Automatic Multi-Organ Segmentation in Dual Energy CT using 3D Fully Convolutional Network

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Introduction

Automatic multi-organ segmentation of DECT is beneficial for biomedical research and clinical applications, such as material decomposition [1] and context sensitive imaging [2], in order to present complex information to the radiologists and to improve the clinical routine. Image fusion is important for this purpose [3].

Contributions:

- Proposed and compared three 3D deep learning architectures for automatic multi-organ segmentation on DECT images.
- Designed a loss function to solve the high class imbalance problem.

Material and Methods

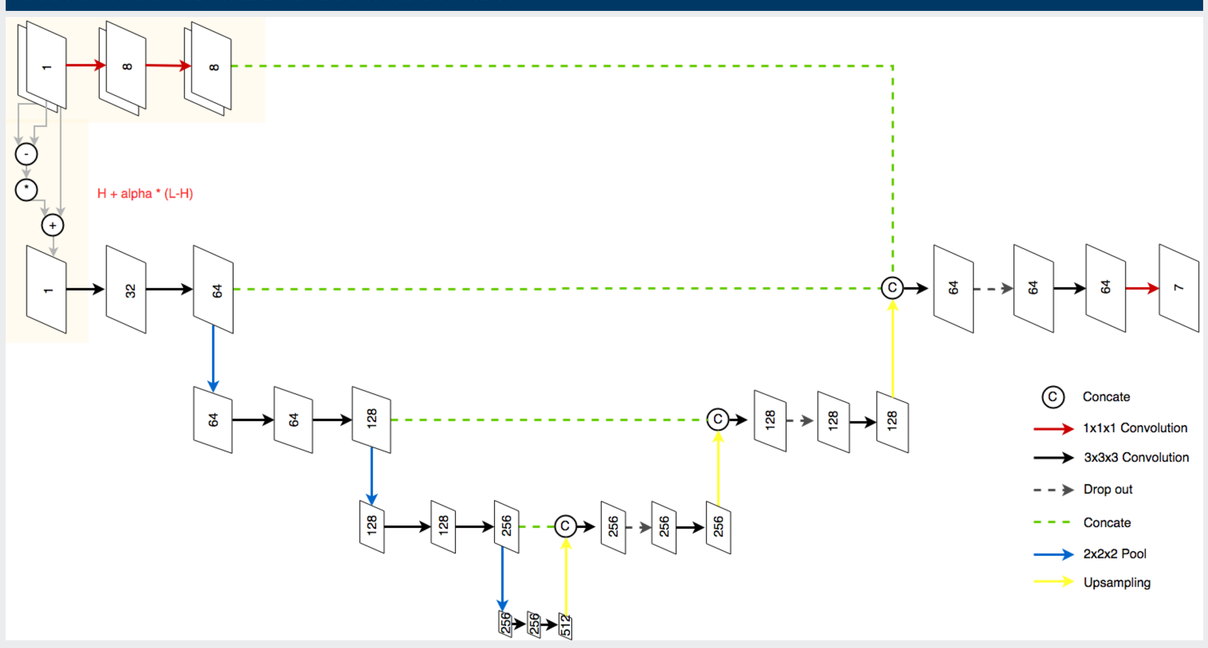

Figure 1: Linear combination based network (LC-net)

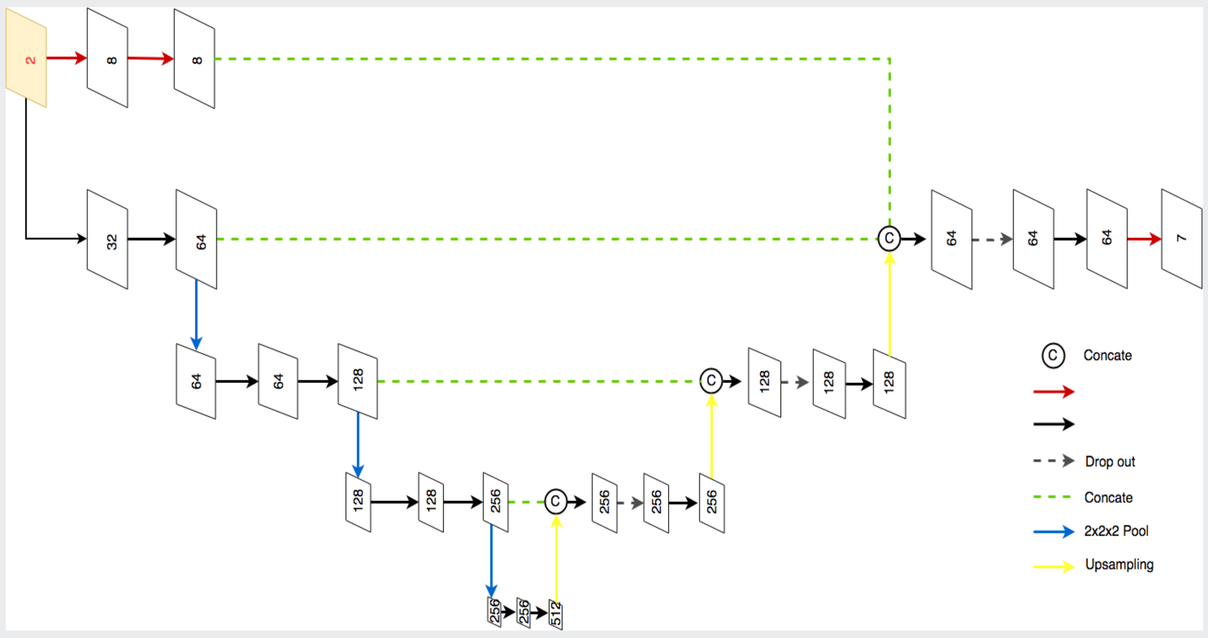

Figure 2: Multi-channel based network (MC-net)

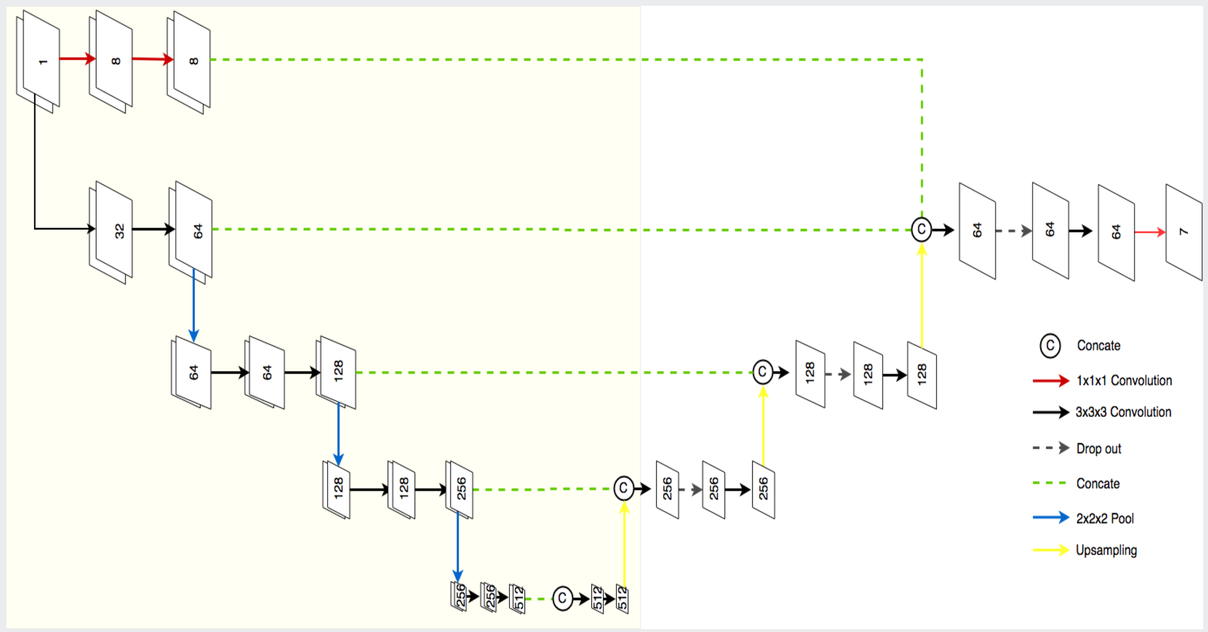

Figure 3: Multi-image based network (MI-net)

- Loss function using DICE with
  - Class balancing using median frequency
  - Edge enhancement [4]

Results and Discussion

- 9-fold cross validation with 26 clinical torso DECT images scanned by 70 kV and Sn 150 kV.
- Best average Dice:
  Right lung 98%, left lung 97%, liver 93%, spleen 91%, right kidney 94%, left kidney 92%.
- MI-net has the best Dice and the lowest Hausdorff distance.

Table 1: Dice score comparison of different approaches

	Right Lung	Left Lung	Right Kidney	Left Kidney	Liver	Spleen
LC-Net	0.97±0.01	**0.97±0.01**	**0.93±0.02**	**0.91±0.05**	**0.92±0.02**	0.88±0.06
MC-Net	0.97±0.01	**0.97±0.01**	**0.93±0.02**	0.84±0.15	0.91±0.02	0.87±0.07
MI-Net	**0.98±0.01**	**0.97±0.01**	0.93±0.03	**0.91±0.05**	**0.92±0.02**	**0.91±0.04**

Table 1: Hausdorff distance (in voxel) comparison of different approaches

	Right Lung	Left Lung	Right Kidney	Left Kidney	Liver	Spleen
LC-Net	4.68±1.71	4.54±1.78	2.27±1.75	3.59±1.47	8.94±5.17	4.76±1.86
MC-Net	4.90±1.93	**4.27±0.97**	3.04±1.92	6.90±7.14	10.25±3.49	4.86±2.24
MI-Net	**3.88±1.20**	4.43±2.58	**1.97±1.08**	**2.78±1.16**	**8.87±3.69**	**4.46±2.71**

- Robust for special clinical scans, such as scan with different acquisition protocol, scan with lung pathology, scan with missing organ, and scan with longitudinal truncation.

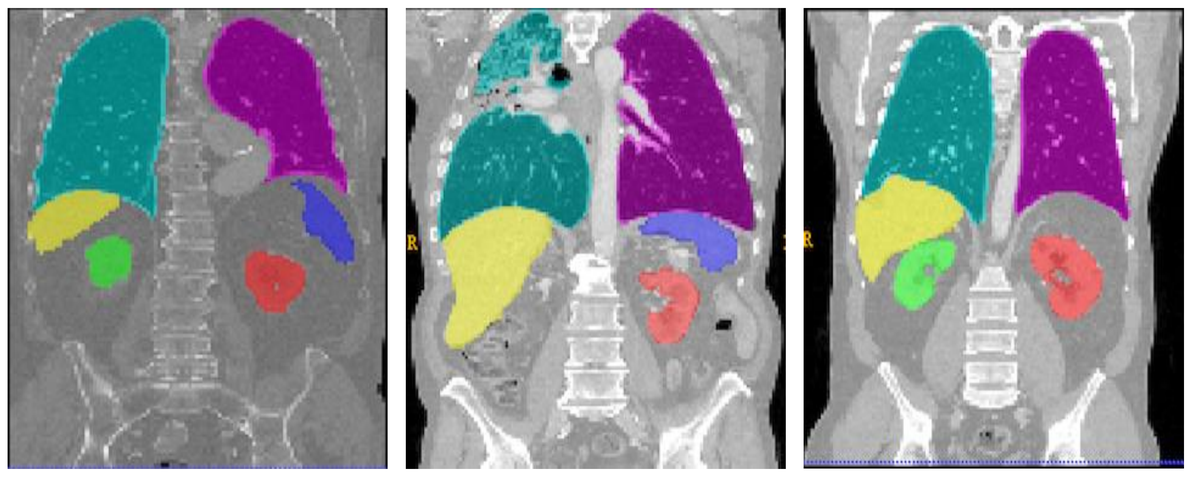

Figure 4: Test examples of special unseen clinical cases with MI-net. Left: scan with different protocol, middle: scan with lung pathology, right: scan with missing spleen.

Conclusion

- LC-net, MC-net, and MI-net are all promising for automatic multi-organ segmentation of DECT images.
- Image fusion techniques affect the segmentation accuracy. MI-net shows the best utilization of images.
- The convergence efficiency of the three networks related to epochs is similar. Image fusion techniques have insignificant influence on the convergence.
- The balancing of the class weight components is important.

References

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