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Empirical combination networks for head and neck organs at risk segmentation

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ABSTRACT

Objective: To comprehensively evaluate popular medical segmentation networks on the CSTRO dataset for head and neck organs at risk (H&N OARs) segmentation, identify top performers, and integrate them into a robust hybrid network (Attention W-Net) for superior performance.

Methods: U-Net, Attention U-Net, R2U-Net, UNet-plusplus, and CE-Net were selected and two novel architectures W-Net and SE-U-Net were developed. Using U-Net as the baseline, a first-stage experiment was conducted to evaluate the segmentation performance of these networks. Following initial evaluations, Attention U-Net, SE-U-Net, and W-Net achieved notably strong performance. Representative blocks were identified and extracted from these three networks to construct three hybrid architectures: Attention W-Net, SEW-Net, and Attention SEU-Net. Subsequently, a second-stage experiment was conducted to determine the optimal hybrid architecture.

Results: In the first stage, U-Net, Attention U-Net, R2U-Net, UNet-plusplus, CE-Net, W-Net and SEU-Net were tested and achieved 0.712, 0.755, 0.706, 0.710, 0.702, 0.708, 0.767, 0.749 of average dice similarity coefficient (DSC), respectively. Then the best three networks Attention U-Net, SEU-Net, W-Net were selected out. The hybrid networks Attention W-Net, Attention SEU-Net, SEW-Net were tested, and achieved 0.776, 0.768, 0.743 of average (DSC), respectively. In terms of the metric, Attention W-Net is the most effective networks for H&N OAR segmentation.

Conclusion: The Attention W-Net and SEW-Net are the better networks which achieve better results than the popular state-of-the-arts networks for head and neck OARs segmentation.

1. Introduction

Precise contouring of organs at risk (OARs) is critical in radiotherapy planning, guiding treatment delivery and dose optimization by medical physicists.[1,2] Accurate segmentation minimizes radiation exposure to healthy tissues and enhances therapeutic precision.[3] Historically reliant on manual methods—demanding significant time, expertise, and introducing variability—delineation now benefits from clinically viable automated segmentation systems offering improved accuracy, reproducibility, and reduced time.[4,5] This underscores the necessity of integrating automation into modern workflows.

Traditional medical image segmentation methods (e.g., thresholding, region-based, active-contour, graph cut3) are increasingly supplanted by deep-learning approaches.[6–12] Semantic segmentation neural networks dominate, with the fully convolutional network (FCN) marking a significant shift.[13] Using VGG16 to extract features and upsample for pixel-level classification, FCN achieved state-of-the-art performance. Seg-Net, structurally similar to U-Net, followed. U-Net itself was introduced specifically for medical images, where consistent target distributions and simpler backgrounds differ from complex natural images.[14] Empirical studies confirmed U-Net's superior suitability, establishing it as a milestone and enduring baseline architecture.[15]

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