Deep-CNN Based Semantic Segmentation of Aortic Dissection Images

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Introduction

- **Type-B Aortic Dissection**: A tear in the intima of the aorta splits the vessel into two channels
- **Management**: Periodic computed tomography (CT) scans and high risk surgery if axial aortic diameter is expanding
- **Challenge**: Many suffer fatal aortic rupture in between CTs. Segmentation of the aorta into true and false lumens can help predict need for surgery.

Figure 1: Left: intimal tear leading to formation of two lumina, Middle: axial view of dissected aorta, Right: aortic rupture

Problem Statement

- **Input:** Axial sequence of Grayscale CT cross-section images.
- **Output:** Pixel-wise segmentation into 3 classes: True Lumen, False Lumen, Background
- **Goal:** Maximize similarity between manually segmented ground truth and output of model

Dataset

- **Dataset**: 24 CT aortograms, 800 Grayscale axial images (256x256) per study, Corresponding ground truths (256x256).
- **Pre-processing**: Normalize CT images, convert ground truth images to one-hot vector, random sampling along Z and across studies

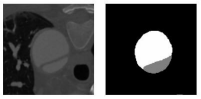
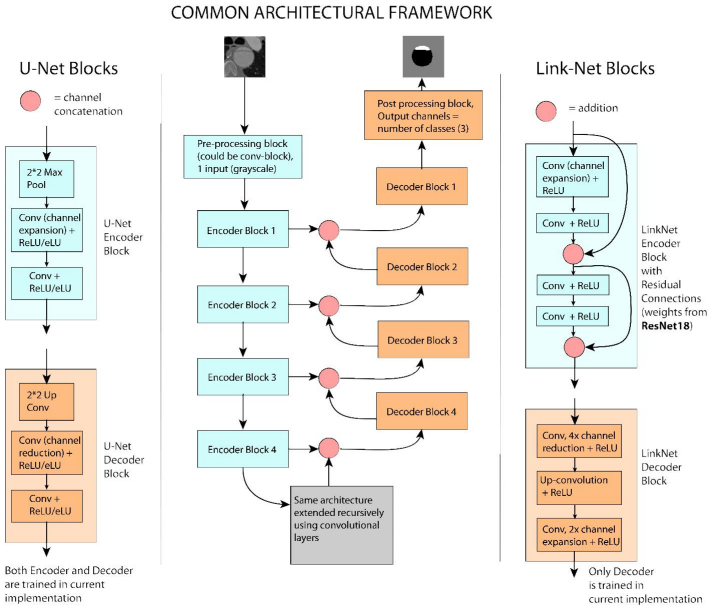


Figure 2: L: CT cross section image, R: ground truth

Models: Two Fully Convolutional Architectures



- U-Net: Learning Rate = 1e-4, Batch Size = 16, Train/Dev/Test Split: 72, 14, 14, Parameters: 3.1e7
- LinkNet: Learning Rate = 5e-4, Batch Size = 20, Train/Dev/Test Split: 72, 14, 14, Parameters: 1.1e7

Combined loss (combining categorical cross entropy and Dice coefficient):

$$L = w_0 CCE + w_1(1 - DE); UNet : (w_0, w_1) = (0.5, 0.5); LinkNet : (w_0, w_1) = (1.0, 0) \quad (1)$$

Summary Of Key Results

Model	Train	Dev	Test	Novel
U-net	0.93	0.89	0.89	0.72
Link-net	0.96	0.91	0.91	0.73

Table 1: Mean DICE Score

Performance on original studies is excellent. Novel studies contain unforeseen geometries: annular separation of lumina. Generalization less than satisfactory. Human error on novel studies is low due to availability of Z-information during manual segmentation of study.

Discussion

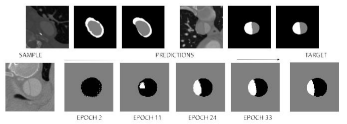


Figure 3: Top: UNet Examples, (L) Novel dataset, (R) Original Dataset; Bottom: LinkNet training sequence example

- Adam Optimization along with Dropout and L2 Regularization to reduce over-fitting
- Dice helps speed up training compared to CCE

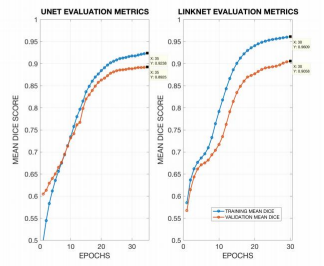


Figure 4: Learning curves for (L) U-Net and (R) LinkNet

Future Work

- Segment scans in both sagittal and coronal planes
- Data augmentation to decrease over-fitting
- Compare conv-LSTM and 3D-CNN approaches

References

- Aortic Dissection background: Nienaber, C. A. et al., Aortic Dissection, Nature Reviews Disease Primers, 2, 16053 (2016)
- Competing pre-print: Li, J. et al., Multi-Task Deep Convolutional Neural Network for the Segmentation of Type B Aortic Dissection.