Segmentation of Head from Ultrasound Fetal Image using Chamfer Matching and Hough Transform based Approaches

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Abstract— **Medical imaging is specifically used to create images of the human body for clinical purposes. Ultrasound Imaging is a gold standard modality for fetal imaging because of its non invasive nature. Also it is a challenging modality due to the properties of image formation, signal dropouts, artifacts, missing boundaries, attenuation, shadows and speckle. In medical imaging, segmentation is a necessary step and is used to obtain the location of objects of interest and its measurements. One of the main objects of interest measured in ultrasound fetal image is fetal head. Biometric measurement such as Head Circumference is estimated from the segmented object and is used for fetus growth assessment. This paper presents a fully automatic method for the measurement of standard obstetric biometric parameters for head; after the segmentation of head object from ultrasound fetal image. This method uses shape based thresholds for preliminary segmentation. There are two approaches used to locate head skull from preliminary segmented image. In first approach, Chamfer Matching based ellipse detection is used. In second approach, Ellipse detection using Hough Transform is used.**

Keywords—chamfer matching, ellipse fitting, fetal, head circumference, hough transform, segmentation, shape based approach, ultrasound .

I. INTRODUCTION

Medical imaging is a collection of techniques that are developed to measure and display distribution of a physical property in living subjects. It is used to create images of the human body for clinical purposes. Medical imaging not only provides useful information for diagnosis but also serves to assist in planning and monitoring the treatment of malignant disease. X-ray, Nuclear, Ultrasound waves, Magnetic fields, Electrical currents and Infrared waves are the various energy types used for imaging. The different imaging modalities are based on physical interaction of different energy types with biological tissues and thus provide images of different physical properties of the tissues. X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Nuclear Imaging, Ultrasound Imaging and Infrared Imaging are the various imaging modalities. Ultrasound imaging is the modality of choice in many clinical applications due to its non-invasive nature and reduced cost compared to other imaging modalities such as CT or MRI. [1]

Ultrasound images are patient-specific, operator-dependent and machine specific which makes image appearance tightly linked to patient characteristics, the expertise of the clinician acquiring the images and the machine used. Besides, due to the properties of image formation intrinsic to ultrasound images, they can be affected by signal dropouts, artifacts, missing boundaries, attenuation, shadows and speckle making ultrasound one of the most challenging modalities to work with. Depending on the orientation of the transducer, the image obtained might not have the expected anatomical significance and can be distorted or incomplete. Further complications arise as the contrast between areas of interest is often low. Also the healthy fetal body changes its shape across gestation, as a result of growth and the different organs that surround the object of interest create high pose and shape variability for the same structure. [1]

It is worth noting that automated analysis of ultrasound images is hard and methods developed for MRI and CT do not necessarily work on ultrasound images. Also general methods for ultrasound image segmentation do not exist and the segmentation strategies are application dependent. [1] Ultrasound imaging is usually used in Echocardiography, Breast, Intravascular, Liver, Kidney, Thyroid, Prostate Ultrasound, Obstetrics and Gynecology; and the segmentation method is distinct for each application. In obstetrics, segmentation provides valuable measurements in order to assess the growth of the fetus and in diagnosis of fetal malformation. [5][6]

2D fetal ultrasound biometrics have been extensively used to establish the gestational age of the fetus, estimate its size and weight, and identify growth patterns and abnormalities. Typically, fetal size is estimated by using 2D ultrasound measurements of head, abdomen and femur at around 20 week's gestational age. These measurements and any at later gestations are then compared with population-based growth charts to identify normal or abnormal growth. Several parameters are used as ageing parameters, the most important of which are the biparietal diameter (BPD), occipito-frontal diameter (OFD) and head circumference (HC). In an attempt to reduce observer variability and create more accurate and reproducible measurements, automatic methods for fetal biometric measurements have been investigated. Low level features and textures were frequently used to find the femur and the skull, because these have a brighter response. [1]

Present work includes development of segmentation technique for head in an ultrasound fetal image. In this method threshold at various intensity levels are applied to an ultrasound image. Then shape based thresholds on thinness, elongation and size are applied. The results are depicted in the single binary image. This binary image contains a collection of the tentative skull bone objects. There are two approaches to locate head skull from binary image. In first approach, Chamfer matching based ellipse detection is used. In second approach, Ellipse detection using Hough transform is used. After the segmentation, standard obstetric biometric parameters for head are measured.

II. MATERIALS

A. Chamfer Matching

Using Chamfer Matching similarity between two images can be calculated. The basic idea in chamfer matching is to extract the contours of a query image as well as target image. Take one pixel of contour in query image and find the distance of the closest pixel of contour in the target image. For each point on the query image find the closest point on the target image and sum the distances for all edge pixels of query image. Lower the value, the higher the similarity.

The steps used for finding the head ellipse using Chamfer Matching are given below. 1. Edge map is computed for the query image (preliminary segmented ultrasound fetal image), 2. Various models of ellipses are given as target image. A boundary fragment in target image is compared to fragments in edge map using chamfer matching, 3. For the best match, ellipse fitting is applied. [3][4]

B. Hough Transform

The Hough transform (HT) is a standard technique for detecting curves. The main advantage of using the Hough Transform to detect an ellipse is its robustness against missing data points.

Hough Transform for ellipse detection relies on 5 parameters. In this method, create an accumulator array with center coordinates, semi-major axis length, semi-minor axis length and orientation as dimensions. The values in the accumulator array are increased every time an ellipse is drawn with the desired semi-major axis length and semi-minor axis length over every edge point. The accumulator, which kept counts of how many ellipses pass through coordinates of each edge point, proceeds to a vote to and the highest count. The coordinates of the center of the ellipse in the images are the coordinates with the highest count. A 'new ellipse detection method for ellipse detection', fits an ellipse by examining all possible major axis (all pairs of points) and getting the minor axis using Hough transform. [7]

C. Ultrasound Fetal Measurement Standards

HC, BPD and OFD are the three standard measurements related to the head object. BPD is the diameter across the developing baby's skull; from one parietal bone to the other (i.e. from ear to ear). OFD is the diameter across the developing baby's skull; from the occipital bone (the very back part of the skull) to the frontal bone (forehead). HC denotes the circumference of the head skull.

The Table I shows approximate measurements of HC, BPD and OFD for various gestation weeks. [8]

TABLE I. Measurements of HC, BPD and OFD

Gestation (weeks)	**BPD (mm)**	**OFD (mm)**	**Head circumference (mm)**
+/- Standard deviations shown in (brackets). Measurements are for completed weeks.			
11	16 (2.0)	21 (2.0)	59 (15)
12	20 (4.0)	24 (2.0)	70 (15)
13	24 (4.0)	29 (3.0)	84 (15)
14	28 (4.0)	34 (3.0)	96 (15)
15	31 (4.0)	38 (3.0)	108 (15)
16	36 (5.0)	46 (3.0)	128 (15)
17	39 (5.0)	50 (3.0)	141 (15)
18	42 (4.0)	54 (3.5)	151 (20)
19	45 (5.0)	57 (3.5)	160 (20)
20	47 (4.0)	61 (3.5)	170 (20)
21	49 (4.0)	63 (4.0)	176 (20)
22	52 (5.0)	68 (3.5)	188 (20)
23	57 (5.0)	76 (4.0)	210 (20)
24	60 (6.0)	79 (4.0)	220 (20)
25	64 (6.0)	82 (4.5)	231 (20)
26	67 (4.0)	84 (4.5)	238 (20)
27	68 (5.0)	86 (4.5)	250 (20)
28	72 (4.0)	95 (5.0)	263 (20)
29	75 (4.0)	97 (5.5)	269 (25)
30	76 (4.0)	98 (5.5)	274 (25)
31	80 (6.0)	101 (5.0)	284 (25)
32	81 (4.0)	102 (5.0)	288 (25)
33	84 (6.0)	107 (5.5)	300 (25)
34	86 (6.0)	108 (5.5)	305 (25)
35	88 (6.5)	109 (5.5)	310 (25)
36	90 (6.0)	112 (5.5)	317 (25)
37	92 (6.5)	113 (6.0)	321 (25)
38	93 (6.0)	116 (5.5)	328 (25)
39	95 (8.0)	119 (6.0)	336 (25)
40	96 (8.0)	120 (6.0)	340 (25)
41	98 (8.0)	122 (6.0)	344 (25)

There are two approaches used here for calculating HC. The first approach uses BPD and OFD for calculating HC. Second approach uses Ramanujan's equation for ellipse circumference; for calculating HC.

$$HC = 3.14(BPD + OFD) / 2 \quad (1)$$

$$HC = 3.14(3(a + b) - \text{sqrt}((3a + b)(a + 3b))) \quad (2)$$

Here 'a' is the major axis length and 'b' is the minor axis length of the fitted ellipse.

Fig. 1 shows the HC, BPD and OFD on an ultrasound image. [1]

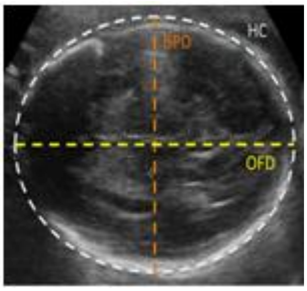

Fig 1. Head Circumference, Biparietal Diameter, Occipito-Frontal Diameter.

III. METHOD

'Preliminary Segmentation' section given below is used to obtain single binary image after preliminary segmentation and 'Detection of the Head Object' section is used for finding head object form the preliminary segmented image. From the segmented head object; HC, BPD and OFD are calculated.

A. Preliminary Segmentation

The skull bones in the fetal ultrasound images usually much brighter than their surrounding objects. This fact implies the possibility for the segmentation of objects of interest by applying intensity threshold. [2]

As the first step, apply high pass filtering on the original image. This make an image appear sharper and emphasize fine details in the image. The next step is to apply thresholds on the original image at multiple intensity levels. The threshold values for multilevel thresholding can be calculated automatically. By applying N intensity thresholds to the original image I, a set of N binary images can be created. On the next step, apply shape based thresholds for recognition of the skull bone objects in binary images, since these objects are usually pretty thin and elongated. Thresholds on Thinness, Elongation and Size are used as shape thresholds. By applying empirical thresholds on Thinness, Elongation and Size candidate objects are selected. The objects that passed thresholds on thinness, elongation and size from every binary image were collected into the single binary image. [2]

B. Detection of the Head Object

The single binary image obtained using above section is corresponding to the skull bones. To detect the actual location of the skull ellipse, try to inscribe ellipses using any possible combinations of the segmented objects [2].

The first approach uses Chamfer Matching to find the elliptical structure. Here the single binary image obtained from the previous section is compared to various template ellipses for getting best match. Chamfer matching method is used to find the similarity between template ellipse and ellipse inscribing in the binary image. For the best match, ellipse fitting is used and it is considered as the head ellipse.

Second approach uses Hough Transform to find the best ellipse that represents the head. This method applies Hough Transform on the single binary image obtained from previous section and draws the ellipse with maximum accumulator count. From the segmented head object, head circumference is calculated using (1) and (2).

IV. RESULTS

The work is implemented in MATLAB. All the ultrasound images for this study were acquired from various hospitals and the images obtained are in BMP and JPEG format. Total 90 images are used for testing.

Table II shows the accuracy of developed method for head segmentation. Here 'head segmentation using Chamfer Matching' shows better performance than 'head segmentation using Hough Transform'. HC, BPD and OFD are calculated in millimeters.

TABLE II. Accurate Segmentation Rates

Head Segmentation Method	**Accuracy (%)**
Using Chamfer Matching	95.55
Using Hough Transform	91.11

A. Segmentation of Head Object using Chamfer Matching method.

Fig. 2 shows the step by step output of each process in the segmentation of Head using Chamfer Matching method.

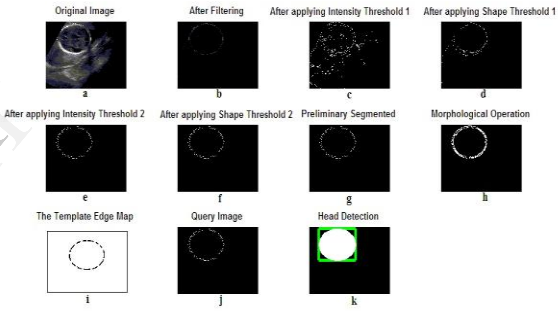

Fig 2. Segmentation of Head Object using Chamfer Matching method.

'Image (a)' shows the original image. 'Image (b)' shows the result of high pass filtering on the original image. Intensity level threshold is applied to the filtered image and it gives the output shown in 'image (c)'. To this image, shape based thresholds are applied and ‘image (d)' is obtained. Similarly applying next level intensity threshold on the filtered image, 'image (e)' is obtained. 'Image (f)' is obtained by applying shape thresholds on this image. The results from the above two shape thresholds are grouped and result is shown in 'image (g)'. The result after applying morphological operations is shown in 'image (h)'. The template edge map for comparison is shown in 'image (i)'. The preliminary segmented object is given as query object for comparison and it is shown in 'image (j)'. 'Image (k)' shows the detected head object.

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B. *Segmentation of Head Object using Hough Transform method*

Fig. 3 shows the step by step output of each process in the segmentation of Head using Hough Transform method.

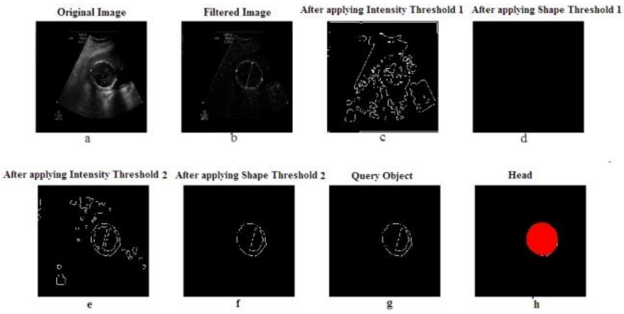

Fig 3. Segmentation of Head Object using Hough Transform method.

'Image (a)' shows the original image. 'Image (b)' shows the result of high pass filtering on the original image. Intensity level threshold is applied to the filtered image and it gives the output shown in 'image (c)'. To this image, shape based thresholds are applied and obtained 'image (d)'. Similarly applying next level intensity threshold on the filtered image, 'image (e)' is obtained. 'Image (f)' is obtained by applying shape thresholds on this image. The results from the above two shape thresholds are grouped and result is shown in 'image (g)'. Morphological operations are applied, followed by Hough Transform and the resulted head object is shown in 'image (h)'.

V. CONCLUSION

The Head object in ultrasound fetal image is segmented and the standard biometry parameters of the Head are estimated. Developed method uses shape based thresholds on thinness, elongation and size. To locate head skull from the preliminary segmented binary image, two approaches are used. Here 'Chamfer Matching based ellipse detection' approach shows better performance than 'Hough Transform based ellipse detection' approach.

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