Iraqi Journal of Science
ISSN: 0067-2904

Noise Reduction and Gestational Age Estimation for Ultrasound Fetuses Images.

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Abstract

Ultrasound imaging is often preferred over other medical imaging modalities because it is non-invasive, non-ionizing, and low-cost. However, the main weakness of medical ultrasound image is the poor quality of images, due to presence of speckle noise and blurring. Speckle is characteristic phenomenon in ultrasound images, which can be described as random multiplicative noise that occurrence is often undesirable, since it affects the tasks of human interpretation and diagnosis. Blurring is a form of bandwidth reduction of an ideal image owing to the imperfect image formation process. Image denoising involves processing of the image data to produce a visually high quality image. The denoising algorithms may be classified into two categories, spatial filtering algorithms and transform domain based algorithms. In this work three adaptive filters are used to denoising speckle noise in ultrasonic (B-mode) images based on calculating the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) value as a metric is presented, then estimated the gestation age from filtered images using MATLAB program, as well as using Wiener filter to restore the degradation images.

Keywords: Noise Reduction , Gestational Age, Ultrasound Fetuses Images.

الحد من الضوضاء وتقدير عمر الأجنة لصور الموجات فوق الصوتية.

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الخلاصة

التصوير بالموجات فوق الصوتية غالباً ما يفضل على تقنيات التصوير الطبي الأخرى لأنها تقنية غيرظارة وغيرمؤينة ومنخفضة التكلفة. ان نقطة الضعف الرئيسية في الصور الطبية للموجات فوق الصوتية هي رداءة نوعية الصور وعدم وضوحها، وذلك بسبب وجود ضوضاء البقع واللطخ. ان ضوضاء البقع واللطخ هي ظاهرة مميزة في عملية التصوير بالموجات فوق الصوتية، والتي يمكن وصفها بأنها ضجيج عشوائي مضاعف ،وجود هذه الضوضاء امر غير مرغوب فيه لأنها تؤثر سلبآ في عملية التشخيص الطبي. ان تقليل ضوضاء الصورة تنطوي على معالجة بيانات الصورة لإنتاج صورة ذات جودة عالية بصريا. وخوارزميات ازالة العشوائية يمكن تصنيفها إلى فئتين، خوارزميات التصفية المكانية وخوارزميات تستند إلى مجال التحويل. في هذا العمل استخدمنا ثلاث انواع من الفلاتر لتقليل ضوضاء البقع واللطخ في صور الموجات فوق الصوتية (B–mode) استناداً إلى حساب متوسط مربع الخطأ (MSE) وذروة إشارة إلى قيمة نسبة الضوضاء

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(PSNR) ، ثم خمنا عمر الجنين من الصور التي تمت فلترتها باستخدام برنامج الماتلاب. ايضاً استعملنا المرشح(Wiener) للتخلص من عدم وضوحية الصور.

1. Introduction

Ultrasound (US) imaging, as a tool for medical diagnosis, is widely used in clinical practice, and in some situation sit has become a standard procedure. the US medical imaging technique used to visualize muscles and many internal organs, their size, structure and any pathological injuries with real time tomographic images. It is also used to visualize a fetus during routine and emergency prenatal care. Obstetric sonography is commonly used during pregnancy. It is one of the most widely used diagnostic tools in modern medicine. This technology is relatively inexpensive and portable, especially when compared with other imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT). It has no known long-term side effects and rarely causes any discomfort to the patient. Small, easily carried scanners are available; examinations can be performed at the bedside. Since it does not use ionizing radiation, US yields no risks to the patient. It provides live images, where the operator can select the most useful section for diagnosing thus facilitating quick diagnoses.

Diagnostic ultrasound (sonography) imaging is obtained from the reconstruction of the reflected echoes. Diagnostic ultrasound typically operates within the (1-15 MHz) frequencies, and the corresponding wavelengths are (0.1-1.5 mm). When performing US imaging at high frequencies (above 15 MHz), the acoustic wave penetrates less due to absorption, and at low frequencies (lower than 1 MHz), far organs can be visualized but low-resolution images are obtained. The brightness of the image at each point corresponds to the strength of the echo that provides information about the position of its origin within the body [1]. Figure-1 represents the US machine and its parts using in medical diagnostic.

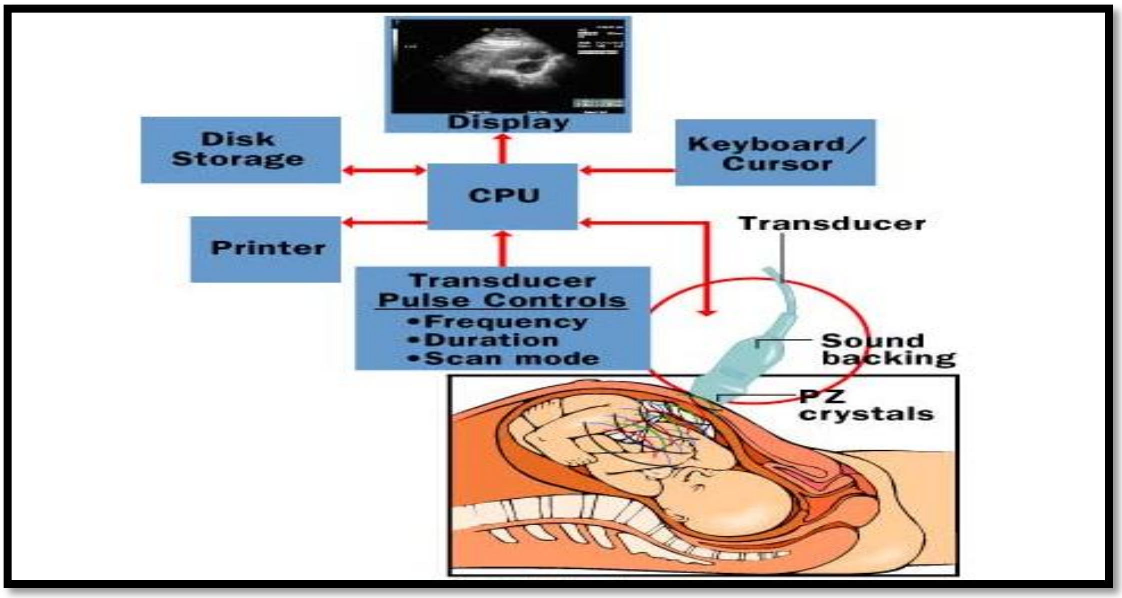


Figure1-The parts of an ultrasound machine[internet web site-www.physics.utoronto.ca].

A basic ultrasound machine has many parts as shown in Figure-1are transducer probe: probe that sends and receives the sound waves. Central Processing Unit (CPU): computer that does all of the calculations and contains the electrical power supplies for itself and the transducer probe. transducer pulse controls: changes the amplitude, frequency and duration of the pulses emitted from the transducer probe. display: displays the image from the ultrasound data processed by the CPU. keyboard/cursor - inputs data and takes measurements from the display. disk storage device (hard, floppy, CD): stores the acquired images, and printer: prints the image from the displayed data.

US images are pervaded by the speckle artifact and. This artifact introduces fine-false structures whose apparent resolution is beyond the capabilities of the imaging system, reducing image contrast and masking the real boundaries of the tissue under investigation. Its occurrence may substantially compromise the diagnostic effectiveness, introducing a great level of subjectivity in the interpretation of the images. Speckle can be defined as a destructive interference artifact and its severity depends on the relative phase between two overlapping returning echoes [2]. In This work three filters are used to suppress speckle in US fetal images are Lee, Frost and Kuan filter.

2. Filtering Techniques

Speckle differs from other types of noise in the sense that it is a deterministic artifact, meaning that two signals or images, acquired under exactly the same circumstances, will experience exactly the same speckle corruption pattern but if some or all of the circumstances differ, the speckle corruption pattern will be different. Speckle texture is usually retained in the high-intensity region. In speckle filtering a kernel is being moved over each pixel in the image and applying some mathematical calculation by using these pixel values under the kernel and replaced the central pixel with calculated value. The kernel is moved along the image only one pixel at a time until the whole image covered.

2.1 Lee Filter

It is developed by Jong Sen Lee in 1981. It is better than others filters in edge preservation. It is based on multiplicative speckle model and uses local statistics to preserve details. Lee filter works on the variance basis, i.e. if variance of the area is low then it performs smoothing operation but not for high variance. That means it can preserve details in low as well as in high contrast hence it has adaptive nature. Mathematical model for Lee filter is given in equation(1) [3]:

$$\mathrm{Img}\,(i,j) = \mathrm{Im} + W^{*}(\mathrm{cp} - \mathrm{Im}) \qquad (1)$$

where: Img = pixel value after filtering.
Im = mean intensity of filter window.
cp = Center pixel.
W = filter window, $W = \sigma^2(\sigma^2 + p^2)$.
σ^2 = is the variance of the pixel calculated as.
$\sigma^2 = [{}^{1}/_{N} \sum_{j=0}^{N-1} (X_j)^2]$.
N = size of filter window, X_j = pixel value at j.
p = additive noise variance, for M size of image and (Y_i) value of each pixel it is given as: $p^2 = [{}^{1}/_{M} \sum_{j=0}^{M-1} Y_i]$.

2.2 Frost filter

Invented by Frost in 1982, is linear, convolutional filter used to remove the multiplicative noise from images. Frost filter works on the basis of coefficient of variation which is the ratio of local standard deviation to the local mean of the corrupted image. Within the kernel the centre pixel value is replaced by weighted sum of values of the neighbourhood in kernel. The weighting factor decrease as we go away from interested pixel and increase with variance. It assumes multiplicative noise [4].

$$\mathrm{DN} = \sum_{n\times n} K\alpha\, e^{-\alpha|t|} \qquad (2)$$

where $\alpha = \left(\frac{4}{n\overline{\sigma^2}}\right)\left(\frac{\overline{\sigma^2}}{\overline{I}^2}\right)$

DN=output value.
K= Normalized constant.
$\overline{I}$ = Local Mean.
σ = Local variance.
$\overline{\sigma}$ = Image coefficient of variation value.
$|t| = |X - X_0| + |Y - Y_0|$.
n = moving kernel size.

2.3 Kuan filter

It was developed by Kuan and Nathan and Kurlander in 1987. It is local linear minimum mean square error filter under multiplicative noise. It is quite advanced than Lee filter in a factor as it has no approximation involved. It transforms the multiplicative speckle model into the additive linear form [5]. Weighted function W for Kuan filter is given by equation (3).

$$W = \left(\frac{1-\frac{cu}{ci}}{1+cu}\right) \tag{3}$$

where: cu = estimated noise variation coefficient.

$cu = \sqrt{1/_{ENL}}$, ENL = equivalent noise looks.

ci = variation coefficient of image.

$ci = {}^{s}/_{Im}$. Im = mean intensity of filter window.

s = standard deviation in the filter window.

To analysis the performance of filters, two performance analysis parameters are used are Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR). PSNR is one of the best known techniques for assessing the amount of noise that an image is polluted with and, for that matter, the amount of noise left in a filtered image. The peak signal-to-noise criterion is adopted to measure the performance of various digital filtering techniques quantitatively [6]. This is defined as equation (4).

$$PSNR = 20 \log_{10}\left(\frac{255}{RMSE}\right) \tag{4}$$

where RMSE It measures the average squared difference between the original (I_{ref}) and filtered (I_{filt}) images, where the original and filtered images have size (X × Y) pixels. Accordingly, the RMSE equation (6) is the root of MSE given in equation (5) [6].

$$MSE(I_{filt}, I_{ref}) = \frac{1}{XY}\sum_{i=1}^{Y}\sum_{j=1}^{X}(I_{filt}(i,j) - I_{ref}(i,j))^2 \tag{5}$$

$$RMSE = \sqrt{MSE} \tag{6}$$

3. Fetal Imaging Ultrasound

Two dimension US is routinely used in obstetric applications to monitor fetal, diagnose congenital abnormalities of the fetus, evaluate the position of the fetus, evaluate the position of the placenta, determine if there are multiple pregnancies, determine the amount of amniotic fluid around the baby, and check for opening or shortening of the cervix or mouth of the womb. US measurements of specific features of fetal anatomy such as crown rump length(CRL) in first trimester ,and femur length (FL) in the second and third trimester, these biometric are used in the determination of GA, assessment of growth patterns, and identification of anomalies.

3.1 Crown Rump Length

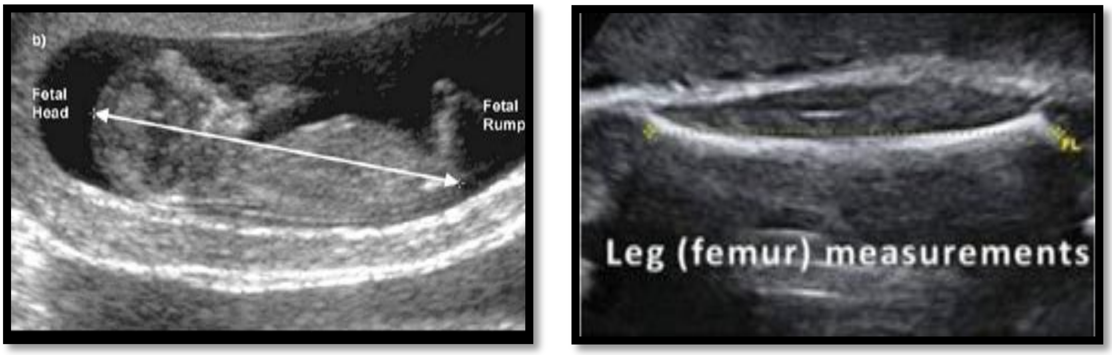
CRL is one of the most reliable ultrasonic biometric parameter. It is used in the first trimester. By seven weeks, the embryo is clearly seen in the gestational sac and its CRL can be measured in long axis. By this time, the yolk sac can be seen in relation to the ventral surface of the embryo. The presence of the yolk sac is deemed to be an encouraging sign of fetal well being and it remains visible until about 10 weeks of gestation[7]. Once the CRL(mm) is computed, the GA(weeks) is computed using the Hadlock regression formula [8].

$$GA = -0.0007\,(CRL)^2 + 0.1584\,(CRL) + 5.2876 \tag{7}$$

3.2 Femur Length

Femur length is a very useful biometric parameter used in the second and third trimesters of pregnancy. It grows linear throughout and is best measured after 14 weeks of gestation. The diaphysis is measured from the greater trochanter above to the lateral condyle below. The outer border of femur is straight and the inner border is curved normally [9], Figure -1 shown the FL and CRL. Once the FL(cm) is computed, the GA is computed using the Hadlock regression formula equation(8) [8].

$$GA = 1.863 + 6.280FL - 0.211FL^2 \tag{8}$$

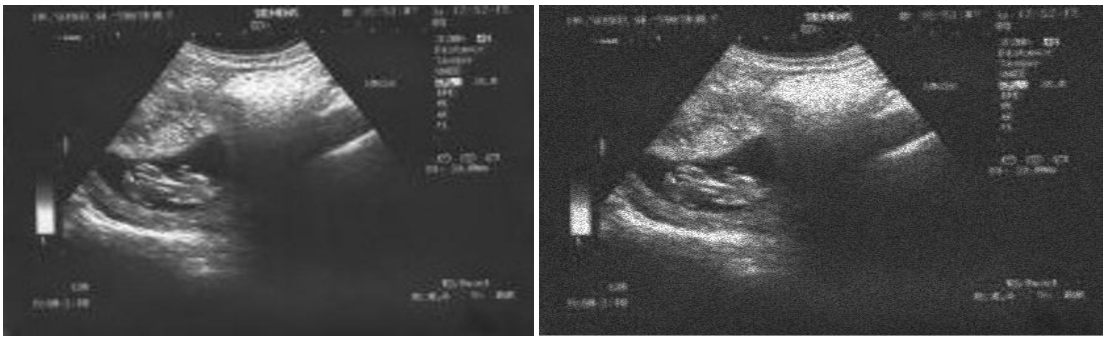


(i) (ii)

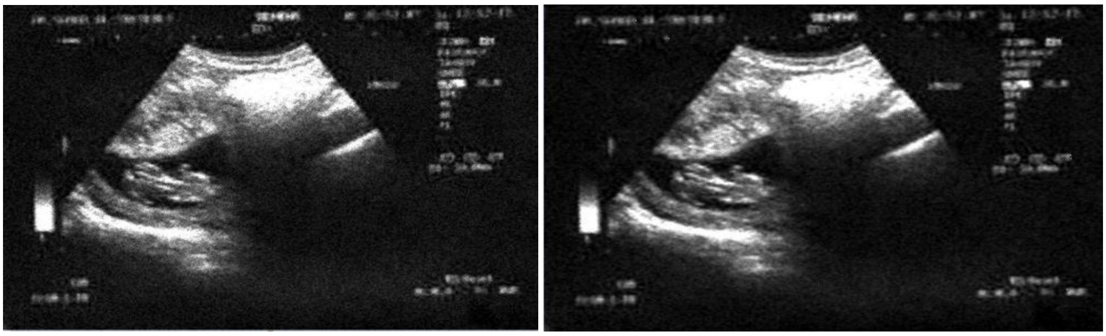
Figure2- (i) represent crown rump length(CRL), (ii)represent femur length (FL) [internet web site-www.researchgate.net].

4. Experimental results and Discussions

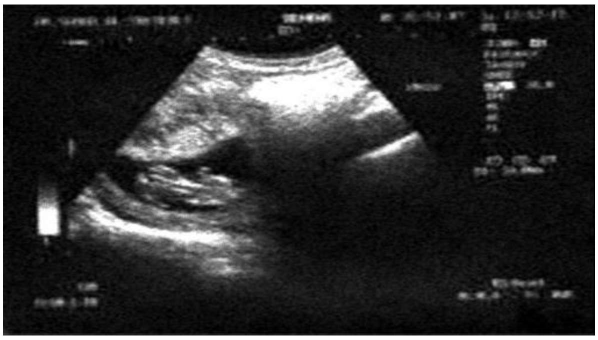
Three samples of US fetal images are used in this work. This work divided into two parts: first part includes speckle noise reduction from US fetal images using Lee, Frost and Kuan filter, the performance of the three filters(with window size 3×3) has been proposed to reducing speckle noise from these samples. Denoising is carried out for US images with Speckle noise of variance equal to (0.03). And the second part includes estimation the GA of the fetus from the best image resulted from filters used, All work is done by using MATLAB program (R2013a).



(a) (b)

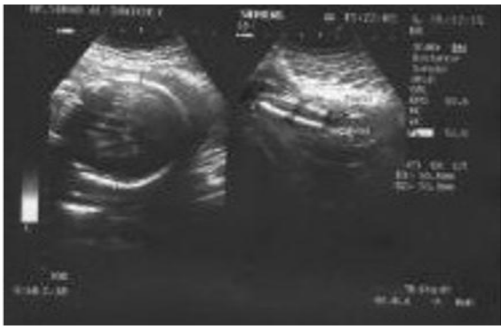


(c) (d)

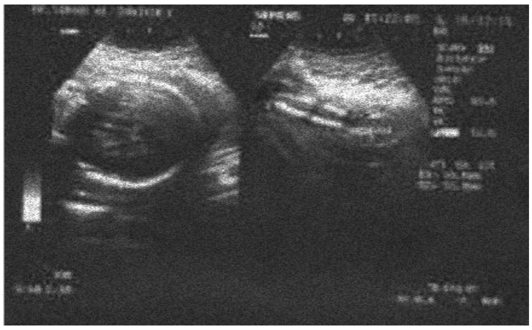


(f)

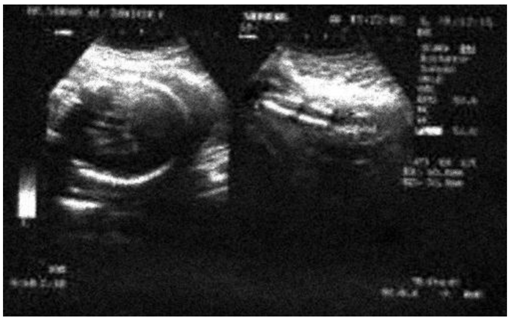
Figure3- (a)original fetus image of size 512×512, (b)noisy image(fetus image with speckle noise), (c)Lee filtered image (d) Kuan filtered images and (f)frost filtered image.



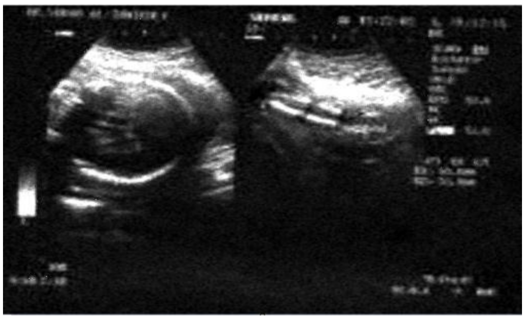
(a)



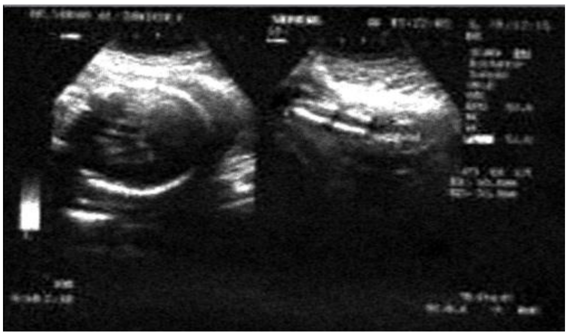
(b)



(c)

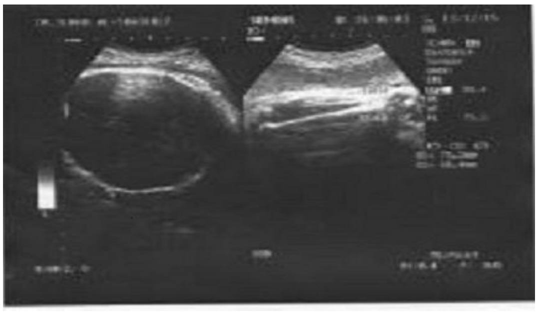


(d)

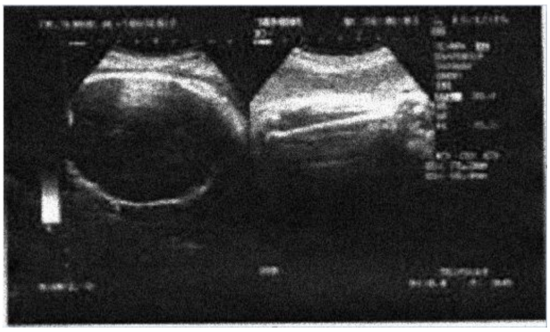


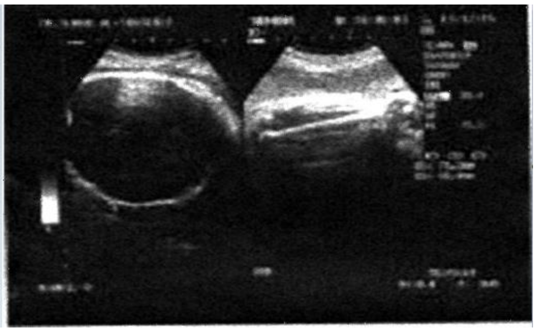
(f)

Figure4- (a)original fetus image of size(870×870), (b)noisy image(fetus image with speckle noise), (c)Lee filtered image (d) Kuan filtered images and (f)frost filtered image.

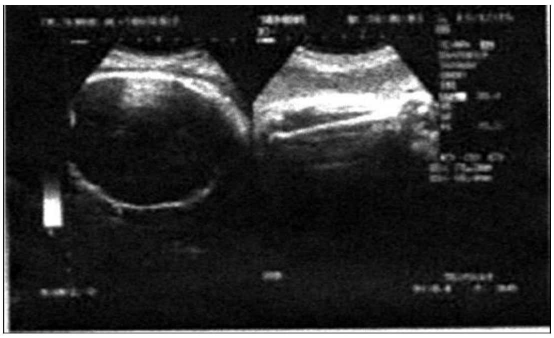


(a) (b)





(c) (d)



(f)

Figure 5-(a)original fetus image of size(870×870), (b)noisy image(fetus image with speckle noise), (c)Lee filtered image (d) Kuan filtered images and (f)frost filtered image.

Figures-3 , 4 and5 shown the different fetal images(original images),noisy images, and filtered images after applied Frost, Lee and Kuan, from these Figures we noted the images (d) in all Figures is clearer than (c) and (f) images, that means the performance of Kuan filter is better than Lee and Frost filter. To analyze the speckle reduction methods the performance parameters RMSE, PSNR are used and compared, for filters used are tabulated in Table- 1.

Table 1- Shows the performance analysis parameters of filters used.

Fetus Image	Filter used	RMSE	PSNR
Figure (2)	Lee filter	4.73	34.62
Figure (2)	Frost filter	4.78	34.52
Figure (2)	Kuan filter	5.00	34.14
Figure (3)	Lee filter	4.77	34.55
Figure (3)	Frost filter	4.97	34.19
Figure (3)	Kuan filter	4.88	34.35
Figure (4)	Lee filter	4.36	35.32
Figure (4)	Frost filter	4.59	34.88
Figure (4)	Kuan filter	4.88	33.98

From Table-1, we noted that the best performance of Kuan filter than Lee and Frost . So we will use the resulting image of this filter for GA estimation .To estimate the GA of image (d)Figure-2, we determined the CRL of baby using MATLAB program, we find the CRL equal to(74.20 pixel) that equal to (19.63mm), to estimate the GA put this value in equation (7), we obtain the GA equal to 8 weeks and 12 days (8W12d) Figure -6.

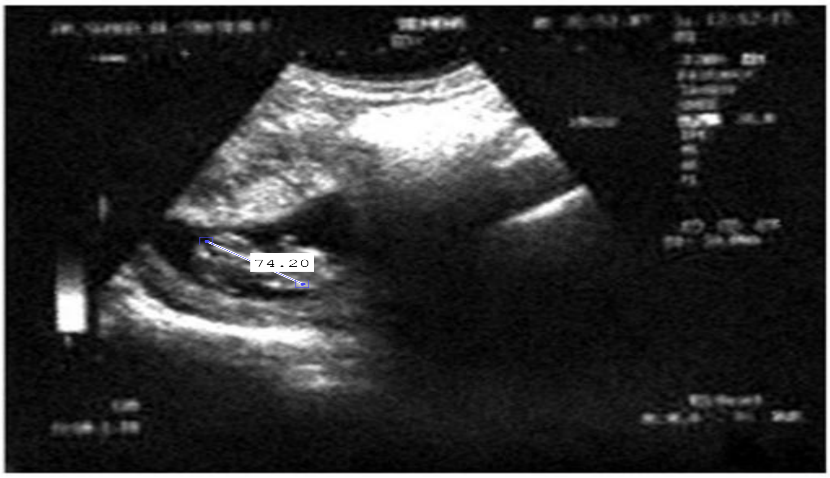


Figure 6- Fetus image at (8W12d).

By using MATLAB program we determine the FL from image (d) Figure-3 we find the FL equal to (157.47 pixel) that equal to (4.16 cm), to estimate the GA put this value in equation (8), we obtain the GA equal to 24 weeks and 3 days(24W3d), Figure-7.

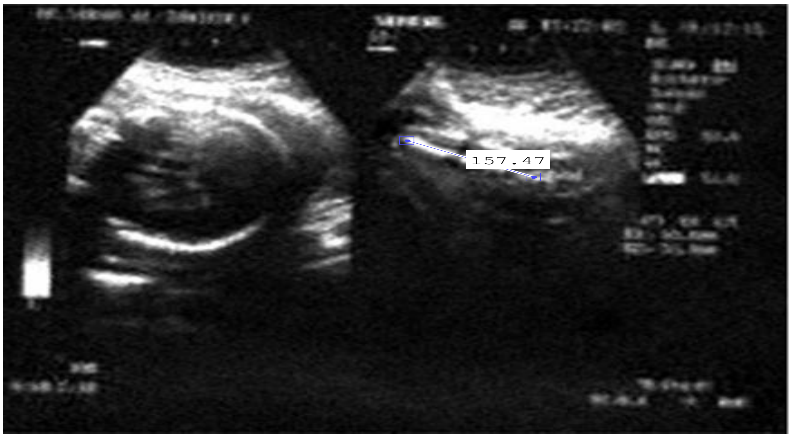


Figure 7-Fetus image at (24W3d).

Also, we obtain FL from (d) image Figure-4 equal to(243.58 pixel) that equal to (6.44 cm), to estimate the GA put this value in equation (8), we obtain the GA equal to 33 weeks and 6 days(33W6d), Figure-8.

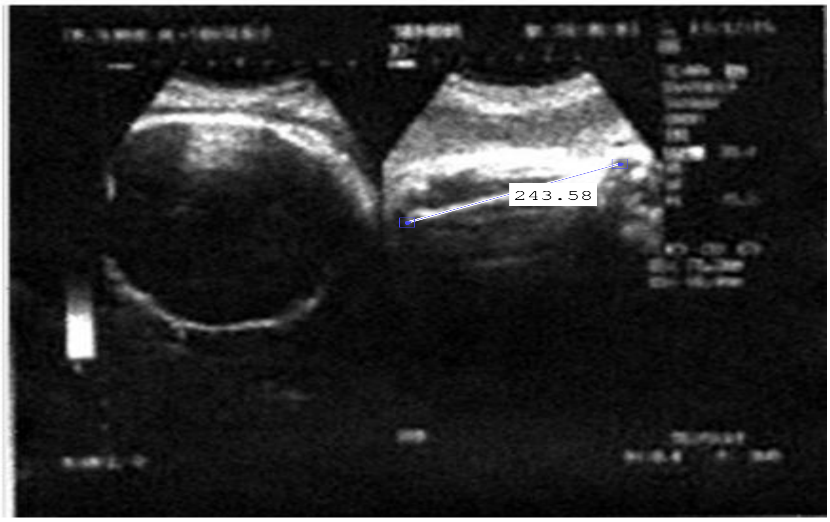


Figure 8- Fetus image at (33W6d)

5. Conclusion

US is one of the most commonly techniques used in medical imaging. The non-invasive nature of US has favored its use over other imaging techniques. Still removal of noise from US images is very challenging task. In this paper three adaptive filters are used to reducing speckle noise from US fetal images, these filters are Lee, Frost and Kuan filter, and Wiener filter are used to restore degradation fetal images that suffer from noise and blurring. After applied all adaptive filters on the noisy images(fetal images with speckle noise) ,we see that the performance of Kuan filter is better than Lee and frost. The resultant images after using Kuan filter are clearly with keep the resolution and structure of original image this is suitable to get a precise extraction of the region of interest(FL and CRL), as well as we obtain the best PSNR values than Lee and Frost filter. So we used the resulted images after applied Kuan filter to estimate the GA after calculated the FL and CRL parameters using

MATLAB program, also from the second part of this work, we noted the best performance of Wiener filter to restore the blurred image, as well as to restore degradation images.

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