SECTION 3. DATA PROCESSING AND SOFTWARE SYSTEMS DEVELOPMENT/ ТЕХНОЛОГІЇ ОБРОБКИ ДАНИХ ТА СТВОРЕННЯ ПРОГРАМНИХ СИСТЕМ

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DEFORMABLE ATTENTION U-NET NETWORK BASED ON FULLY CONVOLUTIONAL DISCRIMINATOR FOR SEMANTIC SEGMENTATION OF FETAL BRAIN ULTRASOUND IMAGES

Abstract. Fetal brain ultrasound image segmentation is a crucial task for prenatal diagnosis and medical analysis but remains challenging due to image noise, low contrast, and limited annotated datasets. To overcome these limitations, this study proposes a Deformable Attention U-Net network integrated with a fully convolutional discriminator for semantic segmentation of fetal brain ultrasound images. The proposed approach draws on the generative adversarial network (GAN) concept, where the segmentation model acts as a generator and the discriminator evaluates segmentation quality to optimize network parameters. The segmentation network improves the standard Attention U-Net by introducing 3×3 deformable convolutions to enhance local feature learning and replacing traditional MaxPooling with gating units that selectively retain informative feature maps. This architecture effectively reduces the dependency on large datasets while improving boundary accuracy. Experimental evaluation on a fetal head circumference dataset demonstrated significant performance gains compared to baseline models. The proposed network achieved an Intersection over Union (IOU) of 93.8%, a DICE coefficient of 96.8%, and an accuracy of 97.9%, surpassing U-Net and Attention U-Net by 14.6%, 9.8%, and 4.7%, respectively. These results confirm that integrating deformable attention mechanisms and fully convolutional discriminators enhances edge segmentation and global consistency in fetal ultrasound images. The proposed model provides a reliable framework for fetal biometric measurement and can be further extended to other medical image segmentation applications.

Keywords: fetal brain segmentation; deformable Attention U-Net; fully convolutional discriminator; ultrasound imaging; generative adversarial network; semantic segmentation.

INTRODUCTION

Fetal ultrasound images contain a significant amount of noise, which hinders the classification and diagnosis of abnormal diseases. Recent research on fetal ultrasound image segmentation has mainly focused on the application of deep convolutional neural networks (DCNNs). Ye Hai et al. [1] proposed a fetal brain ultrasound image segmentation algorithm based on a fully convolutional network. Cerrolaza et al. [2] discussed the application of fully convolutional networks in skull segmentation of fetal 3D ultrasound images. Zahra Sobhaninia et al. [3] presented a multi-scale and deep neural network for estimating fetal biometric parameters. This network outperforms single-task networks in segmentation and ellipse optimization tasks. However, the aforementioned methods are inadequate in leveraging boundary information of fetal brain images, and the segmentation accuracy needs further improvement.

The article's goal. To address these issues, this study proposes a deformable Attention U-net network based on a fully convolutional discriminator for semantic segmentation of fetal brain ultrasound images. This network uses a discriminator to optimize local features of the segmentation network, fully leveraging boundary information, and reducing the dataset

requirements for the segmentation network. Additionally, based on Attention U-net [4], it uses a deformable convolution with a 3x3 kernel to better learn features and employs gating units to replace MaxPooling, selecting beneficial feature maps while suppressing less useful ones. These methods effectively address the problem of limited medical image datasets.

THE RESULTS AND DISCUSSION

This experiment draws on the idea of generative adversarial networks [5] and designs a semantic segmentation network with a fully convolutional discriminator. The overall network structure is shown in Figure 1. The entire network structure consists of two modules: a semantic segmentation network (deformable Attention U-net) and a discriminant network. Through this overall network structure, we can understand how this experiment uses generative adversarial networks for training and obtains semantic segmentation results through generative adversarial learning.

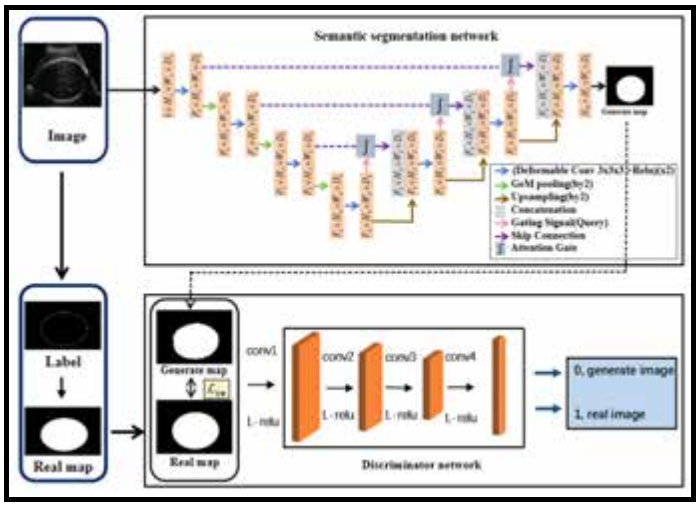

Fig. 1. An overview of the proposed semantic segmentation network based on a general fully convolutional discriminator generative adversarial network.

The improved Deformable Attention U-net model is based on the Attention U-net model but utilizes deformable convolutions with a kernel size of 3x3, aiming to enable the network to better learn features. It also uses gating units to replace MaxPooling, filtering the convolved feature maps to retain the good ones and suppress the bad ones. The specific network structure is shown as the Semantic segmentation network in Figure 1.

The experiment used the U-net [6] network, Attention U-net network, and the deformable Attention U-net network based on the full convolution discriminator used in the final network. Figure 2 shows the experimental results of this experimental network, U-net, and Attention U-net on the fetal head circumference dataset.

Table 1.

Comparison of experimental results

Network Structure	IOU (%)	Dice (%)	Accuracy (%)
U-net	79.2	87.0	93.2
Attention U-net	89.2	94.0	96.4
This experimental network	93.8	96.8	97.9

Table 1 compares the experimental results of our network with U-net and Attention U-net on the fetal head circumference dataset. From the data in the table, it can be seen that with

the use of a fully convolutional discriminator and improvements to the Attention U-net (replacing MaxPooling with 3x3 deformable convolution and gating units), our experiment achieved an IOU increase of 14.6%, reaching 93.8%, a DICE increase of 9.8%, reaching 96.8%, and an Accuracy increase of 4.7%, reaching 97.9% compared to U-net. In comparison to Attention U-net, IOU increased by 4.6%, DICE increased by 2.8%, and Accuracy increased by 1.5%.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

This paper proposes a fetal brain image segmentation network based on a full waveform discriminator. The proposed method adopts the scheme of generative adversarial networks (GANs), which consists of a segmentation network and a discriminator. Deformable Attention U-net is used as the segmentation network in the paper, and the discriminator uses a full partition network to distinguish whether the input image is a probability map of real data and a probability map of the segmentation result of the segmentation network. Through the generative adversarial between this discriminator and the segmentation network, the discriminator continuously optimizes the model parameters of the segmentation network, thereby improving the segmentation accuracy of the segmentation network. And in this learning adversarial process, the network depth of the segmentation network does not increase. A large number of experiments were carried out on the fetal head circumference dataset to verify the effect of the algorithm. At the same time, it was proved that the scheme of adding a full output discriminator is very suitable for fetal ultrasound images, which can further optimize the effect of edge segmentation of fetal ultrasound images and reduce the data requirements of the segmentation network.

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