Assessment of Fetal Growth from Ultrasound Image Using Image Processing Techniques

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Abstract— Assessment of the fetal biometry is one of the important tasks during every phase of pregnancy. The fetal biometry obtained from the fetal Ultrasound images demands well trained and skilled sonographers for the accurate measurements. The fetal biometry are obtained by drawing circles and lines using cursor on the images which may lead to inaccurate measurements and results in inter observer variability. In order to overcome these limitations an automated process is developed. This paper focuses on measuring the head circumference (HC) to compute the gestational age (GA) and monitor the fetus growth. The automated process involves a sequence of image processing techniques to measure the HC that includes non-linear diffusion technique, morphological operations, Thinning algorithm and ellipse fit algorithm. The computed HC are compared with the ground truth values of the considered database. The proposed work yields an accuracy of 92 % in measuring the fetal head circumference. The computed HC helps to calculate the gestational age and estimate the weight of the fetus.

***Index Terms*— Ultrasound images, Kuan filter, Lee filter, morphological operations, Ellipse fit, Thinning algorithm segmentation.**

I. INTRODUCTION

Ultrasound imaging an noninvasive, low cost, real time process used for screening and assessing the growth of the fetus. The normal growth of the fetus is assessed by measuring the fetal parameters. The fetal biometry includes head circumference (HC), crown-rump length (CRL), abdominal circumference, femur length for computing the gestational age (GA) thereby monitoring the fetus growth. In general fetal biometry are computed by drawing lines and circles on the ultrasound image manually using cursor. The interpretation from the ultrasound image is complex due to the presence of speckle noise induced by attenuation, shadows and reverberations of Ultrasound waves during imaging. During manual assessment of the fetal biometry, the complexity in interpretation from ultrasound image demands the well trained and skilled professionals. The shortage of the well trained personnel leads to inter and intra-observer variability in measurement of fetal parameters [1]. The limitation of the manual assessment is overcome by developing an automated process to compute the fetal biometry. During mass screening the automated system overcomes the demand of the trained personnel also aids to obtain the accurate fetal biometry. This paper focuses on developing an automated fetal biometry measuring system using a sequence of image processing measuring techniques. The obtained HC are used to compute the GA and monitor the growth of the fetus. Section II of this paper describes the methodology to compute the HC and the simulated results are discussed in section III followed by conclusion in IV and future enhancement of the work in section V.

II. METHODOLOGY

The automated process of the HC computation involves sequence of image processing techniques that includes removal of speckle noise using the nonlinear diffusion filters and the identification and segmentation of the fetal head using the morphological operators, followed by ellipse fitting algorithm. The flow of the work is represented in the Fig 1. Ultrasound fetal images used for this work are taken from online database that includes image of all trimesters of the pregnancy in JPEG format. The database consists of 999 ultrasound fetal images. The sample images are shown in the Fig 2. The interpretation from ultrasound image demands the removal of the speckle noise using an optimum filter for the considered database. Set of nonlinear filters are applied to remove speckle noise and the optimum filter for the considered database is obtained by analyzing the performance of the considered filters. The quality of the image contributes more in evaluating or segmenting the region of interest in the ultrasound images. The speckle noise in ultrasound image blurs subtle details present in the image. In the segmentation process, the morphological operations and the thinning algorithm are used to remove selected foreground pixels from binary images. Finally ellipse fitting algorithm is applied to the segmented fetal image to detect the fetus head thereby aids to measure the fetal biometry parameters. Using biometry parameters the gestational age, weight and monitor the growth of fetus is determined.

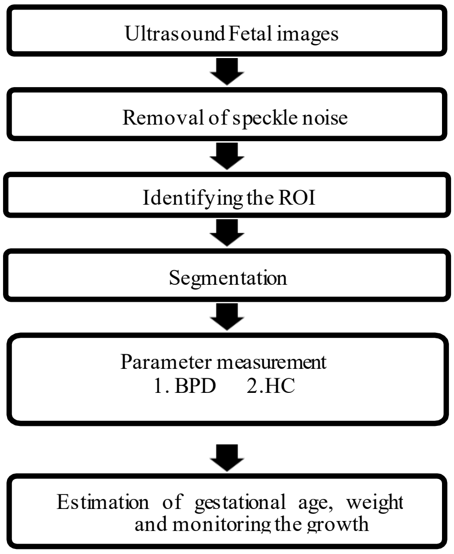


Figure 1 Block diagram

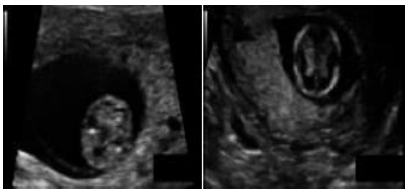


Figure 2 Ultrasound images of fetus taken from the database.

A. ***Preprocessing***

The speckle noise in ultrasound image is characterized by its multiplicative and non-Gaussian nature. Identification of optimum filter to remove the speckle noise demands more challenge compared to the additive noise because the noise intensity varies with the image intensity. The filtering methods considered for removing the speckle noise includes Lee, average, median and Wiener filter. The Wiener filtering operation based on global and local statistics of the window within the image is used for denoising and deblurring, as in (1).

$$z_{ij} = M^{-} + \frac{\sigma_k^2}{\sigma_{k+\sigma^2}^2}(k_{uv} - M^{-}) \quad (1)$$

Where, Z_{ij} denotes the wiener filtered image, M^{-} is the mean of the kernel, σ_k^2 is the local variance, K_{uv} is (u, v)th pixel in the kernel K and is the global variance σ^2. The multiplicative model of the speckle noise is converted into additive model and different weighting functions are determined to perform the Kuan filter operation as in (2).

$$W = (1 - \frac{c_u}{c_i})/(1 + c_u) \quad (2)$$

In Median and Average filter the center pixel values within the 3x3 window of the given image is replaced with the average and mean value of the neighboring pixels.

Lee filter performs the smoothing operation in the low variance area of the considered image. The mean and variance from the kernel of size 3x3 is used for computing the weighting function U as in (4). The difference between the center pixel value and the mean of the kernel of size 3x3 within the image is obtained and multiplied with the weighting function U. Using Lee filter the image is approximated by linear model as in (3).

$$X_{ij} = k^{-} + U*(c - k^{-}) \quad (3)$$

$$U = \frac{\sigma_k^2}{\sigma_k^2 + \sigma^2} \quad (4)$$

The performance of the above discussed filters is analyzed to identify the optimum filter that removes the speckle noise for the considered database. The performance metrics considered in this paper are Signal to Noise Ratio (SNR), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). The qualities of the preprocessed image are assessed as in (5) to (7).

$$MSE = \sum_{ij=0}^{N-1} \frac{1}{M^2}(Y_{ij} - Z_{ij})^2 \quad (5)$$

$$SNR = 10log_{10}\left(\frac{\sigma^2}{\sigma_e^2}\right) \quad (6)$$

$$PSNR = 10log_{10}\left(\frac{I^2}{MSE}\right) \quad (7)$$

The computational time (T_c) time taken by the filter is also considered as one of the perfomance analysis measure for identifying the optimum filter. The optimum filter must have high PSNR, high MSE and less computational time.

B. ***Morphological operations thinning algorithm***

The detection of the region of interest from the fetal ultrasound image is computed using the morphological operations. The hit miss operation based thinning process is considered in this paper for detecting and segmenting the fetal head from the Lee filtered image. The thinning operation is computed, as in (8).

$$X \otimes T = (X \ominus T) \ominus \cap (x^c(w \cap (T^c))) \quad (8)$$

Where X is the kernel of 3x3 in the filtered image, T is a binary structuring element, T^C is its complement. Two sets of the structuring element is considered for removing the unnecessary points in the diagonal, horizontal and vertical directions as shown in the Fig 3. The thinning operation is performed by passing all the mask from both set over the filtered image. The area that survives after passing through the two sets of the structuring element indicates the fetal skull.

0	0	1
0	1	1
1	1	1

A1

0	0	0
1	1	1
0	1	0

B1

1	0	0
1	1	0
1	1	1

A2

0	1	0
1	1	0
0	1	0

B2

1	1	1
1	1	0
1	0	0

A3

0	1	0
1	1	1
0	0	0

B3

1	1	1
0	1	1
0	0	1

A4

0	1	0
0	1	1
0	1	0

A4

Figure 3 Sets of structuring element

C. ***Location of fetal head***

The head of the fetus resembles the oval shape and hence it can be estimated using a ellipse .The simple ellipse fitting (SEF) with origin (0,0) as the center, is fitted on the segmented image to estimate the fetal head circumference as in (9).

$$\text{ellipse}(s,t) = As^2 + Ct^2 + F = 0 = \frac{s^2}{x^2} + \frac{t^2}{y^2} \quad (9)$$

where x is the major semi axis and y is the minor semi axis. *s* and *t* are the coordinates related to the semi axis of the ellipse. The semi axis coordinates are computed as in (10).

$$v = x - x_c \,,\; u = x - y_c \quad (10)$$

D. ***Head circumference measurement &Estimation of gestational age***

HC, one fetal biometry is used to assess fetal size, age and weight. The HC is usually done after 13 weeks of pregnancy. HC may be calculated from major axis and minor axis of the ellipse as: HC = 1.62 ×(major axis(BPD)+ minor axis (OFD)).

III. Simulated Result

The most important aspect for evaluating and segmenting an ultrasound image depends on the Image quality. The speckle noise present in the ultrasound image blocks out the subtle details in the image. The ultrasound fetal image is initially preprocessed to remove the speckle noise using the nonlinear spatial domain filters that includes Lee, average, median and Wiener filters. The simulated output of the considered filters of the fetal ultrasound image is shown in the Fig 4.a &b. The performance of the considered filters is analyzed to identify the optimum one for the considered database. The performance metrics includes SNR, MSE and PSNR for image quality assessment. The performance metrics are computed using original image X and the filtered image Z and tabulated in table 1.

Input image	**Pre-processed Image**
 Original image	 Median Filter
	 Wiener Filter
	 Lee Filter
	 Kuan Filter

Figure 4a Preprocessing of ultrasound images for image 1.

Input image	**Pre-processed image**
 Input image	 Median Filter
	 Wiener Filter
	 Lee Filter
	 Kuan Filter

Figure 4 b Preprocessing of ultrasound images for image 2

Table 1 Performance Analysis of Filtering Operation

Filters	SNR	PSNR	MSE	Computational time
Median	30.77	31.74	41.26	0.32s
Wiener	32.04	31.41	45.75	0.32s
Lee	41.61	32.04	55.16	27.78s
Kuan	18.13	32.94	34.91	210.32s

From the table 1 it can be inferred that the Lee filter performs better than the considered other filters because the value of PSNR, SNR and MSE are high. Hit miss operation based thinning algorithm is computed on the filtered image. The sequence of morphological operation followed by the thinning algorithm is implemented on the filtered image as shown in the Fig 5. The thinning algorithm is performed using the structuring element shown in Fig 3.

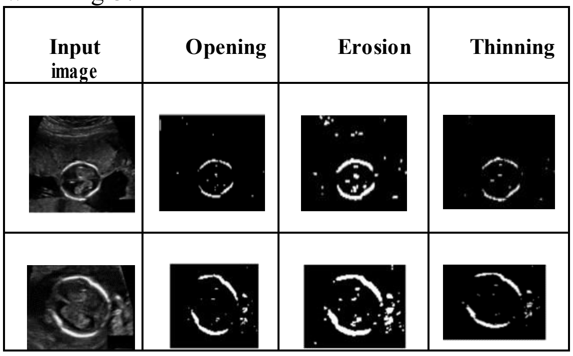


Figure 5 Simulated output of the segmented process.

The ellipse fitting algorithm is used to estimate the fetal head circumference as shown in the Fig 6. The major and minor axis of the estimated circumference, matching the fetal head is computed and tabulated in Table 2.

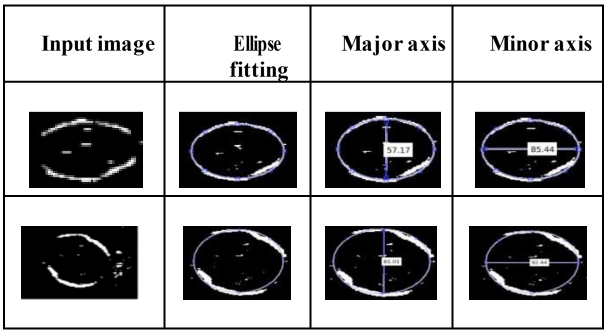
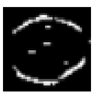
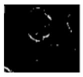


Figure 6 Computation of major and minor axis

TABLE 2 COMPUTED MAJOR AXIS,MINOR AXIS AND THE HEAD CIRCUMFERENCE VALUE IN MM

Image	Major axis	Minor axis	HC Computed	HC Ground truth	Accuracy
	51.7	85.44	119.71	111.5	92.64
	81.01	92.44	140.48	145.19	96.76
	99.3	127.90	184.03	191.72	95.99
	87.17	115.13	163.84	176.33	92.92
	87.17	112.93	162.06	178.31	90.89
	102.57	128.78	187.38	165.67	86.9
	98.62	129.66	184.90	193.79	95.42
	103.02	112.05	184.19	192.29	95.79
	89.10	94.44	168.66	176.53	95.55
	102.26	119.73	170.04	179.5	94.73

The obtained head circumference is compared with ground truth value of the considered database as shown in the table2.From the HC the Gestational Age and fetus weight are estimated as in (11) and (12). The estimated gestational age and fetus weight are tabulated in table 3 for few sample images.

$$\log(GA) = 0.010611HC - 0.000030321HC^2 + 0.43498 * 10^{-7}HC^3 + 1.848 \quad (11)$$

$$AC = \pi\,[(3a + b) - \sqrt{(3a + b)(a+3b)}] \quad (12)$$

TABLE 3 CALCULATION OF GESTATIONAL AGE AND ESTIMATED WEIGHT

Hc obtained in mm	Gestational age in weeks	Estimated weight in gm.
119.71	16	286.75
140.48	18	261
187.38	21	467
184.90	21	459

IV. CONCLUSION

In this paper the assessment of fetus biometry measurement to determine GA and to estimate the weight is done using image processing techniques. An automated system is proposed to reduce the measuring time and inter observer variability. The data set is preprocessed with diffusion technique to filter out the speckle noise. The nonlinear diffusion techniques considered in this work includes median filter, wiener filter, lee filter, and Kuan filter. Lee filter is identified as the optimum filter for the considered dataset by analyzing the performance of the filters. The filtered image is then segmented using morphological operations such as opening, closing and thinning algorithm. Finally to the segmented image the ellipse fitting is implemented to locate the fetal skull using major and minor axis. Using BPD and OFD, head circumference value is calculated in mm. The computed HC value is used to calculate the gestational age, weight and the growth of fetus. The computed HC is compared with the ground truth value of the database considered and the algorithm discussed in this paper produces an accuracy of 92%. This work can further be extended to calculate the other fetal biometrics and the computed HC can be used to analyses the presence of any abnormalities.

V. FUTURE WORK

Further this work can be enhanced by computing other biometric measurements such as Crown Rump Length (CRL), abdominal circumference (AC), femur length (FL), humeral length(HL), intraocular distance, binocular distance and abnormalities can be identified.

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