise. Later new methods were proposed as non-local means (NLM), wavelets, partial differential equation (PDE) and maximum likelihood (ML) and also enhanced to adapt Rician noise. In this paper, we have proposed the overview of the different image modalities, types of noise and their filtering techniques and discussed the removal of rician noise (corrupted data) in MR images using NLM filter.

Section I contains the introduction of some common medical image modalities, Section II contains the types of noise present in them, Section III contains the denoising techniques, Section IV contains the introduction of NLM filter and steps involved in it, section V explains the gaps of literature and literature survey related to the work, Section VI describes conclusions.

II. MEDICAL IMAGE MODALITIES

Table 1: Image modalities with its strengths and limitations

Image Modalities	Description	Area Of use	Strengths	Limitations
Radiography	2types of radiographic images: Fluoroscopy produces real-time images (2D) of internal structures of the body Projectional radiographs (commonly known as x-ray) are mostly used to determine the appropriate type and extent of a fracture.	It helps to diagnose the procedures: Dental examination, Verification of correct placement of surgical markers, Mammography, Orthopaedic evaluations, Spot film or static recording during fluoroscopy.	It is the technique for generating and visualization of internal parts using x-ray techniques to get the presence or absence of disease or some foreign objects, and structural damage	There is a risk of inducing cancer during radiation. When performed on pregnant women it can Cause disturbance in the development of a fetus.

			or anomaly.	
MRI	MRI scanners use strong magnetic fields and radio waves (RF) to take the images of internal structures of the body. A typical MRI scan last from 20 - 90 minutes, depends on the part of the body being imaged [2].	It helps to diagnose the abnormalities of the brain and spinal cord, breast, prostate, and liver, joints, cardiac imaging, blood flow through blood vessels and arteries (angiography), and spectroscopy.	An MRI scanner can be used to take images of any part of the body like head, joints, abdomen, legs, etc. in various imaging direction. It also provides better soft tissue contrast than CT.	Its environment involves a strong, static magnetic field which will attract magnetic objects and may cause damage to the scanner or injury to the patient. The magnetic fields change with time and create loud knocking noises which may harm hearing if adequate ear protection is not used.
Nuclear medicine	This technique uses radiotracers (small amounts of radioactive materials) and can be injected into the bloodstream, inhaled or swallowed. This radiotracer travels through the area that is being examined and gamma rays are produced in the form of energy. These are detected by a special camera and a computer to create images of the inside body.	It helps to diagnose: To visualize heart blood flow. Scan the bones fractures and arthritis and lungs. To visualize abnormalities or disorders in the brain. To detect the presence and spread of cancer and tumors.	Less expensive and more precise information.	Allergic reactions may occur but are rare and mild. There could be slight pain and redness caused by injection of the radiotracer which should resolve rapidly.
Ultrasound	(Sonography) uses high-frequency broadband sound waves in the megahertz range to view inside the body. Real-time moving images (up to 3D) can be obtained.	Most commonly used for imaging the fetus in pregnant women. Other than its Abdominal ultrasound, Bone sonometry, Breast ultrasound, Doppler ultrasound, Echocardiogram, Ultrasound biopsies, and needle placement.	It emits no ionizing radiation.	Ultrasound waves can heat the tissues slightly. It can also produce small pockets of gas in body fluids or tissues [3].
Computed Tomography (CT)or Computed Axial Tomography (CAT)	CT is a procedure that produces cross-sectional images of the body using specialized X-ray equipment in which X-Ray beams spins and picked up by detectors. A computer analyses the information received from a detector and construct an image. This technique produces a (2D image) of the body being examined in a thin section/slice. These cross-sectional images are used for a variety of diagnoses and treatments.	Diagnose disease or abnormality, Monitor the effectiveness of therapy e.g. Cancer treatment.	CT scans provide detailed information to diagnose or plan for treatment, to evaluate different conditions in adults and children. The detailed images provided by CT scans may eliminate the need for surgery.	It includes the risks from the emission of ionizing radiation which may cause risk of cancer, longer lifetime effects in the body.
Echocardiography	It uses sound waves to extract the images of the heart.	Images can use to spot the blood clots in the heart, fluid in the sac around the heart. To detect the problems related to the main artery connected to the heart	It also helps to reveal the defects in unborn babies. It is painless and doesn't use radiation x-ray.	There is a rare chance of irritation and a sore throat.

III. NOISE

Noise is something which is unwanted in the data and which disrupts the original data or image. Noise affects the image by means of its texture, edges, curves, and clarity [4]. Imperfect instruments, problems in transmission and compression, a problem with the data acquisition process are the main sources of noise in digital images. There are different types of noise present in medical imaging as discussed following figure1:

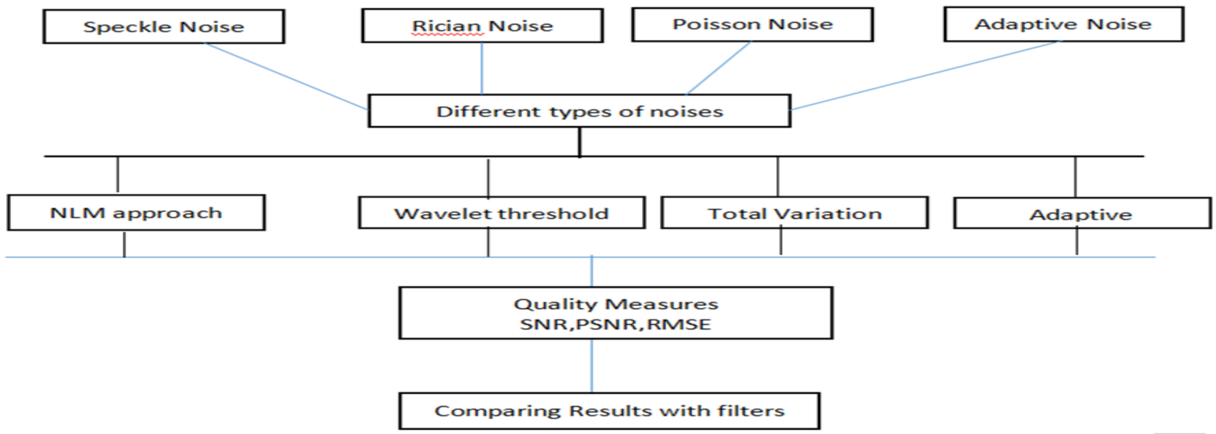

Figure 1: Noise chart

*A. Speckle Noise***:**

It is a granular noise which is mostly found in the ultrasound and Radar. This noise increases the mean grey level. Lee or Forst filter, Kuan filter is the first Speckle removing algorithm discovered by SAR (Synthetic Aperure Radar) [5]. Here wavelet thresholding and partial differential equation are recent on which the denoising approaches are based. In the wavelet thresholding original image is decomposed into small coefficients whereas in the PDE, function energy E_{tv} is minimized which is the following:

$$E_{tv} = \int (|\Delta u(x)| + \frac{1}{2}\lambda\big(v(x) - u(y)\big)^2)dxdy \qquad (1)$$

u=free noise image, v=image that is to be treated, Δ=Gradient operator,
λεR =Scalar Controlling
It is a constrained minimization problem in Total Variation Method. Total variation is proved better as well as with good results. On the other hand the NL-means approach also gives promising results.

B. Rician Noise:

This noise is mostly found in the MRI Data. It is a non-additive noise (Rice Noise). For MRI denoising the wavelet thresholding has also worked well. Nowadays Non Local Means filter is one of the strongest schemes on which our will be based and will discuss below section in detail.

C. White Additive Noise:

This noise basically found in the CT image data. CT image modality is mostly used in medical imaging. These images are corrupted by AWGN Noise which is additive noise. Wiener filter and Median filter are used to reduce it whereas wavelets, multiwavelets transformation, Curvelet transformation are recently used in noise reduction.

D. Poisson Noise:

It is the intrinsic photo shoot meaning natural phenomenon that emits the number of photons per unit time for example x-rays, gamma rays or visible light. The standard Poisson distribution:

$$P_{ph}(N = d) = \frac{e^{-t}(\varsigma t)^d}{d!} \qquad (2)$$

Where N=no of photons measured by the sensor elements, $P_{ph=}$ Uncertainty, ς=predicted no of photons per unit time interval, ςt=rate at which parameter corresponds to the predicted incident photon count.
NL-means is efficient approach for Poisson noise removal.

3.1 Denoising Medical Images

Image denoising is one of the main problems of digital image processing. In the image acquisition process, low-contrast objects are often contained in the medical images obtained from some medical dataset corrupted by random or unwanted noise. Noisy content can fully damage the data when it crosses the threshold limit [5]. To remove the noisy content, firstly the noise is detected and different features are extracted by using various noise removing/reduction mechanisms. The noise cannot be fully removed but the effect of the noise could be decreased up to the certain level and steps are described below in fig (2). Medical images obtained from Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) and Ultrasound imagings (US) are the most common tools for diagnosis. In other words, the presence of noise creates an effect of a grainy, textured, or snowy appearance in the image and can negatively affect on operations such as image classification and segmentation, image restoration, object tracking, and object recognition [6].

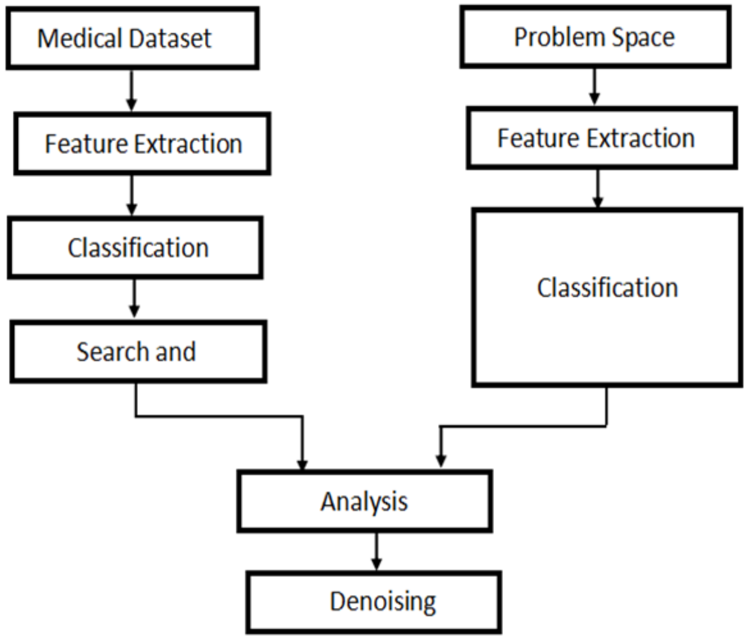

Figure 2: Steps in Denoising

To enhance and produce the visually high quality of the image, image denoising is practiced. Following types of effects can be seen due to noise:

- The loss of original data.
- The quality of the received image is degraded as compared to the original image.
- The image with noise more than the typical threshold cannot be reused anywhere and can be fully lost too.
- Unwanted spots and objects can be seen in the image.
- Different types of images have different types of noise, therefore, there would be a different type of noise models to represent different noises.
- Denoising techniques.
- Lowers visibility.

3.2 Filtering Techniques

Filtering in image processing is used for many purposes like re-sampling and interpolation but here it is used for noise reduction. Use of filters is the method of choice according to the type of Noise to remove it efficiently [6, 7]. Different filters along with its features, strengths, and weakness are discussed in following table 2:

Table 2: Different types of filters and their description

Filters	**Features**	**Strength**	**Weakness**
Spatial filter	The Non-Linear and Linear filter.	To remove dirty/optics or clean output of lasers damages.	Eliminates noise to the extent that it blurs the images or makes edges invisible.
Mean Filter(Linear)	Sliding window spatial filter(averaging filter).	It gives smoothness in an image with the help of reducing the intensity variation between adjacent pixels.	Edge preservation criteria are poor. Used in an application where a certain region is to be processed.

Wiener Filter(Linear)	Uses Information of spectra of noise.	Implements spatial smoothening.	Works well only if given signal is smooth to improve its weakness wavelet transform has come into light [8].
Least Mean Square(LME) Filter(Linear)	To denoise the non-stationary objects.	Simple in computation and helps to denoise salt and pepper noise.	Not better than wavelet.
Median Filter(Non-Line ar)	Less sensitive than the mean filter to extreme values.	No reduction in sharpness of images.	Features don't give a satisfying result.
Bilateral Filter(BF) nonlinear weighted averaging filter	It is a robust filter and it has the ability to preserve edges while doing spatial smoothening.	It averages the local small details and ignores outliers [9].	Can't eliminate salt and pepper noise properly. It produces a staircase effect..
Trilateral Filter(TF)	Shows good performance in the high contrast image.	To denoise multi-dimensional signals in real time video.	Not easy to implement.
Wavelet transform	Analyze data according to scale or resolution at different windows and angles. (soft threshold/hard threshold)	It has properties of muti-resolution and multi-scale so Better than a spatial filter.	Complex computation and not suitable for the Describing the signals which have high dimension singularities such as edges.
Curvelet transform	Multiscale geometric analysis	To detect, represent and process high dimensional data	Does not work well in smooth areas, produce Curvelet like artefacts.
Contourlet Transform	Flexible multi-resolution and decomposition for a different number of directions at each scale.	Properties of capturing contours and fine details in images. Provide sparse representation at both spatial and directional resolutions [10].	High computational complexity because of capturing the smooth contours in the images.

3.3 Performance/Evaluation of Denoising Methods

1. *MSE*: basically compares the similarity between two images denoising and the original image [11]. It gives the difference between the compared images.

   Low MSE – an estimated image is closer to the original one

$$MSE = \frac{1}{MN}\sum_{i=0}^{MN-1} (g(i) - \hat{g}(i))^2 \quad (3)$$

2. *SNR*: gives the relation between the original image and estimation error. It evaluates the improvement in smoothing.

   High SNR – means the favorable performance of the test method.

3. *PSNR:* value is expressed in db. (Decibels).
   High PSNR – Better performance of denoising algorithm.

$$PSNR = 10log_{10}(255^2/MSE) \quad (4)$$

4. *SSIM:* is metric to compare images that correlate with human perception (more appropriately) or based on their structural information. SSIM between 2 image patches if,

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_x + c_2)}{(\mu_x^2 + \mu_x^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (5)$$

μ_x, μ_y – Average grey values

σ_x, σ_y – Variance of patches

σ_{xy} – Covariance

5. *MSSIM:* Its value lies in internal [0, 1].

High MSSIM – means better retention of structural information.

$$SSIM = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \mathrm{SSIM(x, y)} \qquad (6)$$

6. *BC (Bhattacharya coefficient)*: is a measure of correlation for finding the statistical similarity between any 2 images. It computes the probability distribution –

$$BC(\mathrm{J, K}) = \sum_{l=0}^{255} \sqrt{J(l)K(l)} \qquad (7)$$

J, K – normalized histogram of 2 images

l –bin index

As the value goes closer of BC to 1, the more similar are the images.

3.4 Different denoising techniques in MRI

The following figure shows the flowchart and division of approaches in MRI denoising method. In this paper, we have discussed the NLM only.

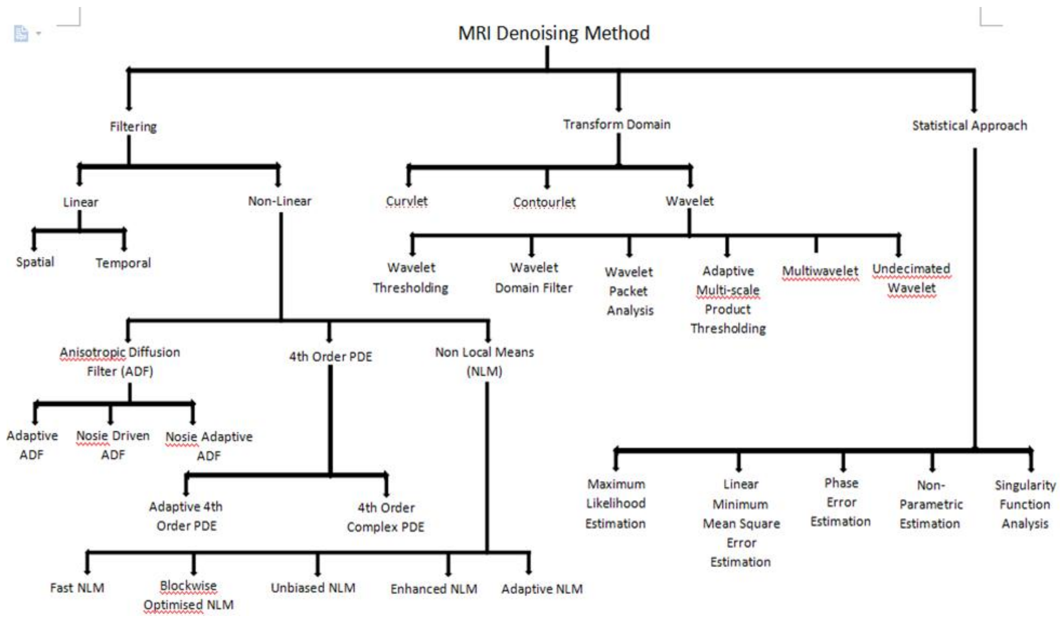

Figure 3: Flowchart of approaches in MRI Denoising

III. NON LOCAL MEANS (NLM)

As explained in the above filters, some of them can smoothen the image but can't reserve the edges and others can help in no reduction of sharpness but difficult to implement. Let's say the Gaussian convolution can preserve the flat zones and it blurs the fine structures. In the case of anisotropic filters, it preserves the straight edges but artifacts can be present in many flat zones.

Now even if we combine the two methods, the Gaussian one could be applied on the flat zones and others could be too straight edges [12]. Therefore still you need filters which can restore the corners and curved edges, or textures. In that case, NLM provides a feasible method or ways to get the least results by reduction of geometrical configuration.

4.1 NLM filters:

Magnetic resonance imaging (MRI) provides significant information to research the tissues as well as organs in the human body with non-invasive style. However, MRI is affected by several noise sources. Random fluctuation of the MRI signal is one of them which are mainly due to thermal noise. Such noise degrades the quality of any quantitative measurements from the data [13]. Consequently, the denoising techniques are required to improve the quality of MRI.

MRI denoising techniques can also be classified as filtering, transform or statistical approach. Filtering methods remove noise and it includes linear or nonlinear filters. Transform methods employ some kinds of transformation to denoising MRI including wavelet transform and Curvelet transform. Maximum likelihood, linear minimum mean square error (LMMSE), Markov random process and empirical Bayes are the estimates of noise in Statistical. In particular, non-local means (NLM) filter has been used to denoise the MRI image, achieving notable results. The NLM filter averages similar image pixels according to those pixels intensity distance. Filters, like the SUSAN (Smith and Brady, 1997) or the bilateral filters are based on the same principle.

Firstly, the NL-means approach is to denoise 2D natural images corrupted by an additive white Gaussian noise. NLM gives the redundancy of the neighborhood pixel to remove the noise. The restored pixel is then considered as the weighted average of the intensities of all pixels within the neighborhood area. Since MRI image has multichannel nature, NLM has been modified to denoise MRI data where the similarity measure can be considered to combine the relative information between different slices [14]. This process has been shown in figure 4.

NLM has applied in the various scientific fields because of simplicity and it has the property to consume the neighborhood information. In other words, the NL-means filter can be viewed as an extreme case of neighborhood filters with the infinite spatial kernel and where the similarity of the neighborhood intensities is substituted to the point-wise similarity of gray levels as in commonly-used bilateral filtering. This new NL recovery paradigm allows combining the two most important attributes of a denoising algorithm: edge preservation and noise removal. It's been restricted its application for 3D MRI data because of the high computational burden. Therefore, has proposed an optimized **block-wise** NLM filter for 3D MRI.

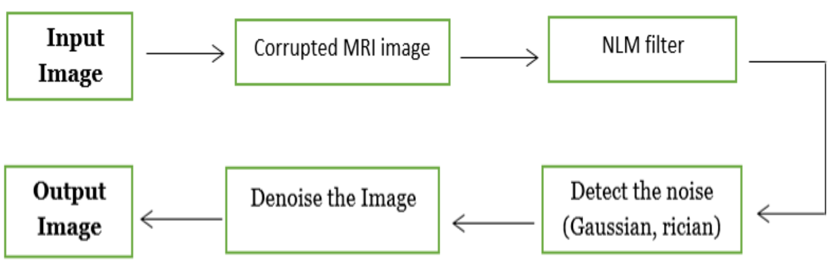

Figure 4: Block Diagram of NLM filter

4.2 Brief Description of NLM Method:

The NLM filter was significantly designed to remove Gaussian noise in an image. Later this filter was modified and enhanced to adapt Rician noise.

Classical NLM filters use the similarities between two local patches in a noisy image. The NLM weights are obtained by first calculating the Euclidean distance (d) between the two local patches.

Exp $(-d^2/h^2)$, h is a smoothing parameter. There are four factors which determine the output of the image quality of the NLM filter in terms of weights.

1. First is similarity measure, d the Euclidean is a usual choice it can be changed too as other similarity measures.
2. Strategy for determining the smoothing parameter (h).
3. Selecting the function to use to determine the weights such as exp $(-x^2)$. Other functions have also been proposed.
4. To determine self-weights for the same pixel in the input and output images.

The filter has been adapted to fit with specific characteristics of the noise in MR image magnitude images (i.e. Rician noise). But there are disadvantages such as time-consuming and inadequate pixel searching. So there are improved NLM filter algorithms such as fast NLM algorithm, an improved algorithm based on kernel regression and moment based non-local means algorithm and K-means clustering algorithm. But these algorithms are not so good in the medical images denoising so the improved parallel NLM method is adapted [15-16]. Suppose having MR image corrupted by Rician noise as shown in figure 6. Then apply denoising steps for NLM filter. When we deduct the noise from the original image figure 5 resultant is the final denoise image as given in figure 7.

Table 3: Gaussian and Rician noise

Distribution	**Noise**	**Formula**
Gaussian NL Means	Gaussian noise N(0,σ2)	$NLMG(x)=\sum xi\in W_i x_i$ $w_i=1/Z(i)$ $e^{-\sqrt{1S\sum S_{k}=1\|y_{k}-z_{k}\|}}$
Rician NL Means	Rician noise	$NLMR(x)=\sqrt{(\sum w_i x_i^2)-2\sigma^2}$ $x_i \in V$

1. As shown in the table the magnitude of the MRI signal is equal to the square root of the sum of the squares of Gaussian distributed real and imaginary parts, so it follows a Rician distribution.
2. In low-intensity regions of the image, the Rician distribution approaches to a Rayleigh distribution while in high-intensity regions it tends to a Gaussian distribution.
3. A contrast of the resultant image is reduced.

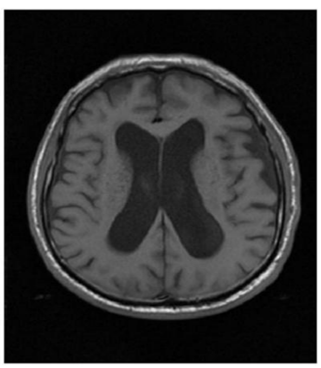

Figure 5: Original image of brain

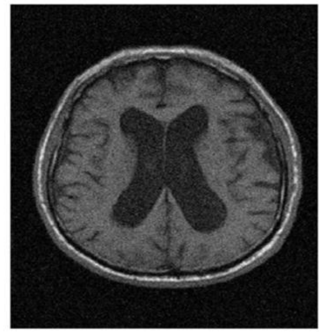

Figure 6: Corrupted by rician noise

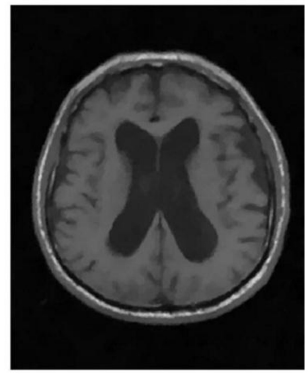

Figure 7: Image Denoise with NL means the filter

Let us take original brain image taken by MRI scanner as shown in figure 5 which is corrupted by rician noise given in figure6 and then denoise it by using different denoising technique that is NLM filter as discussed in this paper shown in figure 7.

V. GAPS OF LITERATURE

The following research gaps were identified through the literature related to all methodologies:

- Unbiased could be used for more better and accurate results.
- Linear expansion of multiple NLMs should also be considered.
- To perform a linear projection of neighborhood to speed and improve the NLM algorithm.
- To better identify the Noise prone transform coefficients.
- To speed up the denoising performance.

Table 4: Evaluation of Different approaches to MRI images

Title, Author, Publication	**Dataset**	**Features/Parameters**	**Tool/techniques**	**Classification approach**

Title: "MRI denoising using Non-Local Means". Author: "José V.Manjón[a,*],José Carbonell-Caballero[a], Juan J.Lull[a], Gracián García-Martí[a], Luís Martí-Bonmatí[b], Montserrat Robles[a]". Publication: "Elsevier(2008)"	Two different datasets covering brain and body locations-fMRI Data Center data-base (http://www.fmridc.org/) -Hospital Quirón of Valencia (Spain)	Root Mean Square Error (RMSE), SNR (Signal -to - noise ratio) standard deviation σ, μ is the mean.	-T1-weighted sagittal MP-RAGE scan acquired on a Siemens 1.5 Tesla Vision scanner (Erlangen, Germany). -Philips 3 Tesla scanner (Achieva, Philips Medical Systems, Best, The Netherlands)	Unbiased NLM filter, wavelet denoising algorithm, ADF algorithm, OSTU thresholding method.
Title: "Image denoising based on non-local means filter and its method noise thresholding" Author: "B. K. Shreyamsha Kumar" Publication: "Springer(2012)"	Standard grayscale images of size (512×51) Images of Barbara, boat, Baboon, and Lena corrupted by simulated Gaussian white noise.	Method noise, visual quality, PSNR and ImageQuality Index. IQI-Image Quality Index. MSE (mean squared error).	Different wavelets like db8, sym8, db16, coif5,Bior6.8 and DCHWT (discrete cosine harmonic wavelet transform (WT) are used to decompose the method noise. SURE-Stein Unbiased Risk Estimator.	Non-Local means filter, Bilateral filter, Wavelet thresholding-Bayes shrink, Multi resolutional bilateral filter (MRBF).
Title: "Biomedical Signal Processing and Control" Author: "J.Mohan, V.Krishnaveni, Yanhui guo " Publication: "Elsevier(2014)"	"Brainweb Database"	Rician noise=9%,11%,15%,LMMSE (Linear minimum mean square error), SNR, MSE, RMSE, QILV	Matlab toolbox	NLM based methods, LMMSE based filters
Title: "Medical Image Denoising by parallel non-local means" Author: "Xu Mingliang, Lv pie, Li Mingyuan, Fang Hao, Zhao Hongling, Zhou Bing" Publication: "Elsevier(2015)"	"4 natural images with additive Gaussian noise"	PSNR values, processing speed improved two orders of magnitude.	CUDA programming platform.	Non Local means algorithm and GPU-based parallel nonlocal means algorithm.
Title: "Fuzzy-Based hybrid filter for Rician Noise Removal." Author: "Muhammad Sharif, Ayyaz Hussain, Muhammad Arfan Jaffar, Tae Sun Choi". Publication: "Springer 2015"	Degrade with Rician Noise Dataset. Brain Web Database And Real Data ISBR (Internet Brain Segmentation Repository).	RMSE, PSNR, SSIM. Retention of Edges.	Matlab toolbox 7.9.0	ADF, AWF, NLM filter, MF filter.

Title: "Local Statistics and Non Local Mean Filter for Speckle Noise Reduction in Medical Ultrasound Image." Author: "Jian Yang, JingFan Fan, Xuchu Wang, Songijuan Tang, Yongiang Wang." Publication: "Neurocomputing 2015"	Clinical Images provided by PLA General Hospital, Beijing (256×256).	Model parameter R=0.5, MSE, SNR, SSIM, Filtering parameter.	Matlab toolbox.	Median, Lee, Frost, Kuan, SRAD, SBF, NLM, OBNLM, NLMLS filters.
Title: "Neurocomputing" Author: "Xu Mingliang, Lv pie, Li Mingyuan, Fang Hao, Zhao Hongling, Zhou Bing" Publication: "Elsevier(2016)"	Random Series of medical images (128*128)(256*256)(384*384), Original natural images with additive Gaussian noise, Size of searching and similar window=(6*6)	PSNR values,	Serial and parallel denoising methods are used.	NLM algorithm, Parallel NLM algorithm, GPU(graphics processing unit) based algorithm
Title: "A first Non Locally Centralized sparse representation algorithm for Image Denoising." Author: "Shioping Xu, Xiaohui Yang, Shunliang Jiang." Publication: "Elsevier 2016"	"TID2013 benchmark Database" "BSO500"	Natural and textural images by NCSR (NCSR, FCSR).	Matlab Codes implemented on 13.44 Hz Intel Core i7-4770 CPU, 84 BRAM.	FNCR algorithm, BM3D, NCSR, NES, SNLM, BM3D-SAPCA, WNNM, FAST NLM.
Author: "P.V.Sudeep, P.Palanisamy, Jeny Rajan, Hediyeh Baradaran, Luca Suba, Ajay Gupta, Jasjit S.Suri" Publication: "Elsevier(2016)"	(Gyne image(size256×256) And carotidimage(size 400×400))	Scale and shape parameter(ρ, β=5-60)Of gamma distribution, PSNR, MSSIM,	Matlab toolbox	SBF filter, NLM filter, SPRAD (Speckle reducing anisotropic diffusion), OBNLM filters.
Title: "Biomedical Signal Processing and Control." Author: "Manoj Diwankar, Manoj Kumar". Publication: "Elsevier 2018"	Dataset obtained from public access (https://eddic.via.cornell.edu/cgibin/datac/logon.cgi)	PSNR, RNSE, EDSE, SSIM, Preservation of edge details and texture, Visibility of low contrast images.	Multidetector, Scanner.	NLM filter, BM3D, Wavelet thresholding, Curvelet.
Title: "FFDNet: Towards Fast and Flexible solution for CNN based image Denoising." Author: "Kiazhang, Wanguang Zuo, Senior member, And Leizhang Fellow, IEEE."	"BSD68", "Set 12", "RN16", "BSD300", "CLIP300", "PA5CALVOC 2012", "CBSD68", "KODAK24", "MACMASTER", "RN15".	PSNR=26.34db and 26.35db, AWGN, Denoising, Flexibility, Robustness.	BM3D, WNNM, MLP, TNRO, RED30, MMNC.	DnCNN, MLP (Multilayer Perception).

Publication: “IEETransaction,2018”				

VI. CONCLUSION

This paper has reviewed the brief information about the different medical image modalities, noise, and comparison of different image denoising techniques. MRI denoising techniques have included as the highlight and NLM filter which is used to denoise the Rician noise. NLM filter is used because the study has proved that this filter enhances the performance and edges, textures as compared to other defined algorithms and filters. Different types of NLM filters are used in the different image modalities. These filters help to achieve a higher speed to meet up the real-time image processing requirements. The images are clearest up to some extent after denoising.

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Damini received her B.Tech Degree in Computer Science and Engineering from Guru Nanak Dev University, Amritsar, India, in 2017. Currently, pursuing the M.Tech in Computer Engineering and Technology at Guru Nanak Dev University, Amritsar, India. Her research interest includes machine learning and image processing.

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