Fetal Weight Estimation Based on Machine Learning

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1. Introduction

Fetal weight is a very important indicator of fetal growth and abnormal intrauterine pregnancy. Accurate estimation of fetal weight can detect fetal growth restriction in time, which is helpful for further diagnosis and treatment, and ultimately achieve a reduction in neonatal mortality. The quality of the ultrasound image and the accuracy of the corresponding biological parameters are very important for the accurate diagnosis of fetal weight and growth status. However, manual contouring of the anatomical contours is very time consuming, and there are significant differences between different physicians in clinical practice. In order to solve the problems mentioned above, this paper discusses fetal weight estimation based on ultrasound images and assists in the accurate estimation of fetal biological parameters and growth status in clinical obstetric examinations.

With the rapid development of artificial intelligence and medical image processing technology, "smart ultrasound" has become an inevitable trend. Zhang et al. extracted the texture features of the fetal anatomy [1] and detected the edges of the image based on texture and brightness information, but the average time was too long. Shan et al. proposed a method based on a feasible variable model [2] to detect the head circumference. The model is based on the Rayleigh distribution. The spatial characteristics of the texture structure are not considered, and the edge detection accuracy is not high. Lu et al. used the K-means clustering method [3] to obtain the highlighted part of the skull, but this method is greatly affected by noise and is highly prone to bias. Carneiro et al. proposed a universal system for rapid and automated measurement of several different anatomical structures of the fetus [4]. For the first time, the system uses machine learning techniques, and the training constraint probability tree classifier identifies the target of interest from coarse to fine and then using the prior statistical positional relationship to estimate the target parameter, but the accuracy of machine learning is lower than that of the expert. There are still some difficulties in applying to clinical practice.

2. Methods

The mainstream weight estimation formula requires biological parameters of the head, femur, and abdomen. Therefore, this paper mainly discusses the automatic measurement of these parameters in the standard measurement plane, and proposes a solution to the problems of attenuation, edge deletion, artifacts, and speckle noise in the ultrasonic image signal in automatic measurement. For fetal head circumference, femur length and other physiological indicators, this paper uses C++ language and OpenCV image processing library to realize automatic measurement of parameters based on improved fuzzy C-means clustering and mathematical morphology. For the parametric measurement of ambiguous boundary information of the abdominal circumference, this paper uses the deep learning model to implement fetal abdomen detection and instance segmentation using the Python language under the TensorFlow and Keras deep learning framework. After using the Canny algorithm for edge detection, a full-automatic measurement of the abdominal circumference in a 2D ultrasound image was finally achieved.

3. Results

3.1 Measurement of Fetal Head Circumference

Through the fetal head measurement algorithm, for the selected standard image of the fetal head, the region of interest (ROI) is first selected, then the fuzzy C-means clustering algorithm is used to extract the bones from the ROI, and then the morphological reconstruction of the binary image is performed. After the operation is refined, the elliptical fitting algorithm ElliFit is used to perform the head circumference fitting on the refined result.

The automatic fitting effect of the algorithm is shown in Figure 1. The blue ellipse in the lower right corner is the final fitting result of the algorithm, and the green part is the head circumference boundary of the expert mark. It can be seen that the two labels are basically consistent.

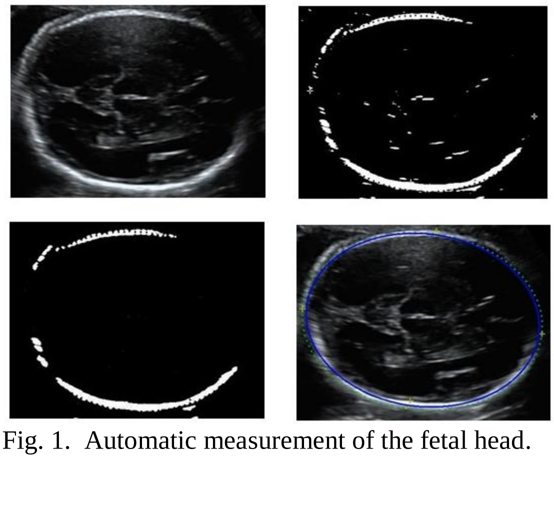

Fig. 1. Automatic measurement of the fetal head.

3.2 Measurement of Fetal Femur Length

In the fetal femur length measurement algorithm, for the selected fetal femur standard ultrasound image, the region of interest (ROI) is first selected, then the ROI is subjected to the fuzzy C-means clustering algorithm to extract the bone, and then the reconstructed morphological opening operation is performed on the binary image. After refinement, the morphological skeletonization algorithm is used to extract the skeleton from the refined results.

The effect of the algorithm is shown in Figure 2. The blue line is the result of the femur fitting of the algorithm, and the yellow punctuation is the two endpoints of the expert calibration.

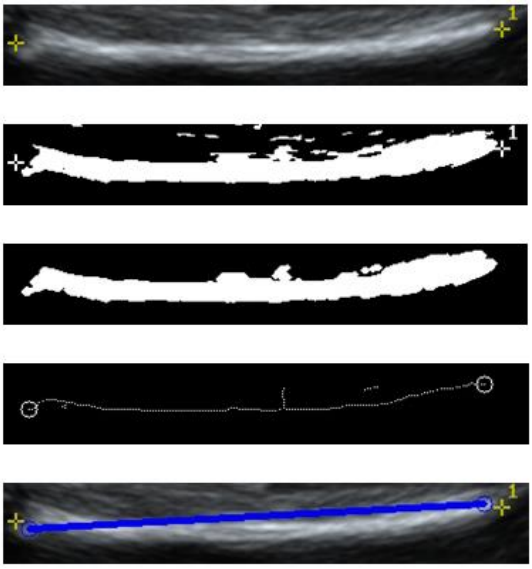

Fig. 2. Automatic measurement of the fetal femur.

3.3 Fetal abdomen segmentation based on deep learning

The deep learning method automatically estimates the fetal abdominal circumference and considers the doctor's decision process, fetal anatomy, and characteristics of the ultrasound image. After using the convolutional neural network to segment the ultrasound images (stomach, amniotic fluid, and umbilical vein), the edge detection algorithm is used to obtain the length of the abdominal circumference, and finally, the automatic measurement of the abdominal circumference in the 2D ultrasound image is realized.

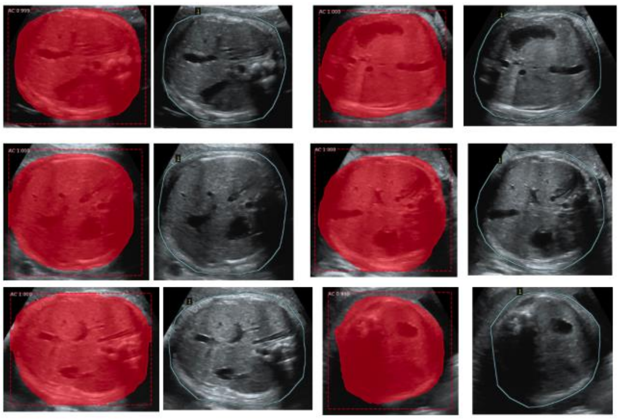

Fig. 3. Fetal abdominal segmentation results.

We selected hundreds of images of the abdominal circumference marked with a doctor for verification. We compared the abdominal circumference estimates from the ultrasound images received by the experts and the algorithm, respectively. Some comparisons of the abdominal contours selected by the experts and the estimated contours of our model are plotted in Figures 3. The red part of the image is the ROI and the abdominal area detected by the algorithm, while the blue is the range of the abdominal circumference marked by the doctor. From a qualitative point of view, the two are highly consistent.

3.4 Prediction of fetal weight using automatic measurement parameters

We use a number of non-linear regression equations to estimate fetal weight. As the name implies, scholars use two or more different parameter combinations to estimate fetal weight. The most influential equation is the Combs formula. Based on the Combs formula, the Combs model was improved for the yellow body mass in Asia, and a relatively more accurate model was obtained:

$$Y = 73.6789 + 0.505184 X_1 X_3^2 - 0.014948 X_2^3 \quad (1)$$

And X_1 is the length of the femur (cm), X_2 is the head circumference (cm), and X_3 is the abdominal circumference (cm). And Y represents fetal weight (g).

4. Conclusion

The experimental results show that the fetal ultrasound parameters and weight estimation system based on ultrasound images are suitable for fetal ultrasound images with different parameters set in the 20 to 38 gestational weeks, and the consistency is over 90% compared with the manual scores of the ultrasonic physicians. At the same time, the automatic measurement method takes less time than the manual labeling method and can meet the needs of clinical real-time performance.

References

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