Fetal Head Detection in 2D Ultrasound Images using Deep Learning

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***Abstract* — Automatic fetus head's boundary detection in the ultrasound image is a very challenging task due to the formation of intensity profile of the image. Ultrasound images are mostly affected by speckle noise and does not show a smooth intensity variation. A computer-based assistance system for the calculation of gestational age of the fetus is useful for the practitioners. Gestational age is a key quantity for an analysis about the baby's healthy growth which is calculated from the fetus head circumference. In this study, a deep learning-based solution is proposed where the layers and the parameters are adjusted in the U-Net architecture to maximize accuracy of the localization of the head region. There after the extracted contour is used to fit an ellipse and measure the age. The algorithm is trained with 899 images and validated with 100 images. Testing results on 335 images reveals promising with almost 100% localization accuracy and 88.96% specification. Detection of small size fetus is affected by the very closest similar intensity pattern. It will be addressed in the future**

Keywords — Gestational age, Deep learning, Fetus head, Ultrasound image

I. INTRODUCTION

Medical imaging modality such as X-ray, MRI, CT, and Ultrasound are playing a critical role in the assessment of several internal organs of a human body. In this regards US imaging is largely adopted in the medical field since it is non-invasive, low cost, and ability for real time scan. Ultrasound image is affected by several factors such as instrument noise, environment noise, background tissues, other organs, and breathing motion. Still, it is preferred for the scanning during prenatal stage.

Assessment on the fetus growth during the prenatal stage is necessary to determine the abnormalities in the development. Gestational age (GA) is one of the biometric measurement used for this assessment. For the calculation of GA, the ellipse parameter extracted from the ellipse that is constructed with the help of the fetus's head circumference (HC) which is extracted from the Ultrasound scan image. The manual examination on the Ultrasound image for the HC is a very tedious task and needs skilled persons. Therefore, an automated system for the GA calculation is useful, which can able to reduce the errors and tiredness during the examination of Ultrasound images.

The process of automatic calculation of GA has several stages where the HC is localized through the segmentation or machine learning or deep learning. Then an ellipse is fitted with the help of contour of the HC. The accuracy of GA depends on the precise segmentation of HC. Image processing based algorithms such as threshold based approaches [1, 2, 4], feature based localization methods such as Haar like features [1, 6], Hough transform [2, 5, 6] are not preferable if the image quality is largely affected by noise. Also, if there are variations in the continuous intensity pattern it will not produce good results. Therefore, researchers wish to make use of learning based methodologies for the HC segmentation in Ultrasound image. Machine learning approaches are good if a large number of samples are available for the training and need more time for learning. Recently Deep learning method such as a convolutional neural network (CNN) [7, 8, 9, 12, 13, 14] becoming popular in semantic segmentation. Among the available network model, U-net [9, 10, 11] is the most preferable for feature extraction and classification in medical images.

In this research study, the U-net is employed for the segmentation of the HC in the Ultrasound image. It is examined the influence of number of layers in U-net and the image size to precisely localize the HC.

II. OBJETIVES

Main objective of this study is to develop a simple deep learning architecture to localize the head region of the fetus in ultrasound image with high accuracy and fit an ellipse around the segmented head region to measure the circumference and gestational age.

III. METHODOLOGY

The U-Net architecture has proven to be excellent for medical image analysis. Thus in this work, CNN with U-Net is utilized for the HC detection. The number of layers is five and each layer has two convolutions and one max pooling. The convolution features of down_sampling layers are concatenated with the same level of the up_sampling convolution layer to improve the detection accuracy. Figure 1 shows the framework of the U-Net.

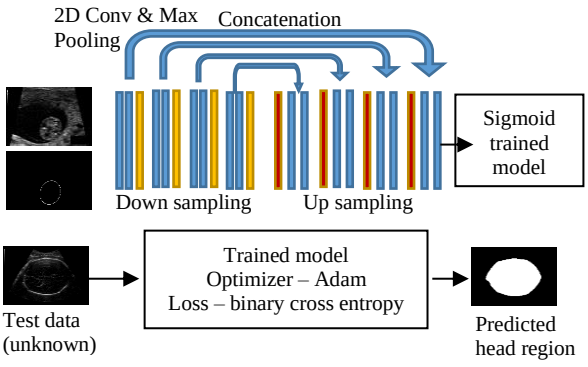

Fig 1: Implemented U-Net for the HC detection.

IV. RESULTS AND DISCUSSION

The proposed framework is trained using 899 Ultrasound images and validated with 100 images. For the testing, 335 Ultrasound images are used in this study. All the data are download from publicly available database. The python program is executed in normal CPU computer (1.8 GHz, 8 GB

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RAM, 64 bit OS) and the epochs are set to 10. The total time taken for execution is around 30 min.

Qualitative results: The proposed framework successfully identifies the fetal head region from the un-annotated ultrasound images. Figure 2 shows the visual evidence for the head region localization by the U-Net architecture.

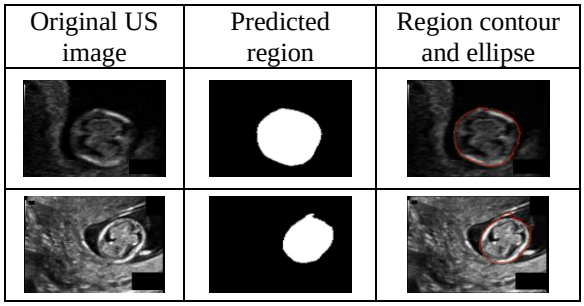

Fig. 2: Visual examples of the predicted HC region in unknown data. Left – original image, Center – predicted region, right – the contour and ellipse are drawn on the image. Red line – contour, green – ellipse. It is viewed clear in large scale image.

Quantitative results: For the quantitative analysis, every predicted region is visually inspected and counted as a correct prediction (TP) if the fitted ellipse goes along with the Head boundary region. If the predicted region is larger than or smaller than the true head region is counted as true negative. It is tested on 335 un-annotated ultrasound images. Therefore,

$$TP = 298$$
$$TN = 7$$
$$Sensitivity = TP/(TP + TN) = 88.96\%$$

The proposed U-net architecture has a sensitivity of 88.96%. On the other hand, the predicted region almost covers the fetal head region. The only thing is over detection and under detection. It will be further improved by adding post refinement process on the predicted region. True negative cases are shown in Figure 3.

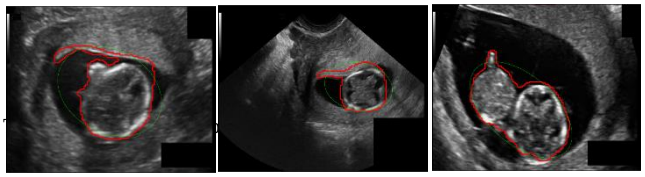

Fig. 3: Example for true negative cases.

The literature reveals that the HC localization in ultrasound images is a challenging task due to the shape and intensity variation of the fetus. Threshold based methods are good if the border information is very clear and no other tissues show the bright intensity. But Ultrasound image is affected by several factors such as instrument noise, environment noise and background tissues. So it would not able to accommodate the intensity variations of the head region. Feature based localization methods has the same issue as in the threshold based methods.

The proposed deep learning based U-net architecture gave a promising result of the localization of the head region with five layers and modified parameters.

V. CONCLUSION

In this study, a deep learning approach with modified U-Net architecture is proposed for fetal head segmentation in ultrasound images. It successfully segments the head region with 88.96% of sensitivity. Further, the true negative cases almost cover the actual region. There will be a further study for the improvement of accuracy. Here the preliminary results are reported. The initial results are promising which implies that it can be improved further in future studies.

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