AORTA AND PULMONARY ARTERY SEGMENTATION WITH CNN AND FULLY CONNECTED CRF

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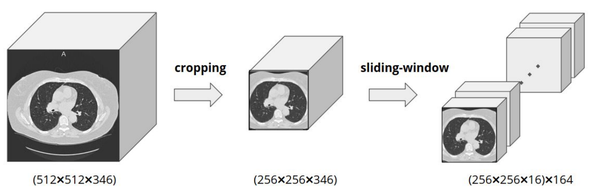
Abstract

Accurate segmentation of aorta and pulmonary artery in low-contrast CT scans is difficult due to the low-contrast between vessels and surrounding tissues, which limits the ability of measuring important risk factors for cardiovascular diseases and COPD. We propose a fully automatic 3D multi-class segmentation algorithm based on **convolutional neural networks (CNN)** and **fully connected conditional random fields (CRF)** models. The proposed pipeline is evaluated on 15 testing CT images quantitatively where we improve the DSC performance from 0.94±0.01 and 0.92±0.01 to 0.96±0.01 and 0.94±0.01 for aorta and pulmonary artery respectively. The experiments demonstrate that the algorithm is highly efficient and able to get state-of-the-art results on testing data.

Training CNN model

- **Source:** Danish Lung Cancer Screening Trial (DLCST)



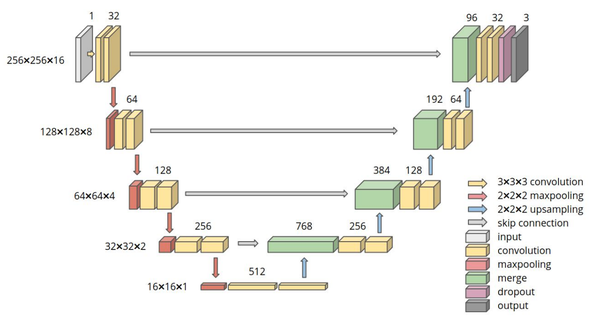
Extracting 3D training patches from CT images on the fly

Original Training data: **10** CT scans

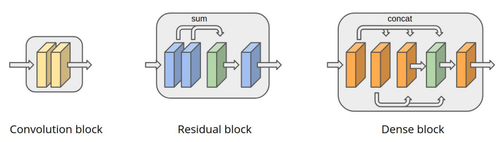
Training sets: **1565** patches

Overlap between patches: **87.5%**

- **Networks:**



3D UNet + Convolution block + dropout (last layer)

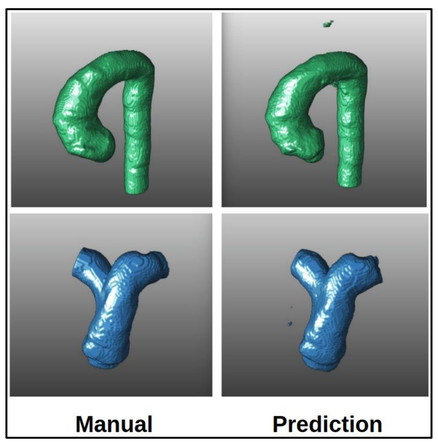


different blocks

	Aorta Dice	Pul Dice	Parameters
UNet (no skip connections)	0.931	0.906	21,182,275
UNet+Convolution Block	**0.957**	**0.941**	23,532,322
UNet+Residual Block	0.929	0.880	27,985,347
UNet+Dense Block	0.875	0.709	23,519,011

Results of different architectures

- **Results:**
  - Testing data: 15 unseen CT images



3D visualization

Aorta

	Mean	std	Min	Max
DSC	0,957	0,0120	0,930	0,972
MaxSD	9,728	7,439	4,719	31,684
MeanSD	0,516	0,326	0,295	1,64
Std SD	1,07	1,075	0,563	4,831
Jaccard	0,918	0,0220	0,869	0,946

Pulmonary artery:

	Mean	std	Min	Max
DSC	0,941	0,0250	0,868	0,966
MaxSD	6,392	3,247	3,179	14,274
MeanSD	0,521	0,214	0,221	1,011
Std SD	0,864	0,449	0,440	1,92
Jaccard	0,889	0,0430	0,767	0,935

CNN results

References

[1] Ronneberger O, Fischer P, Brox T. U-net: Convolutional networks for biomedical image segmentation[C]//*International Conference on Medical image computing and computer-assisted intervention. Springer, Cham,* 2015: 234-241.

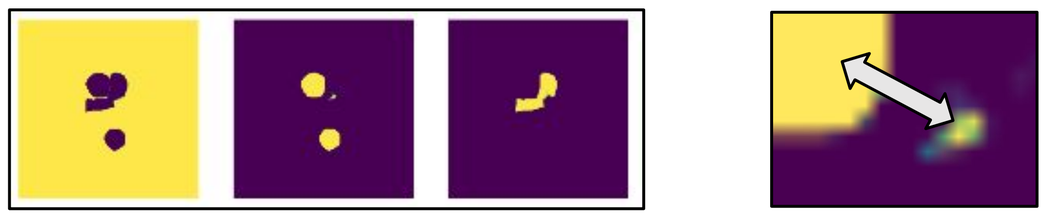
[2] Kamnitsas K, Ledig C, Newcombe V F J, et al. Efficient multi-scale 3D CNN with fully connected CRF for accurate brain lesion segmentation[J]. *Medical image analysis*, 2017, 36: 61-78.

Post-processing using CRF

- **3D Fully connected CRF:**

$$E(x) = \sum_i \psi_u(x_i) + \sum_i \sum_{j>i} \psi_p(x_i, x_j)$$

unary term (CNN output) — pairwise term (Appearance, Smoothness)



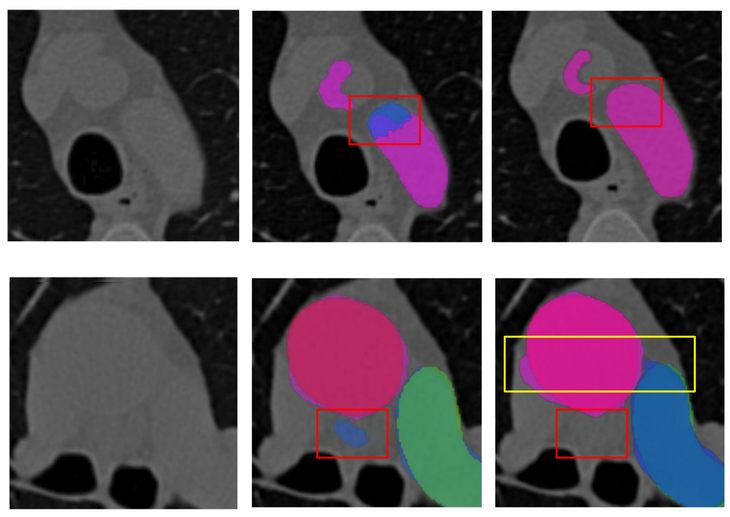
- **Results:**

Similar representations of aorta and pulmonary artery (intensity, boundary, etc.)

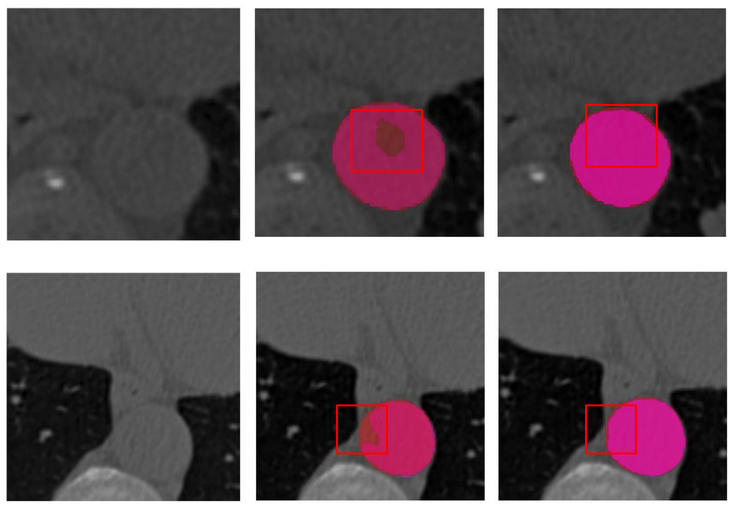
	Aorta	Pul
DSC (mean)	**0.964**	**0.943**
DSC (min)	**0.938**	**0.887**
DSC (max)	**0.974**	**0.967**
MaxSD (mean)	**2.005**	**1.605**
MaxSD (max)	**4.941**	**3.246**
MeanSD (mean)	**0.424**	**0.562**
MeanSD (max)	**1.372**	**1.115**

CRF results

Misclassify



Small holes in desceding aorta



Conclusion

- **3D CNN** could make state-of-the-art segmentation results of aorta and pulmonary artery in chest CT scans, but have some problems in specific regions.
- **Post-processing using CRF** could solve most of the problems, but still have the chance to make over or under segmentations.

Future work:

- Training CNN and CRF together to make them cooperate each other.
- Experiments on more datasets.