abtechchennai@gmail.com
www.abtechnologies.in
9840511458

MODIFIED U-NET (MU-NET) WITH INCORPORATION OF OBJECT-DEPENDENT HIGH LEVEL FEATURES FOR IMPROVED LIVER AND LIVER-TUMOR SEGMENTATION IN CT IMAGES

ABSTRACT

Segmentation of livers and liver tumors is one of the most important steps in radiation therapy of hepatocellular carcinoma. The segmentation task is often done manually, making it tedious, labor intensive, and subject to intra/inter operator variations. While various algorithms for delineating Organ at Risks (OARs) and tumor targets have been proposed, automatic segmentation of livers and liver tumors remains intractable due to their low tissue contrast with respect to the surrounding organs and their deformable shape in CT images. The U-Net has gained increasing popularity recently for image analysis tasks and has shown promising results. Conventional U-Net architectures, however, suffer from three major drawbacks. First, skip connections allow for the duplicated transfer of low resolution information in feature maps to improve efficiency in learning, but this often leads to blurring of extracted image features. Secondly, high level features extracted by the network often do not contain enough high resolution edge information of the input, leading to greater uncertainty where high resolution edge dominantly affects the network's decisions such as liver and liver-tumor segmentation. Thirdly, it is generally difficult to optimize the number of pooling operations in order to extract high level global features, since the number of pooling operations used depends on the object size. To cope with these problems, we added a residual path with deconvolution and activation operations to the skip connection of the U-Net to avoid duplication of low resolution information of features. In the case of small object inputs, features in the skip connection are not incorporated with features in the residual path. Furthermore, the proposed architecture has additional convolution layers in the skip

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connection in order to extract high level global features of small object inputs as well as high level features of high resolution edge information of large object inputs. Efficacy of the modified U-Net (mU-Net) was demonstrated using the public dataset of Liver tumor segmentation (LiTS) challenge 2017. For liver-tumor segmentation, Dice similarity coefficient (DSC) of 89.72 %, volume of error (VOE) of 21.93 %, and relative volume difference (RVD) of -0.49 % were obtained. For liver segmentation, DSC of 98.51 %, VOE of 3.07 %, and RVD of 0.26 % were calculated. For the public 3D Image Reconstruction for Comparison of Algorithm Database (3Dircadb), DSCs were 96.01 % for the liver and 68.14 % for liver-tumor segmentations, respectively. The proposed mU-Net outperformed existing state-of-art networks.