3D U-Net Based Automatic Segmentation of Organs at Risk From CT

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INTRODUCTION

Contouring the organs at risk (OAR) for radiotherapy planning is time consuming and prone to inter- and intra- observer variations. In this study we developed a system for automatic segmentation of OARs from CT volume based on 3D U-Net framework.

AIM

Our goal is to build a neural network based on the improved 3D U-net, and segment the organs at risk in the head and neck, thorax, abdomen and pelvic, so as to obtain a higher segmentation accuracy and apply it in hospitals.

METHOD

Our major contributions include the following:

- We divide neural network training into two phase. In the first stage, we mainly locate and get the bounding boxes of OARs. In the second stage, we precisely segment OARs according to the bounding boxes obtained.
- In the first training phase, we combine focal loss and dice score as our loss function to slove the problem of OARs imbalance.
- In the second stage, we classify the foreground and background of each OAR, which improve dice score by 10% compared with the first stage.

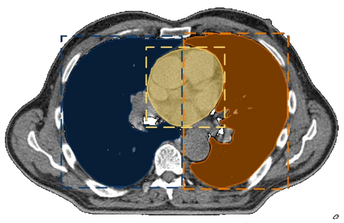

Figure I. Get the bboxes of OARs in the first stage, and segment OAR precisely in the second stage.

RESULTS

We test the system on different body parts and calculated the dice coefficients. The dice coefficient of organs which have obvious boundary with the surrounding tissues such as brain, mandible, lung and kidney, is above 90%, while the dice coefficient of organs which is small or large self-variability such as Optic-Nerve-L and Optic-Nerve-R, is around 35%.

As you can see in Figure II, The area of the optic nerve in each slice is relatively small. During data processing and training, we have taken down sampling and max pooling operation, which leads to the loss of some information of small OARs, making the segmentation accuracy of small OARs low.

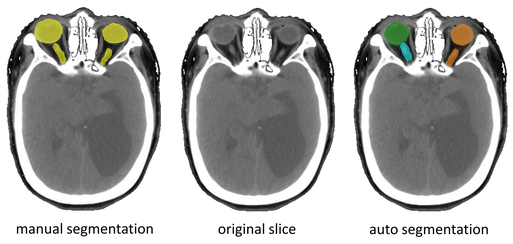

Figure II. of manual and automatic segmentation of Eye-L, Eye-R, Optic-Nerve-L Comparisonand Optic-Nerve-R in head and neck.

Tabel I. Dice coefficient of nine OARs in the head and neck.

ROI NAME	DICE
Brain	0.975
Brain-Stem	0.640
Eye-L	0.846
Eye-R	0.780
Optic-Nerve-L	0.312
Optic-Nerve-R	0.425
Mandible	0.921
Parotid-Gland-L	0.649
Parotid-Gland-R	0.658

Tabel II. Dice coefficient of five OARs in the thorax.

ROI NAME	DICE
SpinalCord	0.823
Lung-L	0.964
Lung-R	0.970
Heart	0.828
Esophagus	0.656

Tabel III. Dice coefficient of four OARs in the abdomen.

ROI NAME	DICE
Kidney-L	0.841
Kidney-R	0.905
Liver	0.920
SpinalCord	0.804

Tabel IV. Dice coefficient of six OARs in the pelvic.

ROI NAME	DICE
Bladder	0.705
Femoral-Head-L	0.745
Femoral-Head-R	0.688
Small-Intestine	0.514
Rectum	0.550
SpinalCord	0.671

CONCLUSIONS

So far, our algorithm has been applied in 65 hospitals. With our in-house developed system for contouring work, physicians just need to fine-tune the results of automatic segmentation, which saves about 80% of the contouring time.

REFERENCES

1 Ronneberger O, Fischer P, Brox T, et al. U-Net: Convolutional Networks for Biomedical Image Segmentation[J]. medical image computing and computer assisted intervention, 2015: 234-241.

2 Milletari F, Navab N, Ahmadi S, et al. V-Net: Fully Convolutional Neural Networks for Volumetric Medical Image Segmentation[J]. international conference on 3d vision, 2016: 565-571

3 Cicek O, Abdulkadir A, Lienkamp S S, et al. 3D U-Net: Learning Dense Volumetric Segmentation from Sparse Annotation[J]. medical image computing and computer assisted intervention, 2016: 424-432.

4 Lin T, Goyal P, Girshick R B, et al. Focal Loss for Dense Object Detection[J]. international conference on computer vision, 2017: 2999-3007.

5 Hu J, Shen L, Sun G, et al. Squeeze-and-Excitation Networks[J]. computer vision and pattern recognition, 2018: 7132-7141.

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