

Deep Learning for Medical Image Segmentation

A Benchmark Evaluation of U-Net Variants

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Abstract

Medical image segmentation is a critical task in computer-aided diagnosis. Deep learning models, particularly U-Net and its variants, have achieved state-of-the-art performance. We systematically evaluate six U-Net variants on three public segmentation benchmarks (BraTS, ISIC, and Kvasir-SEG). Attention U-Net achieves the highest Dice score (0.913) on the BraTS dataset, while nnU-Net shows the best generalizability across all three tasks.

1. Introduction

Accurate segmentation of anatomical structures and pathological regions is fundamental to many clinical applications. In recent years, convolutional neural network architectures have dramatically advanced the state of the art in medical image segmentation.

2. Methods

We implemented six U-Net variants: standard U-Net, Attention U-Net, Residual U-Net, Dense U-Net, UNet++, and nnU-Net. Each model was trained on identical train/validation splits using the Adam optimizer with a learning rate of $1e-4$.

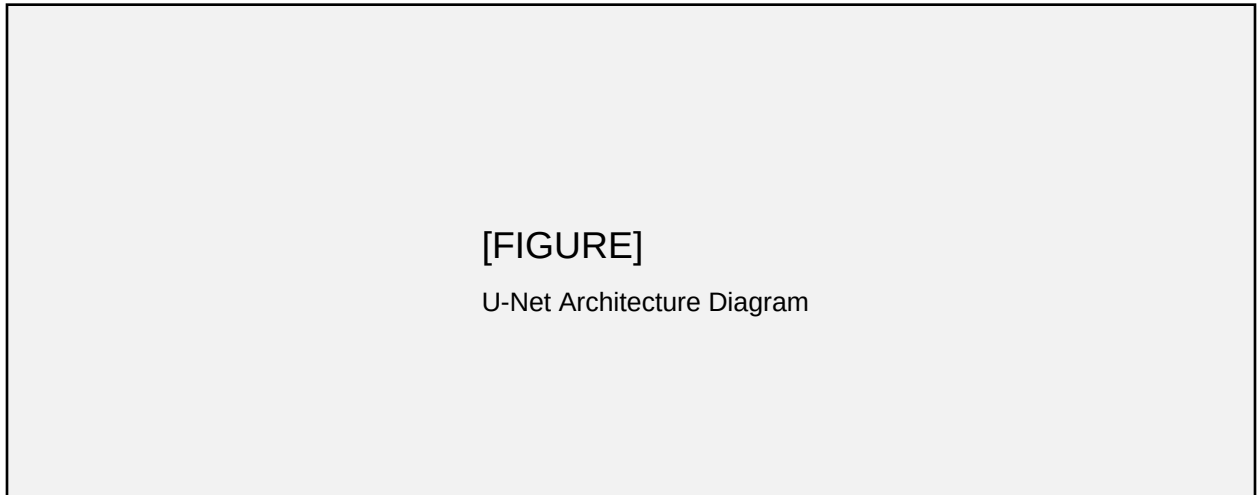


Figure 1: Schematic of the U-Net architecture showing encoder-decoder pathway with skip connections.

3. Results

Table 3 summarizes the Dice scores across all datasets. Attention U-Net consistently outperformed the standard U-Net, particularly on challenging boundary regions.

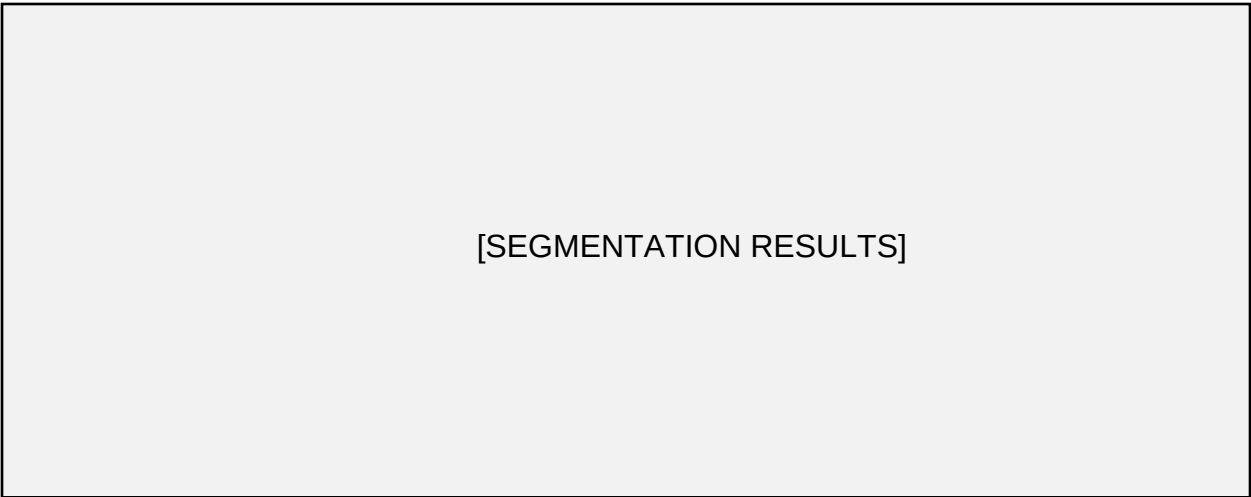


Figure 2: Qualitative segmentation results on the BraTS validation set.
Top row: input images. Bottom row: ground truth (green) and predictions (red).

4. Discussion and Conclusion

Our comprehensive benchmark provides practical guidance for model selection in medical image segmentation tasks. nnU-Net offers the best off-the-shelf performance, while Attention U-Net provides superior accuracy for specific segmentation challenges.

References

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