Automatic Measurement of Fetal Head Biometry from Ultrasound Images Using Deep Neural Networks

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Abstract– **Gestational age (GA) is an illustrative indicator of fetal growth. The GA is estimated through biometric parameters, including the head circumference (HC) and Biparietal diameter (BPD). This paper proposes a deep learning-based method for automatic measurement of the BPD and HC based on the segmentation of the fetal head from ultrasound images. We utilized an efficient convolutional network architecture, named multi-feature pyramid Unet (MFP-Unet) previously proposed for left ventricle segmentation from echocardiography images. The proposed network tackles the main drawback of U-net, which ignores the contribution of all semantic strengths in the segmentation procedure. To train and evaluate MFP-Unet, a set of ultrasound images was used from the HC18 challenge dataset (fetal head circumference challenge). To evaluate the quantitative accuracy of anatomy segmentation, several metrics, including Dice similarity coefficient (DSC) and Hausdorff distance (HD) were employed. MFP-Unet achieved a DSC of 0.95 and HD of 4.5, which indicates the performance of the MFP-Unet algorithm in segmenting fetal ultrasound images for automatic measurement of biparietal diameter (BPD) and head circumference (HC).**

***Index Terms*—Biometry, Deep Learning, Ultrasound**

I. Introduction

GESTATIONAL age (GA) is an illustrative indicator of fetal growth. The GA is estimated through biometric parameters including head circumference (HC), Biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL), wherein ultrasound imaging is the modality of choice for this purpose.

Manuscript was submitted Dec 19, 2020. This work was supported by the Med Fanavaran Plus company.

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Medial image analysis were performed by deep learning algorithms to outperform existed conventional algorithms in different tasks including image segmenation [1] and image enhancement, improvement [2-12]. Most research studies in the field of fetal biometry are devoted to the prediction of fetal head parameters (HC and BPD) owing to the availability of a public dataset of HC challenge (HC18) [13]. Heuvel *et al.* [13] proposed an approach that had two main parts, namely pixel classifier and fetal skull detector. Haar-like features are fed into a random forest classifier (RFC) in the pixel classifier component, to locate the fetal skull. Then, Hough transform, dynamic programming, and an optimization algorithm of ellipse fitting were utilized to extract the HC. In another work, Sinclair *et al.* [14] proposed using a fully convolutional network (FCN) to segment the fetal ultrasound image over almost 2000 images, and then an ellipse shape was fitted to the segmented region using a dedicated optimization algorithm. Irene *et al.* [15] proposed a method which is composed of three main components. First, an object detector (YOLO algorithm) was utilized to detect the bounding box around the desired region in ultrasound images. Second, an edge detector algorithm (Canny edge detector) was applied to the resulting image and then a Hough transform algorithm [16] was utilized to detect the fetal head and abdomen. Finally, the detected regions were segmented by an effective model, called the difference of Gaussian Revolved Along Elliptical Path (DoGell) [15].

This work proposes a deep learning-based method for automatic measurement of BPD and HC based on the segmentation of the fetal head from ultrasound images. The proposed approach in this study addresses the challenges of ultrasound segmentation such as the presence of speckle noise, inherent artifacts of ultrasound images, and difficulties in the presence of low amniotic fluid. We utilized an efficient convolutional network architecture, named multi-feature pyramid Unet, MFP-Unet, previously proposed for left ventricle segmentation from echocardiography images [17]. U-net, which is a well-known image segmentation approach in medical images [18], takes the advantage of network symmetry and skip connections between the contraction (encoder) and expansion (decoder) paths. However, U-net ignores the effect of feature maps at the different scales "directly". In this light, we proposed to use the feature pyramid network (FPN) concept to tackle this issue. In MFP-

Unet, feature maps are extracted at the entire levels of the decoder path separately, and then they are used for final pixel classification.

II. Materials and Methods

A. MFP-Unet

In this study, we utilized a combined architecture of two efficient networks for the segmentation of fetal head from 2-D ultrasound images. Contrary to the U-net architecture, MFP-Unet uses all levels of expansion path to segment an image [17]. A set of 3×3 convolution kernels with 16 feature maps are used to transfer these levels. Then, up-sampling layers and concatenation are used to equalize the feature maps, followed by the segmentation layer.

B. Fetal head measurements

Measurement of the fetal head parameters (i.e. BPD and HC) from segmented regions was the primary goal of our proposed MFP-Unet. An optimization algorithm (i.e. least square) was used for fitting an ellipse shape to the fetal head and abdomen [19]. This method reformulated the fitting task as a linear optimization problem with a quadratic constraint. Five ellipse parameters including ellipse center coordinates, semi-major and semi-minor axes, and the ellipse angle are extracted from the fitted ellipse on the segmented region. Accordingly, the BPD is calculated as the semi-minor axis of the fitted ellipse on the fetal head image and the HC is calculated as the ellipse perimeter in fetal head images.

III. Results

A. Training and evaluation dataset

We used a publicly-available dataset to train and evaluate our proposed network. This dataset was acquired at the Department of Obstetrics of the Radboud University Medical Center, Nijmegen, the Netherlands. The original study was designed for the purpose of head circumference measurement, and later they made the dataset publicly available via the Grand Challenge HC18 [13].

TABLE I. segmentation performance of the proposed method regarding the segmentation of the fetal head.

Method	DSC	HD (mm)
MFP-Unet	0.95	4.5

TABLE II. result of pearson's test between predicted and manually driven parameters

BPD	HC
R = 0.96	R = 0.99
a = 0.99	a = 1
b = 1	b = 0.91

B. Evaluation metrics

For segmentation evaluation, the following metrics were calculated between manually drawn and predicted contours: Dice similarity coefficient (DSC) and Hausdorff distance (HD) (Table 1). For the evaluation of fetal head parameter measurements, Pearson's test was employed to perform the correlation analysis of the results (Table 2).

To evaluate the method in terms of fetal head measurement, we also used correlation and Bland-Altman graphs, which analyze the agreement between predicted and manually driven parameters. Fig. 1 shows the result of these analyses for the fetal head parameters. As Fig. 1 indicates, the most agreement between manual and automatic measurements belongs to HC (R=0.99).

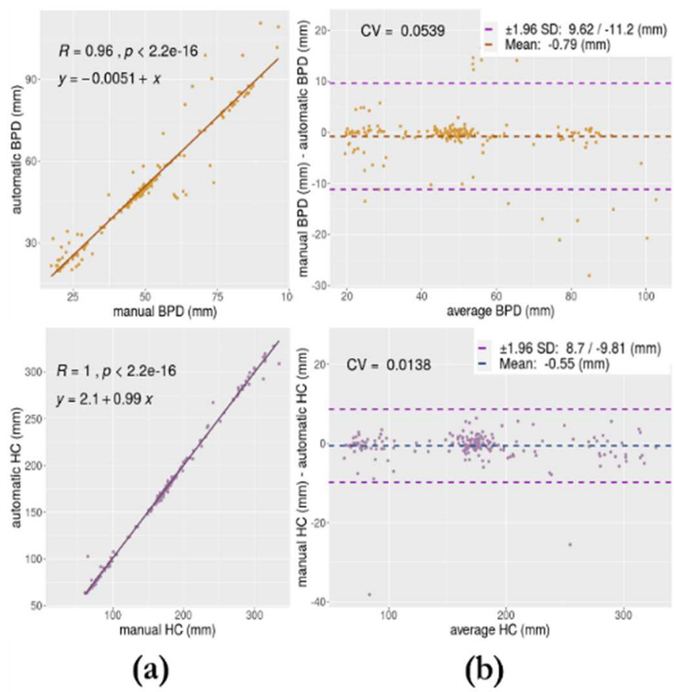

Fig. 1. Correlation analysis (a) and Bland-Altman plots (b) for fetal head parameters.

C. Qualitative result

Qualitative results of the segmentation outcome are depicted in Fig. 2. In this figure, the red line indicates the segmented region by an expert radiologist and the green line shows the automatic segmentation result.

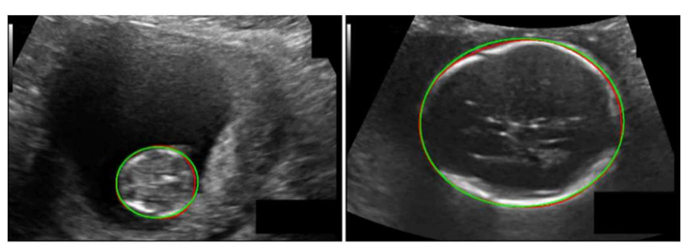

Fig. 2. Segmentation of fetal head. Manual and automatic segmentations are demonstrated by red and green lines, respectively.

IV. Conclusion

This study proposed a convolutional neural network architecture that automatically measures the BPD and HC from ultrasound images of the fetus. Utilizing a relatively large dataset resulted in satisfactory results with clinically tolerable errors.

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