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Cascaded Filter Analysis on Ultrasound Images of Fetus

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***Abstract*—Ultrasound imaging plays a vital role during fetal development. So from past few decades various kinds of research have been done on ultrasound images. One of the challenging tasks in image processing is to remove or reduce noise present in these ultrasound image. In this paper, we have proposed a method to reduce the noise. Various types of filters have been used like Gaussian, median, wiener, laplacian etc. To enhance the features of the fetus, the concept of hybridization of filters is used. As per the experimental results, set the parameters of the filters like Gaussian (Sigma 2), laplacian (Window size 3x3), wiener (Window size 3x3), median (Window size 3x3). It is observed that wiener filter enhance the fetus ultrasound image more effectively while other filters like laplacian, wiener and median produce better enhance image. We will compare the effectiveness of the filters on fetus ultrasound images.**

***Index Terms*— Ultrasound images, filters, PSNR, speckle noise, Cascaded.**

I. Introduction

Fetus recognition and their biometric parameters is a field of ongoing research. A single and fertilized cell transforms into new born human called Fetus which develops from an embryo [1]. Ultrasound imaging system is broadly used for diagnostic tool for medical. Ultrasound in general means sound waves with frequencies which are higher than the upper audible limit of a human. It indicates that humans cannot hear it. These devices operate with frequencies from 20 kilohertz to many gigahertzes. Ultrasound imaging has been introduced in various industrial and medical fields to provide a non-destructive, real-time and non-invasive technique. Ultrasound allows anyone to examine and visualize any part of a human anatomy [2]. Unlike other imaging techniques used in medical field, ultrasound does not use radiation. Because of this reason ultrasound method is mainly used for fetal detection during pregnancy. Ultrasound image quality usually degraded by noise in the process of image acquisition because of low quality image generation system. These noises are main cause which degrades the ultrasound image. It is mandatory to remove the noise speckle noise, Gaussian noise etc., from ultrasound image. There are different types of filters used with different parameters which are useful in removing noise from ultrasound images. Gaussian filter with sigma value 2, laplacian filter with window size 3x3, wiener filter with window size 3x3 and median filter with window size 3x3 have been used here. Because of this the images obtained are unclear for any further interpretation as they may contain artifacts such as shadows and reverberations [3]. (Speckle noise contains a high grey level intensity which ranges between hypo echoic (dark) and hyper echoic (bright) [4].

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II. Literature Survey

To analyse the fetus development, various parameters can be taken into observation such as heart rate monitoring, facial standard plane and biometrics of fetus etc. All these parameters can be evaluated accurately in the form of features. These features are extracted from ultrasound images. These ultrasound images should be noise free. Various types of noise such as speckle noise, salt and pepper noise, Poisson noise and Gaussian noise may exist while capturing images. Henceforth for further evaluation preprocessing of the images must be done. But enhancement and restoration of noisy images is a problem. Various filtering techniques are being used in order to improve the quality of images by removing the noise. Mainly two types of filter are there, linear and non-linear. Some of the filters used are:

- Median Filter (non-linear) Gaussian Filter
- Kalman Filter Mean Filter (linear)
- Laplacian Filter Weiner Filter

Kalman filter (KF) is known to be an effective method to estimate parameters containing Gaussian distributed measurement noise [5]. Kalman filter has proved its potential by correctly estimating the maternal signals in order to extract fHR in electrocardiographic recordings [6]. But after a thorough inspection it is found that among many filters, Weiner filtering technique is best to reduce the speckle present in image without fully eliminating image edges. Weiner filters are mostly used for inverse problems. Based on this filter, adaptive Weiner filtering of image sequences and noisy images was also considered [7]. Main principle of this filter is to minimize a mean square error (MSE) among original and restored image. Weiner filter may provide best signal which is restored with respect to square error averaged over original signal and noise [8]. To estimate the second order statistics, an adaptive weighted averaging approach was used. After applying the filters, the performance is analysed to check which filter works best with help of parameters such as PSNR, MSE and RMSE (Root Mean Square Error). PSNR values evaluates the peak signal to noise ratio, between the two images i.e., the original and the filtered output image. The higher the value of PSNR the better is the quality of the reconstructed or output image. Ada boost was used for anatomical object detection in 2D fetal abdominal ultrasound images, in which the framework was designed to identify the correct abdominal landmarks required for a standard plane [16]. A graph-based approach was applied for automatic detection of the fetal skull, in which the shortest circular path was detected [17]. Random Forest was used to segment a head contour in fetal ultrasound scans which were obtained with a low-cost probe [18]. Random Forests was used to perform fetal femur segmentation from 3D ultrasound volumes [19] which was later updated to automatically detect local brain structures in 3D fetal ultrasound images [20]. Namburete et al. (2015) used Regression Forests were used to estimate the gestational age of a fetus from sonographic signatures in the brain [21]. A convolutional neural network (CNN) was used for standard plane localization of the skull and abdomen from an ultrasound video [22]. CNN was used in standard plane detection for partitioning ultrasound video [23].

III. Methodology

In the proposed work, ultrasound images of fetus have been taken. These images may contain various noises such as speckle noise, Gaussian noise, pepper and salt noise. So, it is mandatory to remove noise from the ultrasound images which makes the image more visible and preserves the features of the fetus. These features are used for the estimation of the proper development of the fetus like gestational age and biometric parameters like length, BPD (biparietal diameter) etc. The cascaded filters are used to remove multiple noises present in an image. The cascaded filter is integration of two filters like wiener followed by median filter, median followed by laplacian filter, Gaussian followed by laplacian filter etc. The process of noise removal is shown in Fig 1.

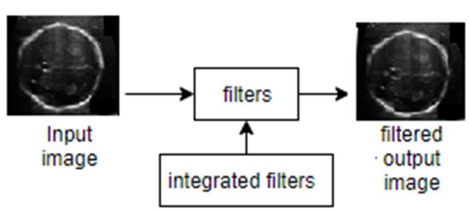


Figure 1: noise removal integrated filters

Cascaded filters are combination of following filters:

A. Wiener filter

Wiener filter is being used to reduce Speckle Noise. Wiener filter decreases noise from the two-dimensional images. Weiner filter is a low-pass filter applied in the frequency domain. The Wiener filtering executes an optimal trade-off between inverse filtering and noise smoothing. Window size as 3×3 used in this experiment. When this filter is applied to an input image the different distribution of image and noise signal is important, as shown in the following equation [24]:

$$R(x, y) = \frac{1}{1+[\frac{S_{ns}(x,y)}{S_{is}(x,y)}]} \qquad (1)$$

Where the symbol S_{is} is density of image signal, and the symbol S_{ns} is density of noise signal. Finally after the estimation of both, noise and image signals, weiner filter does smooth the input ultrasound image.

B. Gaussian filter

The Gaussian filter is discontinuous low pass filter. Gaussian smoothing filter is a instance of weighted averaging. It puts more weight on central pixels and less weights to others or in other words on neighbours. In this technique, the average value of the surrounding or neighbouring pixels is replaced by the noisy pixel based on the Gaussian distribution [25].

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (2)$$

Mean value of Gaussian filter depends on value of sigma. The more would be sigma then the more changes would be in mean and the less would be sigma then the less changes would be in mean. High values of sigma produces broader peak.

C. Median filter

Median filter is a Non-Linear filter used to remove the speckle noise. It is edge preserving filter. It works best with salt and pepper noise. Surrounding pixel values are sorted to an orderly set in the window by the median filter. It replaces the center pixel value with the middle value [26] as shown in equation (3).

$$f(x,y) = median \sum(s,t) \epsilon S_{XY} \{g(s,t)\} \qquad (3)$$

Where S_{XY} represents the set of coordinates in a rectangular sub image window, centered at point (x, y), and Median represents the Median value of the window.

D. Laplacian filter

Laplacian filters are derivative filters which are used to find areas of rapid change (edges) in images. Laplacian filter differ from other operators like Prewitt, Sobel, Robinson and Kirsch as these operators are all first order derivative masks whereas Laplacian is a second order derivative mask. This mask is further classified into two operators: one is Positive Laplacian Operator and other is Negative Laplacian Operator [27]. Masks of laplacian filter are shown as:

0	1	0
1	-4	1
0	1	0

0	-1	0
-1	4	-1
0	-1	0

Figure 2. 3x3 laplacian mask [27]

E. Histogram equalization

Histogram equalization is a technique to intensify the contrast of colour image. It is one of the easiest ways which increases the quality of the image. It diffuses the pixels of the image on wide range for intensifying the contrast of image. It is the procedure which reallocates the pixels of the image [28].

IV. Algorithm

A. Ultrasound images of fetus are taken as input I. If input I images are in 3D then need to convert into 2D images.
B. The 2D input I images are passed through various cascaded filters with the window size 3x3 and parameters like sigma=2.
C. Cascaded filters are:

1. Wiener filter followed by median filter(WM)
2. Median filter followed by laplacian filter(ML)
3. Gaussian filter followed by median filter(GM)
4. Gaussian filter followed by wiener filter(GW)
5. Gaussian filter followed by laplacian filter(GL)
6. Wiener filter followed by Gaussian filter(WG)
7. Histogram equalization followed by wiener filter(HW)

D. The various enhanced output images are found from step 2 and compared using PSNR values.

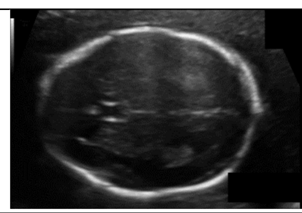
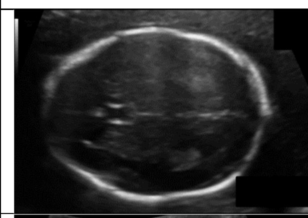
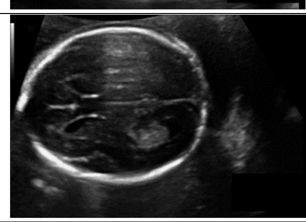
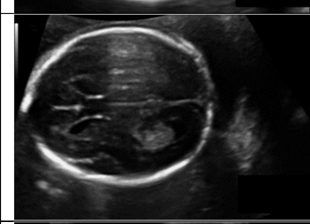
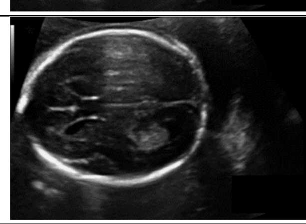
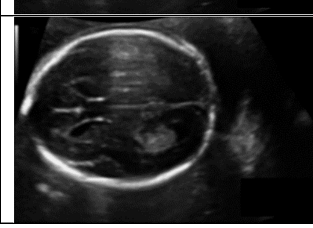
V. EXPERIMENTAL RESULTS AND ANALYSIS

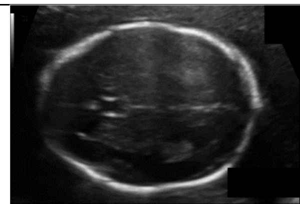
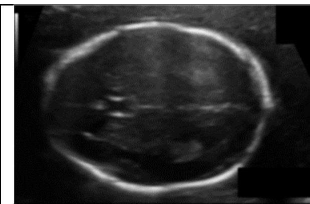
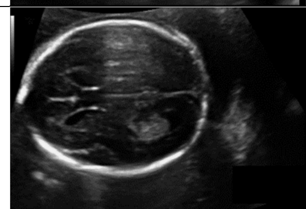
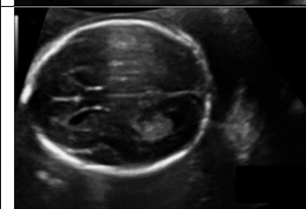
In this experiment fifteen 2D ultrasound images of fetus are used [29]. These ultrasound image size is 800×540 in x, y direction. Seven cascaded filters are simulated over MATLAB 2017b 9.3.0. For efficient noise removal from the ultrasound images, a combination of different filters is considered taking window size 3×3 and proposed sigma value is 2. Calculate the Peak Signal to Noise Ratio PSNR values and compared it. PSNR value measures the quality between original image and compressed image. It is defined as [31]:

$$PSNR = 10log_{10}\frac{peak^2}{MSE} \tag{4}$$

In the above equation (4), *peak* is the maximum value of 8 bit representation which is commonly chosen as 255. Histogram equalization with filters is used to remove the noise which results in lesser PSNR value. A quantitative analysis of combination of filters: wiener with median, median with laplacian, Gaussian with laplacian, laplacian with wiener, Gaussian with wiener, Gaussian with median etc. These cascaded filters are used for noise reduction. Cascaded filters and the output images of 15 ultrasound images are shown in table 1.

TABLE 1: CASCADED FILTERED ENHANCED IMAGES OF FETUS

Cascaded filter	Average PSNR for 15 us images	Original image	Filtered image
Wiener and median Window size 3x3 Iteration single	46.68		
Median and laplacian Window size 3x3 Iteration single	38.27		
Laplacian and wiener Window size 3x3 Iteration single	38.15		

Gaussian and median Sigma 2 Window size 3x3 Iteration single	34.45		
Gaussian and wiener Sigma 2 Window size 3x3 Iteration single	34.33		
Gaussian and laplacian Sigma 2 Window size 3x3 Iteration single	34.11		

The performance analysis of these filters measured on the basis of the performance index PSNR with the different parameter selection. PSNR values obtained after passing the images through the cascaded filters are shown in the table 2. From table 2 it is evident that the combination of wiener and median gives best performance with an average value of 46.682 (range lies between 44 - 48). Median with laplacian also gives good result but less effective when compared to the above combination of filters. It can be observed that Gaussian with median and Gaussian with wiener and Gaussian with laplacian give almost similar results for all the images used because they have same average PSNR values 34db (range between 32db- 36db) for all 15 ultrasound images. So essence of cascaded filters GM, GW, GL are same and PSNR value of images becomes approximately same. WM and ML have best PSNR values for all images because ideally PSNR value should be greater than 35db and all input images have greater than 35db PSNR. Histogram equalization and wiener cascaded filter able to produce worst PSNR value (8.9db). Its range lies between 7db-11db because in histogram equalization, all the pixel values are to be transformed in CDF (cumulative distribution function). And wiener filter transform or change the pixel value in a normalized value 0 to 1. Due to this reason, intensity values have been changed. After the analysis with the help of corresponding result we observed that median with wiener performance is very effective in order to remove noise from ultrasound image. PSNR values of the cascaded filters are given in the table 2:

TABLE II: PSNR VALUES OF CASCADED FILTERS OF FETUS IMAGES

	WM	ML	GM	GW	GL	WG	HW
Name	PSNR	PSNR	PSNR	PSNR	PSNR	PSNR	PSNR
img1	44.852	36.610	32.830	32.716	32.488	30.467	8.908
img2	45.625	36.909	33.199	33.073	32.945	30.759	10.433
img3	47.259	38.756	35.086	34.997	34.797	32.749	7.700
img4	47.027	38.601	34.696	34.577	34.304	32.148	9.087
img5	47.744	39.340	35.528	35.422	35.148	32.987	7.973
img6	45.296	36.759	32.832	32.688	32.502	30.277	9.708
img7	47.126	38.413	34.650	34.537	34.325	32.064	8.980
img8	44.672	37.166	33.527	33.438	33.254	31.421	7.903
img9	46.759	35.889	32.623	32.530	32.347	30.421	10.292

img10	44.630	35.700	32.254	32.108	32.063	29.933	12.489
img11	46.579	38.183	34.385	34.273	34.030	31.925	8.136
img12	47.200	38.773	34.819	34.699	34.436	32.197	8.751
img13	47.495	36.773	33.593	33.498	33.375	31.442	11.560
img14	47.237	38.261	34.533	34.422	34.188	32.032	8.563
img15	47.914	39.908	36.088	35.996	35.713	33.559	7.916
img16	47.688	40.498	36.192	36.061	35.747	33.429	8.021
img17	47.418	40.797	35.849	35.715	35.315	32.805	7.678
img18	44.404	37.653	33.332	33.185	32.963	30.832	8.734
img19	48.156	40.379	36.362	36.259	36.007	33.720	7.624
img20	48.564	40.216	36.642	36.576	36.330	34.218	7.937
AVG	**46.682**	**38.279**	**34.451**	**34.339**	**34.114**	**31.969**	**8.920**

TABLE III: COMPARISON OF PSNR VALUES OF PROPOSED METHOD WITH OTHER METHODS

SNO	Author/Paper	Method		PSNR Value		
1	Speckle Noise Reduction in Fetal Ultrasound Images [9]	Wiener +Median +UDWT (undecimated wavelet transform)		88.81- 90.37		
2	Despeckle Process in Ultrasound Fetal Image using Hybrid Spatial Filters [10]			σ2 =0.04	σ2 =0.06	σ2= 0.08
		Mean		33.33	33.34	33.28
		Median		32.79	32.59	32.28
		Weiner		34.17	33.93	33.63
		M.Med (NDMax) +M..Medn (N4Max)		45.93	45.67	45.72
3	Study of Speckle Noise Reduction from Ultrasound B-mode Images using Different Filtering Techniques [11]	Median		36.4		
		Frost		34.3		
		Lee		34.9		
		Kuan		34.9		
		Weiner		38.3		
4	Speckle Reduction on Ultrasound Liver Images Based on a Sparse Representation over a Learned Dictionary [12]			σ =10	σ =15	
		Frost		32.46	28.96	
		Median		34.59	25.49	
		Kuan		32.89	28.27	
		Weiner		33.78	29.21	
5	Comparative Analysis of Spatial Filtering Techniques in Ultrasound Images [13]	LINEAR	NON-LINEAR	LINEAR	NON-LINEAR	
		Kaun	Max	33.4713	24.9032	
		Lee	Min	34.5362	25.5246	
		Mean	Median	34.5221	35.6084	
6	Speckle Noise Reduction in ultrasound fetal images using edge preserving adaptive shock filters [14]	Kaun		16.57		
		Lee		8.57		
		Frost		20.65		
		Gabor		20.73		
		Adaptive Shock		21.53		
7	Performance Enhancement and Analysis of Filters in Ultrasound Image Denoising [15]			σ =0.01	σ =40	σ =100
		Gaussian		25.6709	25.7037	25.7035
		Bilateral		25.6709	10.6169	10.5807
		Laplacian		19.5289	10.7212	10.7915
8	Proposed Method- Cascaded filter analysis	Weiner+ Median		46.682		
		Median+ Laplacian		40.379		
		Gaussian+ Median		36.642		
		Mean+ Weiner		40.240		

The proposed cascaded filter with the existing comparing filters for noise reduction in ultrasound images are shown in table 3. As shown in the table 3, filters used such as mean, median, Gaussian and Weiner gave different PSNR (Peak Signal to Noise Ratio) values. On an average median filter gave 35.60, Mean filter gave 34.50 and Weiner filter gave 33.20 PSNR value. Cascaded filters give better results where images are passed through these filters like Weiner + Median gave highest value with 46.68. Above obtained results show that the proposed method achieve better results compared to individual filters. All the four proposed cascaded filters give higher PSNR as compare to other individual filters.

VI. Conclusions

Advancement in different technologies led to advanced ultrasound diagnostics. Still many ultrasound images are found with noise. De-noising can be done by applying filtering techniques. Even though many methods (using filters) have been applied to remove the noise, there is still a need of good filtering technique. To resolve this problem in this paper we have proposed a method in which noise is removed by using cascaded filters rather than individual filters. The enhancement of the image and noise reduction is performed by the WM cascaded filter. ML cascaded filter produced better noise reduction while GM, GW, GL have same essence of noise reduction. Histogram and wiener cascaded filter distort the spatial pixel values because of histogram equalization. So histogram equalization is not a good solution to de-noise an ultra sound image.

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