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Machine Learning Approach for Comparative Analysis of De-Noising Techniques in Ultrasound Images of Ovarian Tumors

Ms.Smital D. Patil[1], Dr. Pramod J. Deore[2]
[1]Research Scholar, Department of Electronics and Telecommunication
R. C. Patel Institute of Technology
Shirpur, India
smitalpatil55@gmail.com
[2]Professor, Department of Electronics and Telecommunication
R. C. Patel Institute of Technology
Shirpur, India
pjdeore@yahoo.com

Abstract— Ovarian abnormalities such ovarian cysts, tumors, and polycystic ovaries are one of the serious disorders affecting women's health. In ultrasound imaging of ovarian abnormalities, noise during capturing of the image and its transmission process frequently corrupts the image. In order to make the best judgments possible at the appropriate moment, ovarian cysts in females must be accurately detected. In computer aided diagnosis of ovarian tumors, preprocessing is a very important step. In preprocessing, de-noising of medical images is a particularly a difficult task since it must be done while maintaining image features that are essential for diagnosis. In this research work we are using various denoising filters on ultrasound images of ovarian tumors. For different noise denoising techniques, performance measures like MSE, PSNR, SSIM, and UQI etc. are calculated. According to experimental findings, Block matching 3-D filter outperforms all other methods. Radiologists can better diagnose the condition with the use of this computer-assisted system.

Keywords- Image de-noising, ovarian cysts, Machine learning, Block-matching, Polycystic ovaries.

I. INTRODUCTION

Ovaries are reproductive glands found only in females. An ovary is a reproductive gland that creates reproductive cells in female. These ovaries are held in place by a membrane on either side of the lower abdomen, adjacent to the uterus. The ovaries are an essential part of a woman's reproductive system. They lie on each side of the uterus and produce estrogen and progesterone that are related to menstruation and pregnancy. An ovarian tumor is a cyst or an abnormal tissue growth (tumor) that may be non-cancerous i.e. benign, or malignant that develops in one or both female ovaries.

•Ovarian cyst: A cyst is a tiny sac that contains liquid, air, or another substance

•Ovarian Tumor: Any abnormal growth of additional tissue is referred to as a tumor.

•Ovarian mass: A mass may be a cyst or a tumor growth that may be benign (non-cancerous) or malignant (cancerous).

•PCO: Polycystic ovary (PCO) is a female endocrine disorder caused due to hormone imbalance that affects about 1 in 10 women. These are small follicular cysts.

Ovarian abnormalities such ovarian cysts, tumors, and polycystic ovary are among the serious disorders affecting women's health (PCO). In order to make the best judgments possible at the appropriate moment, ovarian cysts in females must be accurately detected. Ovarian ultrasound imaging is an effective tool in infertility treatment as well as in ovarian cysts detection. Monitoring the follicles (poly-cystic ovaries) and ovarian tumors/cysts is especially important when women's health is concerned. Radiologists manually observe and predict the presence of follicles or ovarian cysts.

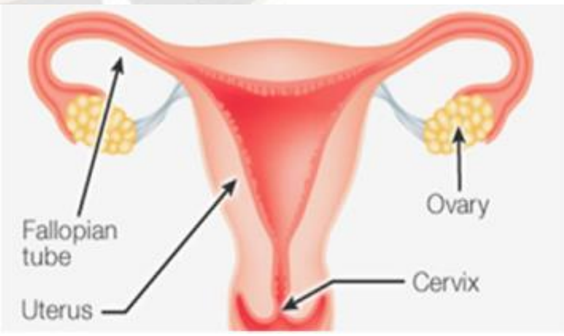

Figure 1: Female Reproductive System (everydayhealth.com)

When an ultrasound image is acquired, transmitted, and retrieved, noise is always introduced. Speckle noise, AWGN (Additive White Gaussian Noise) and salt and pepper noise are

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the three types of noise that can be found in ultrasound images [14]. The methods used to obtain medical images typically cause some noise depending on the imaging modality.

Speckle noise generally tend to reduce the image contrast and resolution and it is mostly present in ultrasound images. The image's grey level values are affected by speckle noise. As a result, the diagnostic accuracy of ultrasound imaging is reduced. In fact, the effectiveness of ultrasound imaging is degraded by speckle noise which is caused during image acquisition.

Hence noise has to be removed from such images without significantly degrading features of images used for diagnosis. . In order to make the best judgments possible at the appropriate moment, ovarian cysts in females must be accurately detected with the help of different modalities like ultrasonography, MRI or CT scan etc. In computer aided diagnosis of ovarian tumors, de-noising of medical images is a particularly a very important and difficult pre-processing task. It must be done while maintaining image features that are essential for diagnosis. In this research work we are using ultrasound images of ovarian tumors. The goal of this research is to investigate and analyze various medical image de-noising methods on ultrasound images of ovarian cysts.

II. RELATED WORK

Various image de-noising techniques used for noise removal include convolutional neural networks [23], Spatial Adaptive Mask Filter [2], Median, Gaussian and Wiener Filter [8].

The various image transformation techniques including Wavelet, Curvelet, Contourlet, Ridgelet Transform, etc., are used for the de-noising purpose in [16]. Authors in [7] have very well described image de-noising techniques based on K-SVD algorithm and bilateral filter. A bilateral filter divides the image into an edge and residual layer. Residual layer is processed by K-SVD algorithm to preserve edges of the image. A brief review of various image de-noising techniques is done [5].

Authors in [6] have compared the effectiveness of several speckle reduction filters, including Gaussian Median, Bilateral, Wiener, Guided, Non-Local Means (NLM), and Anisotropic Diffusion. Authors in [10] analyzed the different irregularities present in terms of noise in the ultrasound images and also discussed about the numerous noise filtering techniques which are used for noise removal. In comparison to the classical Wiener filter, an approach for noise reduction is found out based on the Enhanced Wiener filter. This approach automatically tunes its kernel leading to effective noise reduction by preserving edges [1]. Speckle noise present in medical ultrasound images of ovaries is removed using Gabor filtering technique in [11]. An image de-noising technique with the combination of Gaussian noise and speckle noise has been proposed in [13]. To get unique noise coefficients, the dual-tree complex wavelet transform is applied and then thresholding is used to extract the coefficients. The reconstructed image is again obtained by inverse transform. Authors in [26] have conducted a detailed analysis and review of various image denoising techniques. Convolution Auto Encoder (CAE), Fast Non Local Mean Filter (FNLM), Curve let transform, Wavelet transform and Convolution Neural Network (CNN) techniques are used for medical image denoising in [27].

III. FILTERING TECHNIQUES

Various filtering techniques are applied on available database and performance measures are calculated.

MEDIAN FILTER:

A non-linear filter used to smooth images is called the median filter. Here the value of pixel is altered by the median/middle value of its neighbors. It sorts values and finds out the middle one. It is a good strong noise removal filter but it preserves some details. The Median filter retains the edges of the image and removes noise from it. This filtering method finds the median for the center pixel and replaces it. The variations of the intensities in the image is reduced by the median filter [9]. Algorithm for median filter is shown below.

1	4	0	1	5	4
2	2	4	3	1	1
1	0	1	1	4	3
1	2	5	3	2	4
2	5	3	4	1	0
5	1	0	1	3	4

1. Read pixels-1, 4, 0, 2, 2, 4, 1, 0
2. Sort list- 0, 0, 1, 1, 1, 2, 2, 4, 4
3. Get median- 0, 0, 1, 1, **1**, 2, 2, 4
4. Replace pixel
5. Move window to next pixel

Figure 2: Median filter Algorithm

Figure.3 a) original image b) Median Filtered Image

GAUSSIAN FILTER:

Speckle noise is generally present in ultrasound images of ovaries. The Gaussian filter is commonly used to remove speckle noise from US radiographs. It is a linear filter. In this filtering technique, based on Gaussian distribution, the noisy pixel present in the image is replaced by the average value of the surrounding or neighboring pixels. In 1-D, the Gaussian function is –

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$$\mathbf{G(x)} = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-x^2}{2\sigma^2}} \quad \textbf{(1)}$$

Figure.4 a) original image b) Gaussian Filtered Image

LAPLACIAN FILTER:

This filter is used for edge detection. These filters are used to extract edges (horizontal and vertical) of the image. Laplacian for an image I(x, y) can be expressed as-

$$L(x.y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad \textbf{(2)}$$

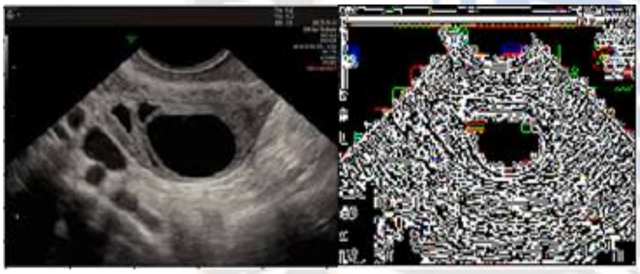

Figure .5 a) original image b) Laplacian Filtered Image

UNSHARP FILTER:

It is a sharpening operator used to enhance the edges of the image. In this filtering technique, smoothed or unsharp version of the image is subtracted from the original US image. Fig.6 shows the process of an unsharp filter.

$$\mathbf{g(x,y) = f(x.y) - f_{smooth}(x,y)} \quad \textbf{(3)}$$

Where $f(x,y)$ is the original image, $f_{smooth}(x,y)$ is the smoothed version of $f(x.y)$ and $g(x,y)$ is the edge image.

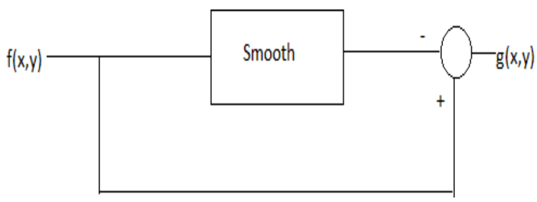

Figure .6 Unsharp Filter

Figure.7 a) original image b) Unsharp Filtered Image

BILATERAL FILTER:

The bilateral filter is a non-linear filter which preserves edges and also smoothens images. Each pixel's intensity is transformed to a weighted average of values from nearby pixels. This filter preserves the features of the image while smoothing it.

Figure. 8 a) original image b) Bilateral Filtered Image

GABOR FILTER:

A technique for denoising a digital image contaminated by additive noise is Gabor filtering. To acquire precise frequency information locally, a Gabor filter bank is used. Results of Gabor filter is shown in fig.9.

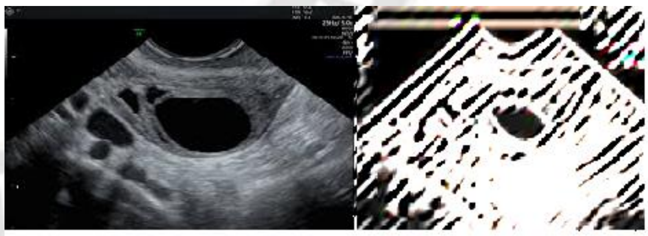

Figure.9 a) original image b) Gabor Filtered Image

NON-LOCAL MEANS FILTER:

With regard to how closely the pixels match the primary or target pixel, non-local means filter takes the mean or average of all the pixels in the image. It is simple and has good noise removal performance while retaining the edges of an image. NLM can be expressed as-

$$\mathbf{NLu_{(p)}} = \frac{\mathbf{1}}{\mathbf{C_p}} \int \mathbf{f(d(B_{(p)}, B_{(q)}))\, u_q d_q} \quad \textbf{(4)}$$

Where $d(B_{(p)}, B_{(q)})$ is Euclidean distance, Cp is the normalizing and f is a decreasing function.

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BLOCK MATCHING AND 3-D FILTERING:

It is a collaborative filtering process in which based on similarity, image fragments are grouped. Block matching is the grouping of fragments. If its dissimilarity with a reference fragment falls below a specified threshold, all blocks are then stacked together to form 3D cylinder like shape. The filtering process is done on every block by applying linear transform followed by Wiener filter. At the end, image is transformed in its 2D form.

IV. EVALUATION OF PERFORMANCE METRICS

Images are subjected to various types of distortions from capturing to displaying process. Hence evaluation of image quality at different stages of processing is very essential. Image de-noising techniques can be evaluated using different performance metrics.

MSE:

MSE stands for Mean Square Error. It can be calculated by averaging squared intensities of input (original image) and output (resultant) image pixels. If MxN is size of the image then-

$$\mathbf{MSE} = \frac{1}{N * M}\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}[x(i,j) - y(i,j)]^2 \qquad (5)$$

Where $x(i,j)$ is original image and $y(i,j)$ is the resultant or noisy image.

PSNR:

Peak Signal to Noise Ratio is referred to as PSNR. The higher value of PSNR indicates an adequate reconstruction. It can be expressed in dB as-

$$\mathbf{PSNR} = 10\log_{10}\left(\frac{L^2}{MSE}\right) \qquad (6)$$

Where L denotes the dynamic range of pixel intensities which is 255 for an 8-bit image.

RMSE:

Root Mean Square Error is referred to as RMSE. It is the square root of Mean Square Error (MSE). It indicates a change in pixel while processing.

$$\mathbf{RMSE} = \sqrt{MSE} \qquad (7)$$

SSIM:

The resemblance between two images is determined using structural similarity. It requires a reference image and a processed image to find similarity. The SSIM is given by-

$$\mathbf{SSIM} = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu^2x + \mu^2y + c_1)(\sigma^2x + \sigma^2y + c_2)} \qquad (8)$$

Where $\sigma^2 x$ and $\sigma^2 y$ denotes the variance of x and y respectively μ_x and μ_y are average values of x and y respectively while σxy is the covariance.

UQI:

UQI stands for Universal image quality index. It is used for measuring distortions in an image [24]. It can be calculated as-

$$\mathbf{Q} = \frac{\sigma_{xy}}{\sigma_x\sigma_y}.\frac{2\bar{x}\bar{y}}{(\bar{x}^2)(\bar{y}^2)}.\frac{2\sigma_x\sigma_y}{\sigma_x{}^2+\sigma_y{}^2} \qquad (9)$$

VIFP: (PIXEL-BASED VISUAL INFORMATION FIDELITY):

The VIF index uses combination of a channel (distortion) model and Natural Scene Statistical (NSS) models to measure the information shared between the resultant and original images.

V. PERFORMANCE PARAMETERS AND RESULTS

The dataset consists of total 187 ultrasonography images of ovarian tumors out of which 112 images are benign (non-cancerous) and 75 are malignant (cancerous) (source: osf.io/n9abq) [25] and the simulation results are obtained.

All performance parameters are calculated using Python open source software programming language. Table 1 gives performance measures obtained from ultrasound images (US) of ovarian cysts and poly-cystic ovaries (PCO).

Ideal values of all performance measures are also mentioned in table 1. Table 1 shows that BM3D filtering approach gives better performance as compared to other filtering methods on available database. This BM3D approach outperforms with optimal values in all performance measures with PSNR (71.88), MSE (0.00), SSIM (0.999), RMSE (0.0010), UQI (0.964) and VIFP (0.999). Fig.10 reveals the simulation results for ovarian cyst and PCO US images using different filtering techniques and graphical analysis of all parameters of different filters is shown in fig.11.

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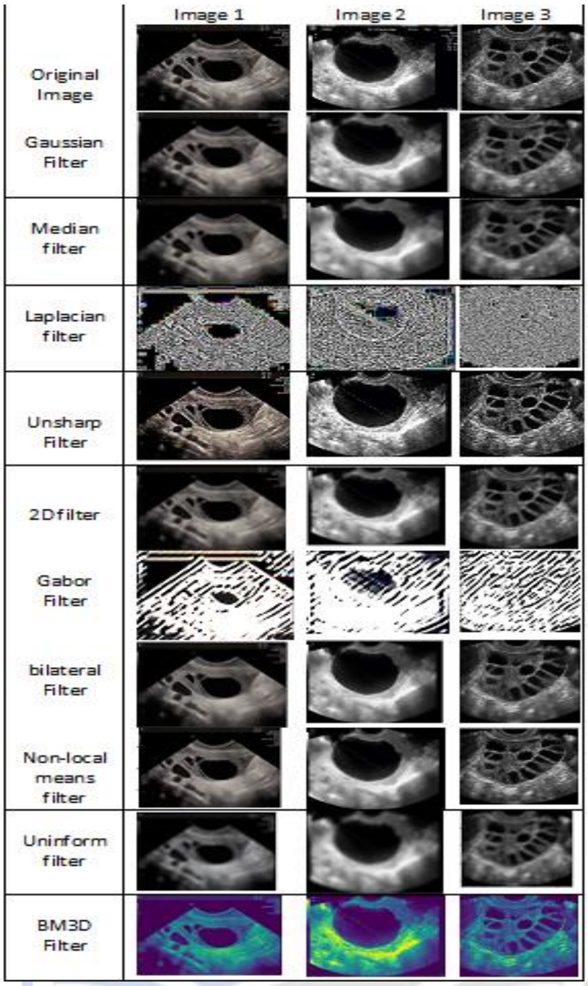

Figure 10. Simulation Results of Ultrasound Images of Ovarian Cysts and PCOs

TABLE I: Performance Measures for Ovarian Tumors and PCO ultrasound images

SN.	**Filtering Methods**	**PSNR**	**MSE**	**SSIM**	**RMSE**	**UQI**	**VIFP**
	Ideal Values	**INF**	**0**	**1**	**0**	**1**	**1**
1	Gaussian Filter	24.79	54.31	0.701	0.1837	0.921	0.333
2	Median filter	23.52	53.91	0.61	0.2127	0.904	0.265
3	Laplacian filter	7.59	11888.78	0.102	1.2657	0.037	0
4	unsharp Filter	9.55	7648.43	0.13	0.995	0	0.002
5	Gabor Filter	4.35	93.36	0.07	1.844	0.328	0.017
6	bilateral Filter	32.24	39.69	0.872	0.0913	0.925	0.525
7	NLM filter	33.3	22.08	0.906	0.0673	0.96	0.654
8	**BM3D Filter**	**71.88**	**0**	**0.999**	**0.001**	**0.964**	**0.999**

Fig.11 Comparison of all parameters for various filtering methods

VI. CONCLUSION

The ovarian ultrasound images in grayscale are influenced by noises like Poisson Noise, Speckle Noise, Salt and Pepper and Gaussian Noise. This noise has to be removed without losing significant features from image. Hence machine learning techniques have been used to implement various de-noising methods with filters. Results show that BM3D filter performs well in all denoising methods applied. In future, we can use hybrid image denoising techniques to get better performance. After denoising, the images can be processed for segmentation, feature extraction and classification. This approach will definitely help in computer aided diagnosis of ovarian tumors.

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None.

CONFLICT OF INTEREST

The authors declare that they have no financial or other conflicts of interest.

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