Measurement of Fetal head circumference using Ultrasound

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BI12-338 Data Science

March 2024

Abstract

This project focuses on automating the measurement of fetal head circumference using ultrasound images. The UNET model, a convolutional neural network architecture, is utilized for accurate and reliable measurements. Training the model using the dataset of annotated ultrasound images provided by the HC18 Grand Challlenge.

Evaluation is performed on a separate dataset, comparing predicted segmentations with ground truth using the Dice score. Results indicate promising performance, with the UNET model achieving a Dice score ¿ 0.7. This suggests its potential for accurate measurements to aid in monitoring fetal growth and identifying abnormalities during pregnancy.

1 Introduction

The term "fetal" refers to the unborn offspring in the womb during pregnancy. The fetal head, as a vital part of the developing fetus, plays a crucial role in monitoring fetal growth and assessing overall health. Fetal head circumference, a key parameter, serves as an important indicator of fetal well-being and development. Ultrasound, a non-invasive imaging technique that uses high-frequency sound waves, has become a standard tool in prenatal care. It provides real-time visualization of the fetus, allowing healthcare professionals to assess various fetal characteristics, including fetal head measurements. The use of ultrasound for fetal head circumference measurement offers advantages such as safety, accessibility, and the ability to monitor growth throughout pregnancy. Machine learning, a branch of artificial intelligence, involves the development of algorithms that enable systems to learn and make predictions from data without explicit programming. Applying machine learning techniques to measure fetal head circumference using ultrasound images allows for automation and standardization of the process, reducing the reliance on subjective manual measurements. The application of machine learning models, such as convolutional neural networks like UNET, in fetal head circumference measurement brings promising possibilities. These models can learn from a vast collection of annotated ultrasound images to accurately segment and measure the fetal head region. By leveraging machine learning, healthcare professionals can obtain precise and reliable measurements, aiding in the identification of potential abnormalities and providing better care for both the fetus and the expectant mother. In summary, the introduction highlights the importance of fetal head circumference measurement, the role of ultrasound in this process, and the potential benefits of applying machine learning techniques. This research aims to explore the integration of machine learning algorithms with ultrasound imaging to enhance the accuracy and efficiency of fetal head circumference measurement, ultimately contributing to improved prenatal care and patient outcomes.

2 Background

2.1 Fetal head circumference

Fetal head circumference is a critical measurement taken during prenatal checkups and after birth to assess the newborn's growth and development. It is a measure of the size of the newborn's head, specifically the distance around the largest part of the baby's head. The measurement is taken from the top of the baby's head, following the curve of the skull around to the back of the head, and then around to the front again. The measurement of fetal head circumference is essential for tracking the baby's growth and development throughout pregnancy and after birth. During pregnancy, healthcare providers use ultrasound to measure the fetal head circumference to monitor the baby's brain development and overall growth. After birth, healthcare providers continue to measure the newborn's head circumference to ensure that it is growing at a healthy rate. An abnormal fetal head circumference measurement can indicate various health issues, such as developmental delays, genetic disorders, or brain abnormalities. A larger-than-average head circumference may indicate hydrocephalus, a condition characterized by the accumulation of fluid in the brain, while a smaller-than-average head circumference may indicate microcephaly, a neurological disorder that affects the baby's brain development.

2.2 Approach Analysis

In this project, we utilized CNN and a modified U-Net architecture to automate fetal head circumference measurement from ultrasound images. The CNN model captures complex spatial patterns, while the U-Net architecture improves segmentation accuracy by preserving spatial details. We also introduced a double CNN based on U-Net for enhanced performance. Training involved optimizing model parameters using a loss function such as Dice loss. Performance evaluation utilized metrics like IOU scores and accuracy. Our approach aims to provide accurate measurements for monitoring fetal growth and detecting abnormalities during pregnancy. The U-Net

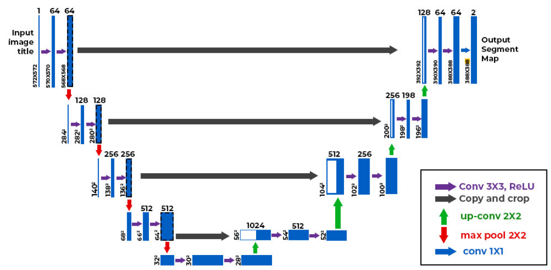

Figure 1: UNET architecture

architecture is a CNN model specifically designed for image segmentation tasks. It consists of an encoder pathway and a decoder pathway. The encoder pathway captures high-level features and global context by using convolutional layers with downsampling operations. The decoder pathway recovers spatial details and performs segmentation by using upsampling operations and convolutional layers. It also includes skip connections that connect corresponding layers between the encoder and decoder. These skip connections enable the U-Net model to combine both global context and local information, resulting in accurate and detailed segmentation results.
The U-Net architecture is commonly used in medical image segmentation tasks, including fetal head circumference measurement from ultrasound images, due to its ability to handle limited training data and imbalanced class distributions.

3 Methodology

My desire when creating this architecture is to make a simple one. Due to the limitations of hardware(I use Kaggle with GPU P100 16GB), I have to drop my network from 4 types of kernel size which are [64,128,256,512] to [64,128,256]. The number of parameters go down from 33M to over 7.7M.

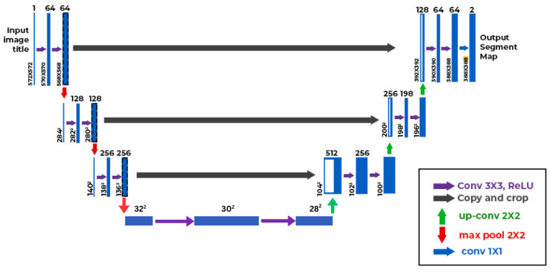

Figure 2: Model architecture

4 Evaluation

4.1 Dataset

4.1.1 Background

During pregnancy, ultrasound imaging is used to measure fetal biometrics. One of these measurements is the fetal head circumference (HC). The HC can be used to estimate the gestational age and monitor growth of the fetus. The HC is measured in a specific cross section of the fetal head, which is called the standard plane. The dataset for this challenge contains a total of 1334 two-dimensional (2D) ultrasound images of the standard plane that can be used to measure the HC. This challenge makes it possible to compare developed algorithms for automated measurement of fetal head circumference in 2D ultrasound images.

4.1.2 Detailed description of the data

The data is divided into a training set of 999 images and a test set of 335 images. The size of each 2D ultrasound image is 800 by 540 pixels with a pixel size ranging from 0.052 to 0.326 mm.
For the training phase, we split into train and validation dataset which are 799 and 200 images respectively. In order to fit with our hardware, we also resize the image into 150 by 100 pixels. Below is example of the image and its annotation: Since the distribution is imbalance, I will apply under-sampling for Abnormal class.

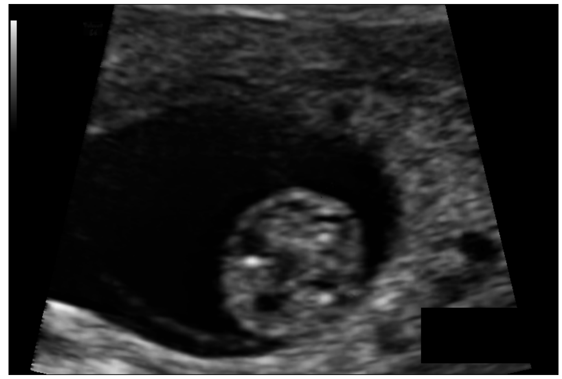

Figure 3: Sample image

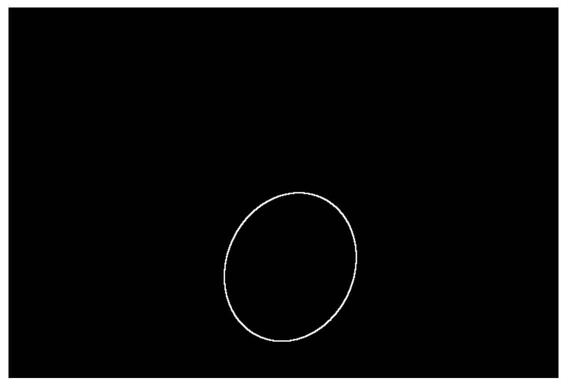

Figure 4: Sample of its annotation

4.1.3 Data preprocessing

Due to the form of model's input, I converse the annotation from bounding line into an ellipse mask.

4.2 Training phase

I train this model in only 10 epochs which batch size is 3. The ratio for train, validation, and test dataset is 80-10-10. Since, the dataset is large, training time is about 20 minutes with average time for each epoch approximately 2 minutes. It is easy to recognize that overfitting is not here. Therefor, our model with nearly 88% is acceptable(without considering too much about its practical application).

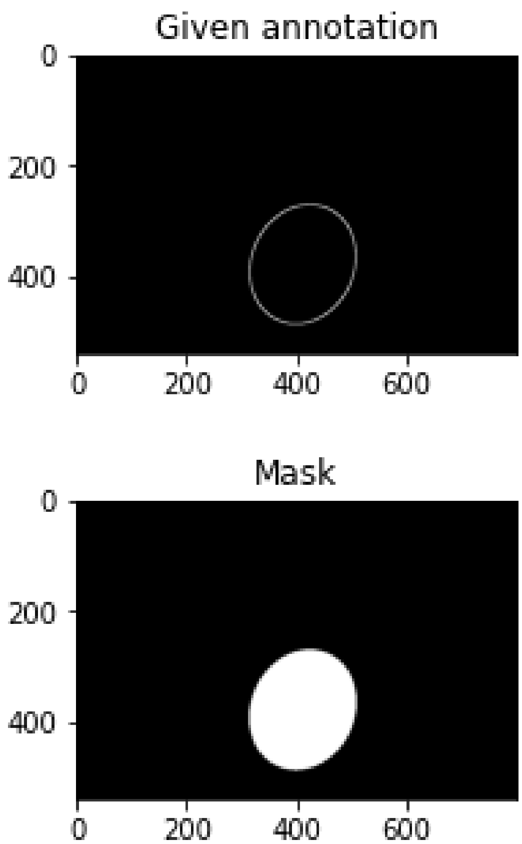

Figure 5: Ellipse mask

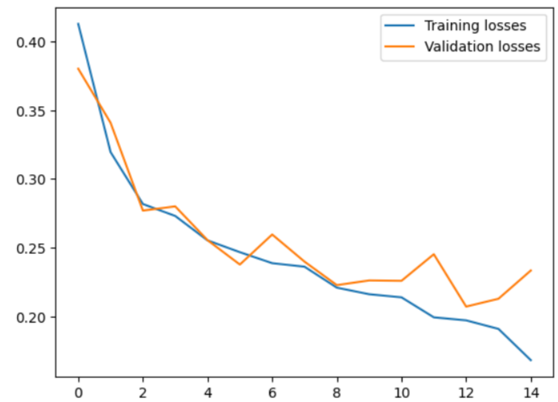

Figure 6: Loss in training phase on train and validation dataset

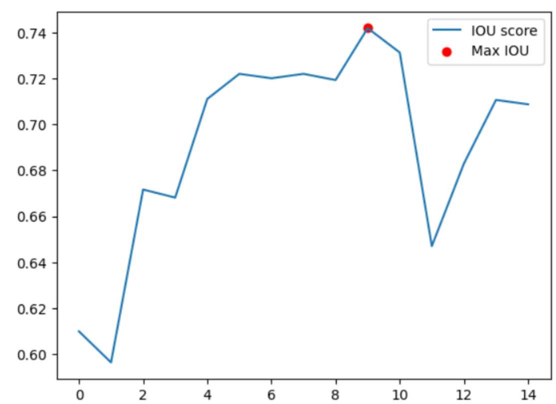

Figure 7: IOU score in training phase on validation dataset

4.3 Metric

The IOU (Intersection over Union) score, also known as the Jaccard Index, is a common evaluation metric used in computer vision tasks, such as object detection and image segmentation. It measures the similarity between two sets, typically the predicted region and the ground truth region.
The IOU score is calculated by dividing the area of intersection between the predicted and ground truth regions by the area of their union. The formula for calculating the IOU score is as follows:
IOU = (Area of Intersection) / (Area of Union)
The IOU score ranges from 0 to 1, where a score of 1 indicates a perfect overlap between the predicted and ground truth regions, and a score of 0 indicates no overlap at all.
The IOU score is a useful metric for evaluating the performance of models in tasks like object detection and image segmentation since it provides an indication of how well the model's predictions align with the ground truth annotations. Higher IOU scores generally indicate better performance and better alignment between predicted and ground truth regions.

5 Conclusion

An IOU score above 0.7 indicates a significant overlap between the predicted segmentation mask and the ground truth annotation of the fetal head. This suggests that the modified U-Net model performs well in accurately identifying and segmenting the fetal head in ultrasound images. However, due to the limitation of time and my ability, I could not do further step to estimate the circumference which is the target of this challenge. This could appear in the future work when I complete all my stucks at this time :(