DARN: Deep Attentive Refinement Network for Liver Tumor Segmentation from 3D CT volume

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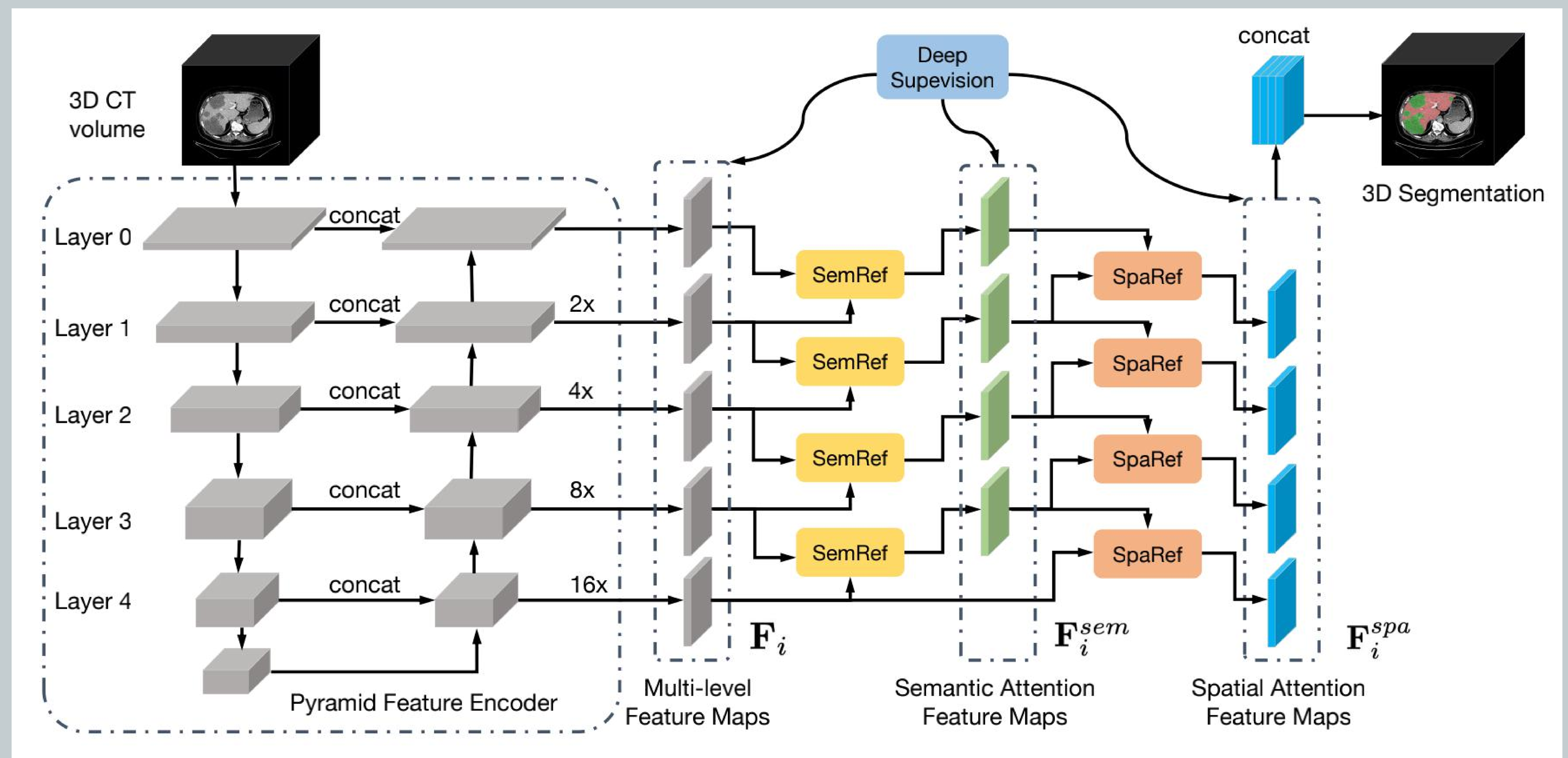
Introduction

Automated liver tumor segmentation from the contrast-enhanced CT volumes is a very challenging task. First, the liver tumors have various sizes, shapes, textures and locations within the patients, therefore it is difficult to design features to extract the characteristics of liver tumors. Second, there exist no clear boundaries for some liver tumors, which brings the difficulties for both data annotation and segmentation.

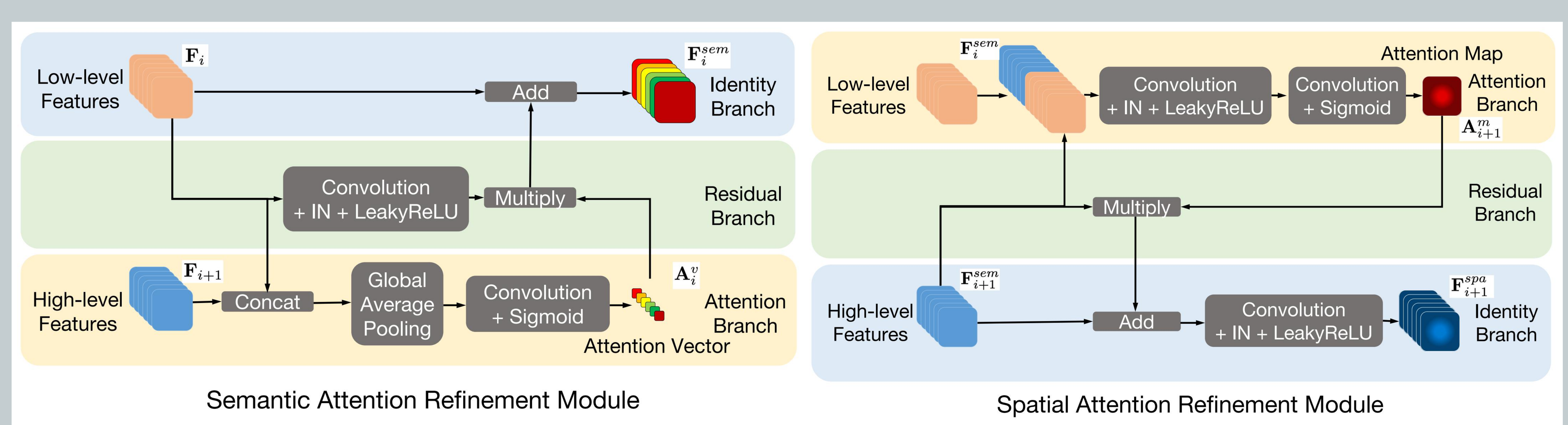
In consideration of the aforementioned characteristics of liver tumor, fusing various features from all levels is beneficial to liver tumor segmentation. High-level semantic features contribute more to the category recognition of tumor regions, while low-level spatial features bring advantage to generate sharp, detailed boundaries of liver tumor for high-resolution prediction

How to effectively leverage multi-level features embedded in different layers of FCN for better liver tumor segmentation remains an open question. To this end, we propose DARN for more precise liver tumor segmentation from CT volumes by adaptively enhancing multi-level features with the guidance of neighboring high- or low-level features.

Method



The proposed Deep Attentive Refinement Network (DARN), composed of a Pyramid Feature Encoder (PFE), a Semantic Attentive Refinement (SemRef) Module, and a Spatial Attention Refinement (SpaRef) module. First, PFE extracts multi-level features maps from the input 3D CT volume. Then, SemRef and SpaRef modules make a further refinement to enhance the multi-level feature maps with respect to semantic and spatial dimensions, respectively. Last, the refined feature maps are aggregated for final segmentation.



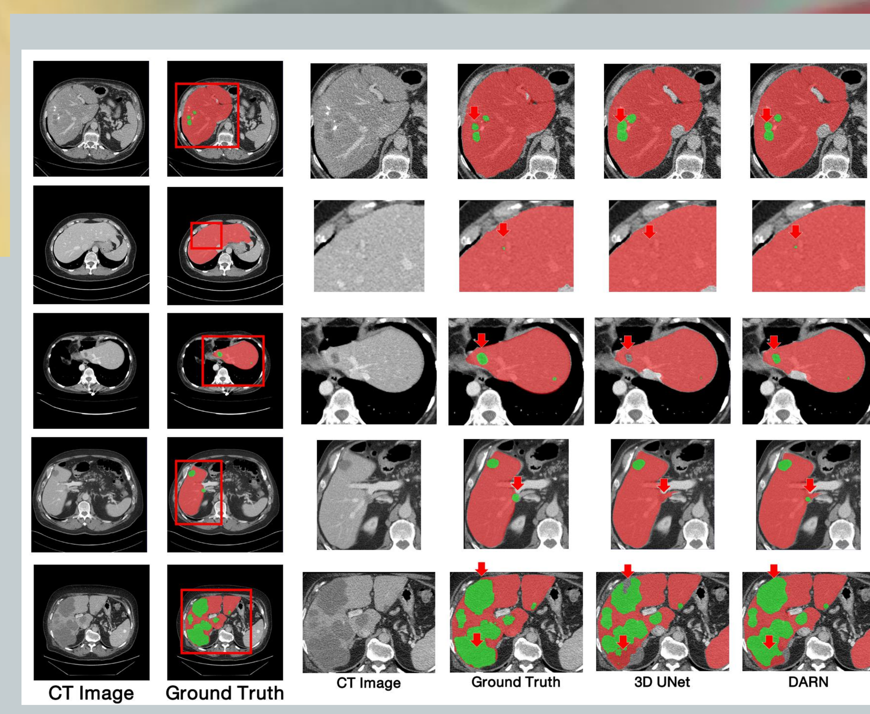
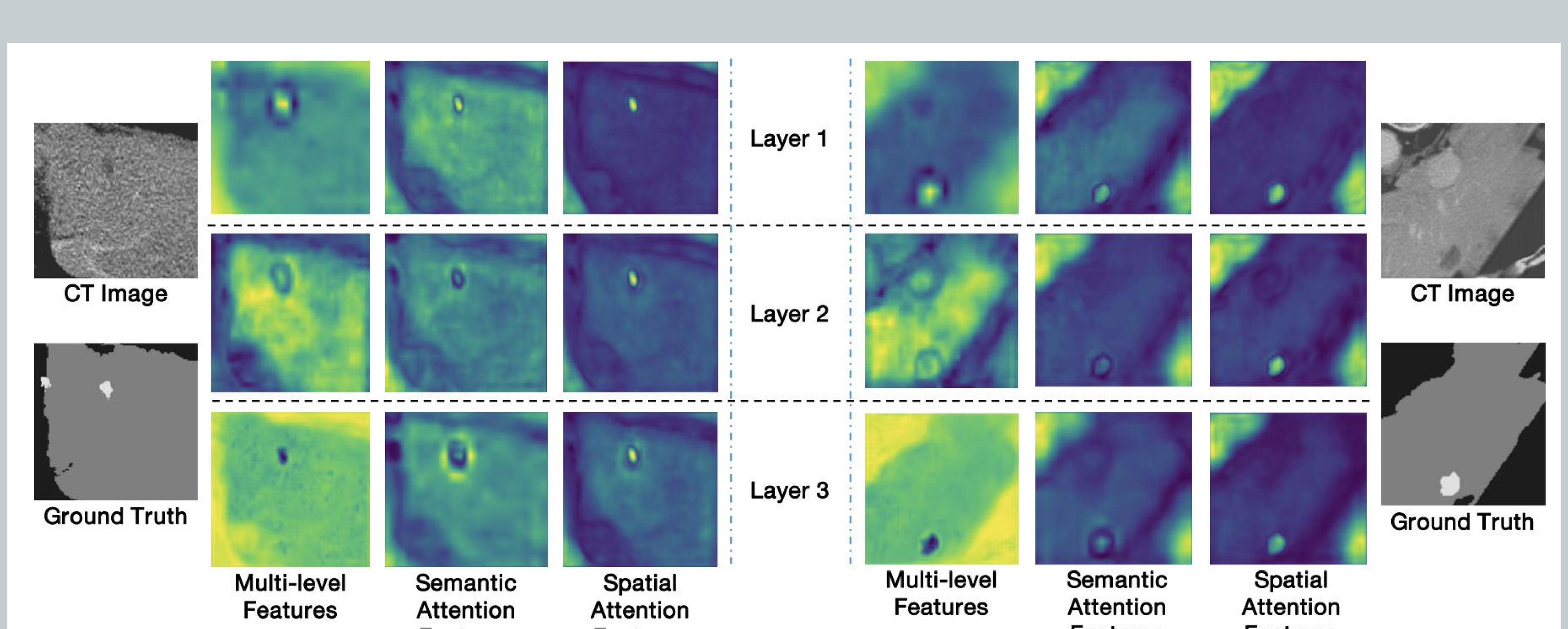


TABLE III
COMPARISON WITH STATE-OF-THE-ART METHODS ON LITS ONLINE TEST DATASET.

Method	Year	Method	Dice per case [%]	Dice global [%]
3D AH-Net [15]	2018	2D + 3D FCN	63.4	83.4
H-DenseUNet [14]	2017	2D + 3D FCN	72.2	82.4
LW-HCN [16]	2019	2D + 3D FCN	73.0	82.0
VA-MaskRCNN [17]	2019	2.5D MaskRCNN	74.1	81.3
DARN (Sem + Spa)		3D FCN	75.1	82.6
DARN (Spa + Sem)		3D FCN	75.9	82.8

Experimental Results

Our model is trained and tested on the publicly available dataset from MICCAI 2017 LiTS Challenge. The dataset contains 131 and 70 CT volumes for training and testing respectively.



Experimental Results

The proposed DARN employs SemRef and SpaRef modules to refine multi-level features in both top-down and bottom-up ways, and integrate multi-level features by leveraging features from neighboring level as a guidance. Our method achieves state-of-the-art performance for liver tumor segmentation on LiTS benchmark dataset, demonstrating the effectiveness for robust and precise 3D liver tumor segmentation. Furthermore, the proposed method is generalizable and can be easily extended to other medical volumetric segmentation applications.