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RESEARCH ARTICLE

Speckle Noise Reduction and Segmentation Techniques in Ultrasound for Detection of Fetal Abnormality - A Survey

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ABSTRACT

Ultrasound is a non-invasive diagnostic medical tool used by the healthcare practitioner to evaluate, diagnose and treat medical conditions. Obstetric ultrasonography is an imaging technique used to create real time visual images of the developing fetus in the uterus and is used to detect abnormalities such as heart diseases, kidney problems, limb abnormalities, chromosomal abnormalities, bone disorders, etc. A major problem prevailing in fetal ultrasound is the lack of clarity of an image and is unable to be diagnosed by the physicians. In the ultrasound detection of fetal abnormalities, the edges and the fine details of the images are affected by speckle noise. It is a granular noise that degrades the quality of images, and it affects image interpretation. This can be overcome by using various filtering techniques. The fetal abnormalities can be analyzed and interpreted using image segmentation which involves detection, recognition and measurement of objects in images. The quality of an image is influenced and also enhanced by various image segmentation methods. This paper is a survey of recent studies developed for de-noising and segmentation of ultrasound images in the detection of fetal abnormality. So far the methods are implemented using MATLAB, and for better processing, the filtering and segmentation techniques can be designed and developed using Open-CV in Python.

Keywords: Obstetric ultrasonography, De-noising, Segmentation, Ultrasound image, Filters.

1. INTRODUCTION

Ultrasonography concept becomes more popular than various medical procedures like MRI, CT, ultrasound, etc. because of its cost efficient and non-invasive nature. Ultrasound imaging technique is used to observe the dynamic behaviour of internal organs of the body and identify the possible problems that help to take necessary actions. Ultrasound imaging technique also uses higher frequency, which is used to record and display the fetus in the uterus at the time of routine parental check-ups. One of its major disadvantages is speckle noise, which degrades the quality of images. At the time of medical examination, this speckle noise causes severe problems in image interpretation. It degrades the quality of ultrasound images. Hence there are many efforts made in researching field to formulate various despeckling methods for de-noising ultrasound images. Many filters have been used to improve the performance of filter, which is assessed quantitatively based on quality metrics such as Peak Signal to Noise Ratio (PSNR), Structure Similarity Index Measurement (SSIM) and Root Mean Square Error (RMSE). Segmentation is vital in image processing, where the image is subdivided into number of parts. All the subdivision is performed well to identify the fault and

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recover from it. Segmentation process is kept on repeating till the error gets identified and rectified. In fetal ultrasound, it helps to find out the heartbeat and length of the fetus and limb movement, and to detect diseases affecting it [1-12]. The filtering and segmentation algorithms are designed and developed using MATLAB.

2. SPECKLE DE-NOISING TECHNIQUES

[13] has defined a local statistics noise filtering algorithm based on Lee filter to remove the speckle noise. This technique consumes more time and it reduces the quality of the image. Then, [14] has come up with a different filtering technique i.e., Kuan filter. It recovers from the effects of Lee filter. But this filter is also not much helpful in removing the entire speckle noise; Similar to Lee filter, Kuan filter also consumes more time. [15] elaborates another filter technique named Frost filter, which replaces the present pixel with the help of weighted sum values in n*n moving window. Frost filter has the capability to maintain the original version of the image; but image blurring is the disadvantage that has to be checked. [16] Nonlinear filtering technique based on median filter overcomes the speckle noise from ultrasound images. The median filter assigns median value of its neighbourhood to each and every pixel. This filter relatively works slowly irrespective of the fast sorting algorithms. But there is no degradation in the quality of the image. Figure 1 shows the output images of certain de-noising filters.

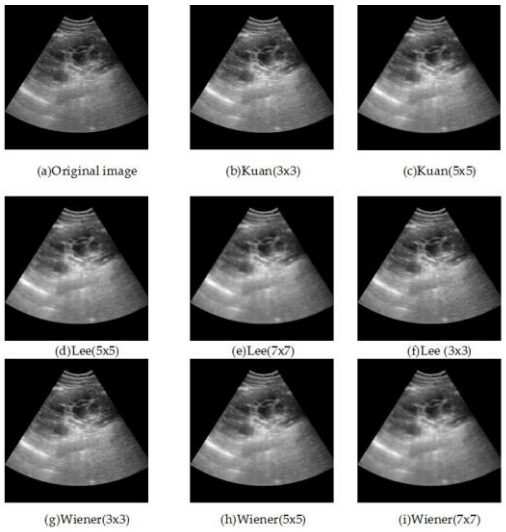

Figure 1.Output images of de-noising filters

Then the median filter is further modified and proposed as hybrid median filter [17] also named as corner preserving median filter. It helps to overcome the effect of median filter. The modification of hybrid median filter helps to recover the ultrasound image from speckle noise [18].

[19] has stated that with the help of wavelet analysis theory and fuzzy theory, ultrasonic image enhancement and de-noising algorithm can be performed well. Using multi-scale wavelet transform, ultrasonic image turns into high and low frequency components. Low frequency coefficient is enhanced in the fuzzy domain and for de-noising, soft threshold technique is applied to high frequency coefficients. It analyses the results of median and wiener filters along with the Haar and Symlet discrete wavelet transform approach [20]. Speckle noise is added to an ultrasound image and filters are applied to reduce noise at some extent. Then Symlet and Haar wavelet transform has been applied on both the filtered image, and to get the original image, inverse discrete wavelet transform is applied. The comparison between different filtering techniques such as hybrid wiener-H filtering technique, LSH frequency domain filtering technique and advance Mexican hat linear spatial filtering technique are described which gives a better result for ultrasound medical images by speckle noise removal and enhancement of the image quality [21].

[22] has specified the block coding approach to eliminate noise based on dynamic block sliding with boundary region preservation. This method is used to select the block size based on the averaging of pixel distribution in the given image. To detect the tracing edge, a multi-orientation tracing algorithm is used. This approach of block based coding derives an optimal block trace order via edge tracing, thus resulting in the filtration of image smoothing at the edge region and image content. [23] uses Shearlet transform to de-noise the images. It is sparse and has multi-scale and multidirectional properties, which optimally represent images with edges. This article compares various thresholding methods with respect to PSNR. Speckle noise related to the ultrasound images can be reduced by enhancing the input image, which in turn improves diagnosis. [24] employs Un-decimated Wavelet Transform

(UWT) to perform decomposition of the image signal to the coefficient values. Values of image pixel are replaced with the help of given coefficient values in the original ultrasound image and thus the result is obtained using the median filter. Afterwards, on applying smoothing directional filter, the new diagonal coefficient formed is redirected and inverse UWT is taken in order to obtain the noise-free resultant image. So the proposed method gives a clear view about various ultrasound images and overcomes the problems faced by conventional statistical measurements and other common methods used for the removal of speckle noise.

[25] has stated that speckle noise in the image is easily identified with the help of technique using fuzzy logic. Here the neighbouring pixels help to recover the healthy pixel. The signal loss results in noisy or blur image. In this regard, Binning based method has been used to work efficiently to recover the image by removing noise. [26] presents a method named as Brushlet based Block Matching 3D (BM3D). It is mostly used to remove the noise from ultrasound image. First it divides the image pixels into various multiple divisions and then it is combined on the basis of similarities. These combined blocks form a 3D image, and for each image filtering process is carried out by Brushlet thresholding. After the completion of the filtering process, the image should be reconstructed by de-noising scheme and thus good performance can be achieved when compared with other methods. Also by this method, the cardiac and ultrasound images of fetal can also be evaluated. Hence quality of ultrasound image can be improved by analysing the homogeneity and contrast of de-noised images. [27] Extra Energy Reduction (EER) function is employed in vector field; in where the vector triangular formula addresses EER. The vector triangular formula yields lesser pixel energy than the common absolute distance energy of the similar pixel. The implementation of this function reduces the energy consumption and gives an impressive result on noise reduction without data loss.

[28] gives an extension of technique used for Non-Local Means (NLM). It is the common adaptive technique used for the removal of multiple noises by considering segmentation process. This method is effective to de-noise the corrupted noise that is common in 3D ultrasound image. [29] has proposed a devoted filter that adjusts the anisotropic diffusion to the attributes of the multiplicative noises and makes the filter processing simpler. It also reduces the processing time due to the usage of parallel processors. The comparison result shows that, this method is better in terms of real time implementation.

[30] The performance of filters to remove the speckle noise in ultrasound images is compared. Among the traditional filters, adaptive shock filter that is commonly based on partial differential equations gives desirable results in terms of MSE and PSNR.

3. SEGMENTATION TECHNIQUES

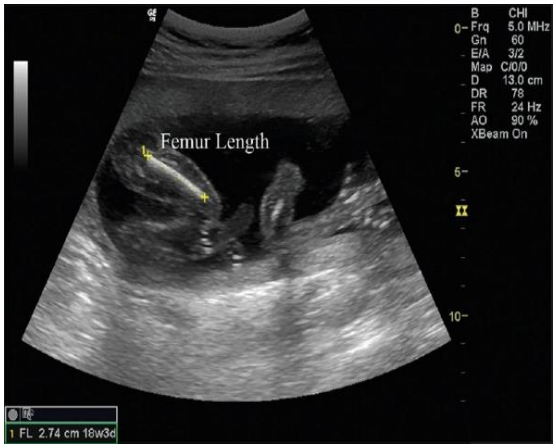

Figure 2.Image segmentation of fetus

Figure 2 shows the image segmentation of fetus. [31] has proposed Conditional Random Field (CRF) approach to segment the ultrasound images of fetus and to rectify various problems such as high noise and low contrast and property of ultrasound images like similarity between grey level and texture level of two tissues/ organs. It also manages the challenges associated with segmentation of ultrasound images of fetus. It uses wavelet dependent features to represent the support vector machine and ultrasound image. The result obtained from this method manages well with noise and the fetus similarity of the images. [32] has proposed the segmentation of ultrasound images on the basis of fuzzy connectedness concept. It states that by using feature assymmetry and local phase, the affinity function can be defined to drive the algorithm. It also combines the object on the basis of shape, and the result obtained can be

regularised by mean curvature flow. On the basis of fetus nutrition, the images can be identified to characterize the early stage of fetus. [33] Cranial dysmorphisms can be detected at the time of pregnancy which can be achieved by processing the shape of cranial from the 2D image ultrasound of fetal head. Segmenting the cranium of fetal is considered as a major problem due to the complication in the fuzzy boundaries and variations in the fetal position and head shape. To overcome these limitations, some algorithms have been proposed and introduced a framework that includes an important feature which contains the detailed information regarding the statics and shape of cluster pixel. The performance of these features can be evaluated on the basis of segmentation of pixel with the help of random forest classifier. Results obtained from this concept give 97.22% accuracy on the fetal cranial segmentation in ultrasound image.

[34] has proposed an important segmentation technique to extract the envelope of fetus from 3D image ultrasound. This segmentation method produces a low quality output. Hence to overcome these limitations, a framework is introduced that includes three types of different information which are as follows: shape of fetus envelope, intensity of pixel distribution and a model that varies with the age of fetus. The results are visually and quantitatively satisfactory when compared with other methods.

Biometric measurements of fetal can be used in order to determine the age as well as the growth of fetus and these measurements are considered as an important diagnostic tool. Modern scanner manually measures the fetus by extracting the contour or diameter of the images. But the manual measurement produces inaccurate output, hence considered as inconsistent. Hence to overcome these, automatic measurements with respect to entropy based segmentation method for femur segmentation have been proposed [35] to focus mainly on the measurement of femur. This also introduces the automatic scheme to segment the femur image and to compute the segmented femur length. The result obtained proves that it is an effective one in case of biometric properties of femur. [36] has developed isointensity contour and volume fitting method to determine the volume of fetus based on the sound of ultrasonic image. Here segmentation technique can also be used. If the quality of the image input is poor, then it can be improved by edge enhancement method. Also, this technique smoothens the unwanted edges of image and enhances only the important fetal edges. There are other techniques to enhance the image such as anisotrophic diffusion technique, edge focusing and isointensity technique. In isointensity technique, pixel with equal intensity value is selected whereas in edge focusing method, the importance is mainly given to the image edges. It is important to determine the contour set of points so that shape of fetus can be fixed. Normally the head or body shape is ellipse or sphere and a selected shape is to be fitted. After the completion of fitting process, it is necessary to calculate the fetus volume and then the processing method can be used to process the image of fetus using MATLAB.

[37] has focussed on machine learning method that has been available before: multilayer super pixel classification using random forest. The ultimate aim is to improve the accuracy by exploring the compactness parameter in the formation of super pixels. The moment features also improve the performance of image segmentation. [38] has proposed an automatic fetal head and brain system to measure the anatomical structure using 3D image ultrasound. The input which is given should be pre-processed and filtered with the help of hybrid mean filter. The gray level thresholding method can be used to segment the image and the value of threshold is selected based on k-mean clustering algorithm. It has fast run time and hence used in clinical purposes.

[39] has aimed to determine a fully automated strategy that identifies and segments lumen as a basis to quantify aortic intima media thickness. This is performed using AdaBoost classifier based on anisotropic filtering and level set methods and the results are effective in case of fully automated system. For an echographic image, manually extracted anatomical structure of fetal's contour is considered as a challenging one because of the presence of speckles and lower contrast feature. It is necessary to determine the contour of fetal body. In most of the recent schemes, global shape and its appearance are integrated but the variations in localize appearance cannot be handled accurately. Random forest has been

used in the segmentation of head contour in ultrasound scan with low cost and it can be used in any places, especially in remote areas because of its portability [40].

[41] has proposed a conventional method combined with deep learning system to automatically detect and measure the abdominal contour. It confirms that the neural network based method is better than other textural factors and typical classifiers to overcome the binary classification problem. Many experiments are conducted on 70 sets of images and testing has been done by comparing with another 70 set of images. Automatic measuring systems play a crucial role; in this regard [42] focussed on automatic segmentation process for heart chamber by patch based scheme. Horn-Schunck's optical flow algorithm is used for extraction purpose. The result obtained after segmentation process shows nearly 2.17% of segmentation error in average.

[43] has suggested watershed algorithm for segmenting fetal ultrasound images based on multi resolution method. The input image can be decomposed into multi resolution space based on B-spline two-dimensional wavelet transform. For each pixel, the system builds the feature vector which includes the gray level, moment and texture information. In fuzzy c-means clustering method, feature vectors are considered as an input resulting in a segmented image, where the regions are different from each other. Enhancement of fetal ultrasound images is done by an adaptive center weighted median filter. Preliminary investigation shows active results but further investigations on these studies are required to analysis the potential of wavelet. Currently, radiologists indicate femur endpoints with an interactive marker device.

[44] has explained that the major objective is to work efficiently along with less time consumption and the algorithm used is based on morphology, which recognises femur contour in ultrasound images of fetal. Morphological operators are used to metamorphose the images thus femur shape can be refined. This refining process is done until a femur's pixel-wide skeleton is available in an effective time manner. The skeleton endpoints are assumed as femur endpoints and the femur length is defined as the distance between end points. The gestational age can be estimated based on this femur length. The execution time of this algorithm is nearly 4 seconds. The measurement obtained by automation algorithm is correlated to the measurement performed manually. Thus this algorithm is considered as time efficient, and the gestational age estimated by this algorithm is compared with those of the existing methods.

Visually obtained information occupies a key role in day to day life. This system uses transducers, beam forming, contrast agents and pulse compression to measure blood flow and to provide three dimensional imaging. Ultrasonic imaging is easy to use, very fast, accurate, and is of low cost and also offer efficient way to examine the tissues in human bodies. [45] has elaborated several existing algorithms that are used in medical images. The applications of these algorithms are identified and thus characteristic behaviour is further evaluated for segmenting images. This paper focuses on current segmentation algorithms such as thresholding, clustering, histogram, region based segmentation, water shed segmentation, etc. for medical images.

[46] has recommended an algorithm to measure thalamic diameter from 2D ultrasound brain images. It helps to overcome the limitation of ultrasound image modalities, high speckle noise etc. Automatic estimation of the thalamic diameter with the measurement accuracy is achievable based on this method. To measure the fetal femur length and to promote age estimates which is important to estimate the fetal development, computer assisted processing system is considered. It also determines the gestational age to enhance the regulation of femur measurement.

Based on the above literature studies, it is deduced that the modified hybrid median filter gives better results compared to Lee, Kaun and Frost filters. De-noising can also be done using wavelet transform and adaptive filters with the help of GPU. By means of several segmentation algorithms such as random forest classifier, CRF, edge detection, volume fitting, k-means clustering method, the part that has to be analyzed is segmented. Random forest classifier gives desirable outcome among all segmentation methods. The summation is given in table A1.

5. CONCLUSION AND FUTURE SCOPE

Different types of filters and algorithms to reduce speckle noise have been surveyed and performance of de-noising concept is accomplished by means of quantitative performance measures like MSE and PSNR. Almost all the algorithms focussed on reducing the speckle noise and identifying the noise models. Segmenting the desired abnormal region is an important role in the field of medical observation. Various segmentation algorithms have been studied for detection of fetal femur length, fetal brain, heart and abdomen, fetal volume movement of the limbs, etc. So the finding of suitable algorithm for the purpose of segmentation is based on the application of the input image. Filtering and segmentation techniques have been designed using MATLAB. In MATALB, the limitations like slow execution speed, need for resources, etc. can be overcome by using OpenCV in python.

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APPENDIX

Table A1.Summation of the reviewed methodologies

Segmented part	Segmentation technique	Advantages	Future work	References
Fetus from amniotic fluid and placenta	Conditional random field	Accurate object identification Robust system	Use for larger dataset	[19]
Fetal soft tissue	Fuzzy Connectedness	Good performance with respect to manual segmentations	Implementation for other applications	[20]
Fetal head	Machine learning	High accuracy (97.22%)	Developments needed for assessment in utero fetal cranial morphology	[21]
Fetal envelope	Intensity distribution and shape priors	Accurate results with 0.72 mean, 0.89 similarity index, 0.97 sensitivity index are obtained	Consequence of error during the registration of back model can be rectified	[22]
Fetal femur	Entropy-based femur segmentation	Proposed approach achieved 1st place on femur segmentation sub-challenge	Implementation for other applications	[23]
Fetal volume	Isointensity and edge focussing segmentation	Optimum results are produced with greater accuracy	Rectification of error due to Perona and Malik enhancement and isointensity contour	[24]
Fetal head, femur and humerus	Multilayer super pixel and image moment feature	Fetal femur and humerus segmentation gives high accuracy, F-1 score, recall and specificity	Enhancement in fetal head segmentation accuracy	[25]
Fetal head	Gray level thresholding and K-means clustering	Execution time is fast	Statistical analysis of proposed system is yet to be done	[26]
Aortic lumen	Adaboost classifier, edge based level set	Results shows 0.97% accuracy	Implementation for other applications	[27]
Fetal head contour	Random forest	The approach lead to more efficient analysis suitable for low income countries	Prediction of gestational age	[28]
Fetal abdomen	Convolutional neural network	This method distinguishes abdomen and non-abdomen regions with mean DICE coefficient of 0.90	Extraction of CNN features explicitly	[29]
Fetal heart chamber	Possibilistic clustering	Early sign of haemoglobin Bart's disease is detected	Reduction of segmentation error	[30]
Fetal femur	Morphological operators	Mean execution time is around 4 seconds	Implementation for other applications	[33]