Ultrasonic Image Fetal Head Segmentation Task Report

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1 Methodology

The data provided by https://hc18.grand-challenge.org/ contains a set of 999 ultrasonic scans and 999 matching annotated segmentation images in png format. To make the dataset compatible with nnUNet's requirements, the pngs obtained has to be converted into nii.gz format. As the testing data provide by the website does not contain labels, the training data has to be split into subsets for training and testing in a $7:3$ ratio.

nnUNet splits the training data into 5 folds and trains 5 distinct models. Each model can be used and evaluated individually, but I opted to use the ensemble prediction as it should be more accurate.

2 Evaluation

For the evaluation of the models, 3 metrics are selected for the evaluation process, which are:

1. Dice coefficient of the set of pixels between the set of pixels that make up the segmentation in the predicted output and the expected output
2. Hausdorff distance between the two set of pixels in the predicted and expected output
3. Root Mean Square Error of the head circumference

The following subsections will discuss on how these metrics are calculated.

2.1 Dice Coefficient

The dice coefficient can be calculated with the following equation.

$$Dice = \frac{2 \times ||S_p \cup S_t||}{||S_p|| + |S_t||} \tag{1}$$

Where S_p and S_t are the set of pixels that are marked on the prediction segmentation and the expected segmentation respectively.

Using equation 1, the average dice coefficient over the selected evaluation samples is **0.31**.

2.2 Hausdorff Distance

The Hausdorff distance can be calculated using the following equation.

$$H_{dist} = \max_{p \in S_p} \min_{t \in S_t} d(p,t) \times \alpha \tag{2}$$

Where d is the euclidean distance between points p and t, which on a 2D images, can be calculated using the pixel coordinates, and α is the pixel to mm scale factor.

Using equation 2, the average Hausdorff distance over the selected evaluation samples is **2.46mm**.

2.3 Head Circumference RMSE

We can treat the head of the fetus as an ellipse and using related mathematical equations to approximate the circumference of the segmentation that was inferred by the model.

The general form of an ellipse is expressed by the standard equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \tag{3}$$

Given set of pixel coordinates which form a partially complete ellipse, the implicit form of the ellipse can be fitted and approximated in such a form.

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0 \tag{4}$$

Where A, B, C, D, E, and F are all coefficients of the implicit equation. These coefficients can then be used to obtain the general form coefficients of an ellipse shown in equation 3.

$$a, b = \frac{-\sqrt{2(AE^2 + CD^2 - BDE + F(B^2 - 4AC))((A + C) \pm \sqrt{(A - C)^2 + B^2}}}{B^2 - 4AC} \tag{5}$$

$$x = \frac{2CD - BE}{B^2 - 4AC} \tag{6}$$

$$y = \frac{2AE - BD}{B^2 - 4AC} \tag{7}$$

Finally, the circumference of the ellipse can be approximated by the following equation.

$$C \approx \pi(a + b)(1 + \frac{3h}{10 + \sqrt{4 - 3h}}) \times \alpha \tag{8}$$

$$h = \frac{(a - b)^2}{(a + b)^2} \tag{9}$$

The error of this approximation is of order h^5, and again α is the pixel to mm scale factor

Using an algorithm to fit the coordinates into the form of equation 4 then approximating the circumference with equation 8, the root mean square error of the selected evaluation samples is **3.51mm**. Which is a **1.27%** error given that the average circumference of the selected evaluation samples is **275.48mm**.