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Multiple resolution residual network for automatic thoracic organs-at-risk segmentation from CT

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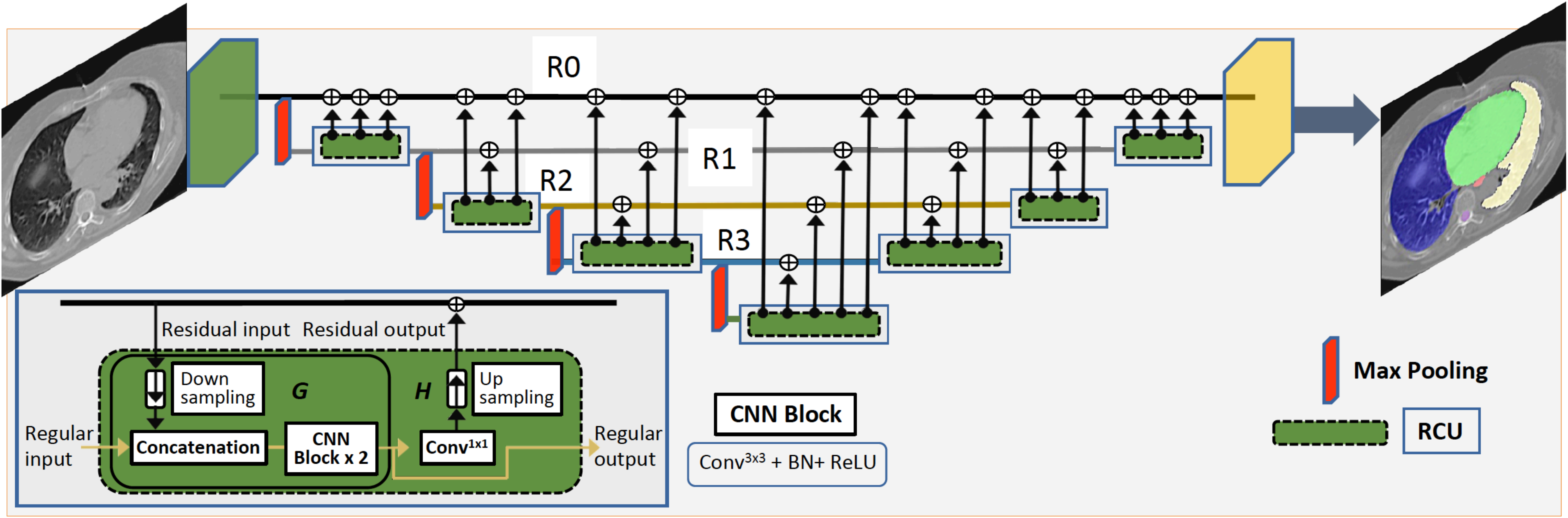
Motivation

- Radiotherapy treatment planning requires highly accurate segmentations for precise tumor targeting while reducing unnecessary dose to critical normal organs[1]
- Clinical treatments use manual delineations done by physicians[2]
  - Time consuming
  - Highly variable between same and different physicians
- Current methods for automatic segmentation of thoracic OARs (e.g. U-Net and FCN architectures) still pose a challenge for narrow, thin structures located in the mediastinum (with little soft-tissue contrast) such as the esophagus
  - Loss of resolution in the deeper convolutional layers

1. Thomas Rockwell Mackie et al. Image guidance for precise conformal radiotherapy. International Journal of Radiation Oncology, Biology, Physics, 56(1):89-105, 2003
2. Jinzhong Yang et al. A statistical modeling approach for evaluating auto-segmentation methods for image-guided radiotherapy. Comput Med Imag Graph, 36(6):492-500, 2012

Multiple Resolution Residual Network (MRRN)



The MRRN simultaneously combines information from multiple feature streams computed at different image resolution levels through residual connections

Jiang J, ... Veeraraghavan H. Multiple Resolution Residually Connected Feature Streams For Automatic Lung Tumor Segmentation From CT Images. IEEE Trans Med Imaging 2019;38:134-144

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Experiments

- Datasets
  - CT scans of 241 internal patients with LA-NSCLC
    - Training: N = 206
    - Validation: N = 35
  - 60 CT scans from the 2017 AAPM Thoracic Auto-Segmentation Challenge[3]
    - Testing set 1: N = 48 (training + offline testing)
    - Testing set 2: N = 12 (online testing)
- Implementation
  - Training in 2D with 21441 images, validation with 2104 images
  - Image size: 256x256, after cropping and resizing

3. J Yang, Veeraraghavan H, Armato S.G., K Farahani, J.S Kirby, J Kalpathy-Kramer, W van Elmpt, A Dekker, X Han, X Feng, P Aljabbar, B Oliviera, B van der Heyden, L Zamdborg, D Lam, M Gooding, and G.C. Sharp. Autosegmentation for thoracic radiation treatment planning: A grand challenge at AAPM 2017

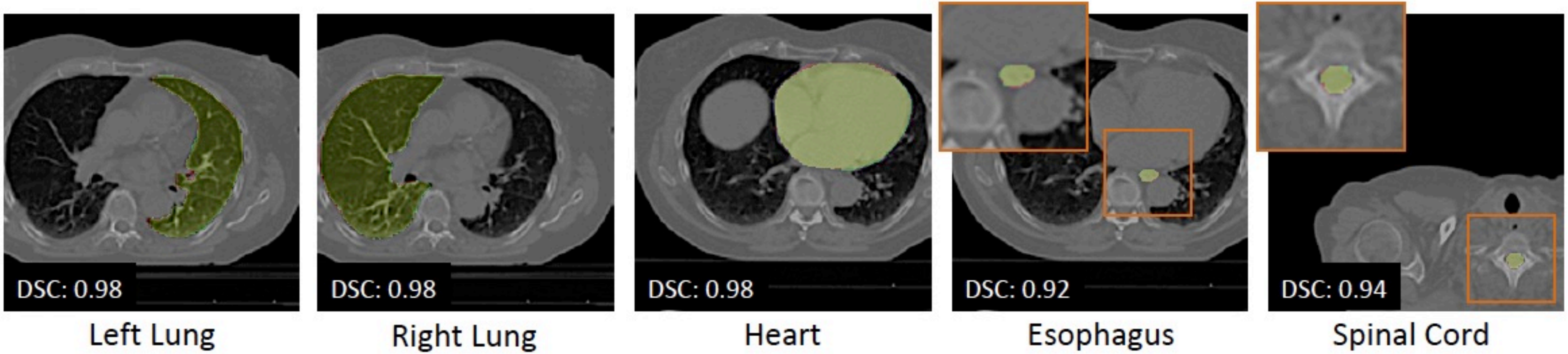
Results

- Median DSC and IQR achieved for testing set 1
  - 0.97 (IQR:0.97-0.98) for the left and right lungs
  - 0.93 (IQR: 0.93-0.95) for the heart
  - 0.78 (IQR: 0.76-0.80) for the esophagus
  - 0.88 (IQR: 0.86-0.89) for the spinal cord

DSC achieved for thoracic OARs in the AAPM online testing set (testing set 2)

Method	2D/3D	Left Lung	Right Lung	Heart	Esophagus	Spinal Cord
MRRN	2D	0.96 ± 0.01	0.96 ± 0.02	0.93 ± 0.03	0.77 ± 0.04	0.87 ± 0.017
Elekta	2.5D/3D	0.97 ± 0.02	0.97 ± 0.02	0.93 ± 0.02	0.72 ± 0.10	0.88 ± 0.037
UVa	3D	0.98 ± 0.01	0.97 ± 0.02	0.92 ± 0.03	0.64 ± 0.20	0.89 ± 0.042
Mirada	2D	0.98 ± 0.02	0.97 ± 0.02	0.91 ± 0.02	0.71 ± 0.12	0.87 ± 0.110

Results



Example segmentations for the analyzed organs. Green mask = expert delineation, red mask = algorithm-generated segmentation, yellow mask = combined segmentation