UNIVERSITY OF COPENHAGEN

Extraction of Airways using Graph Neural Networks

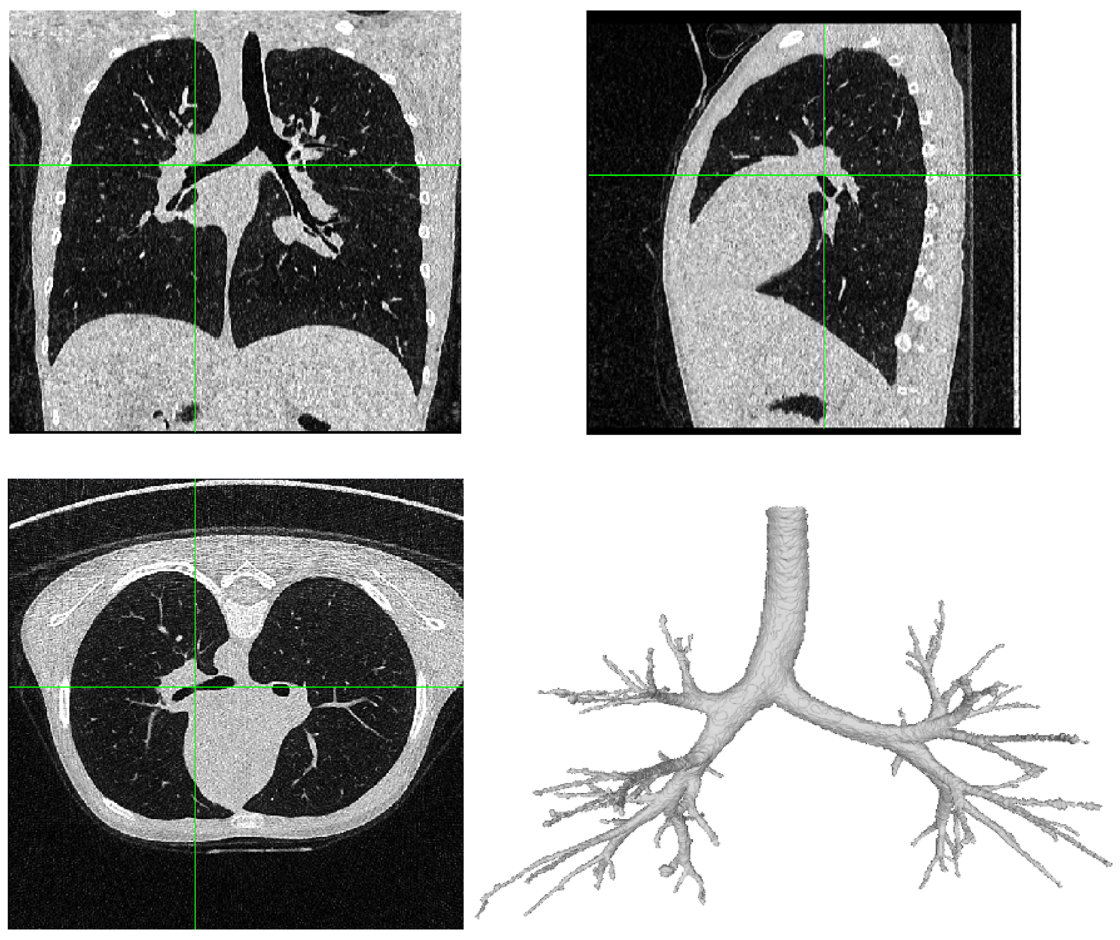
Raghavendra Selvan [1], Thomas Kipf [2], Max Welling [2,3], Jesper H. Pedersen [4], Jens Petersen [1] & Marleen de Bruijne [1,5]

[1]University of Copenhagen, [2] University of Amsterdam, [3] Canadian Institute for Advanced Research, [4] University Hospital of Copenhagen, [5] Erasmus Medical Center, Rotterdam

Abstract

We present extraction of tree structures, such as airways, from image data as a graph refinement task. To this end, we propose a graph auto-encoder model that uses an encoder based on graph neural networks (GNNs) to learn embeddings from input node features and a decoder to predict connections between nodes. Performance of the GNN model is compared with mean-field networks in their ability to extract airways from 3D chest CT scans.

Airway Extraction



3-D view of a chest CT scan along with the airway tree

- Automatic airway extraction has useful clinical applications
- Study of airway morphology
- Useful biomarker in prognosis and diagnosis of lung diseases

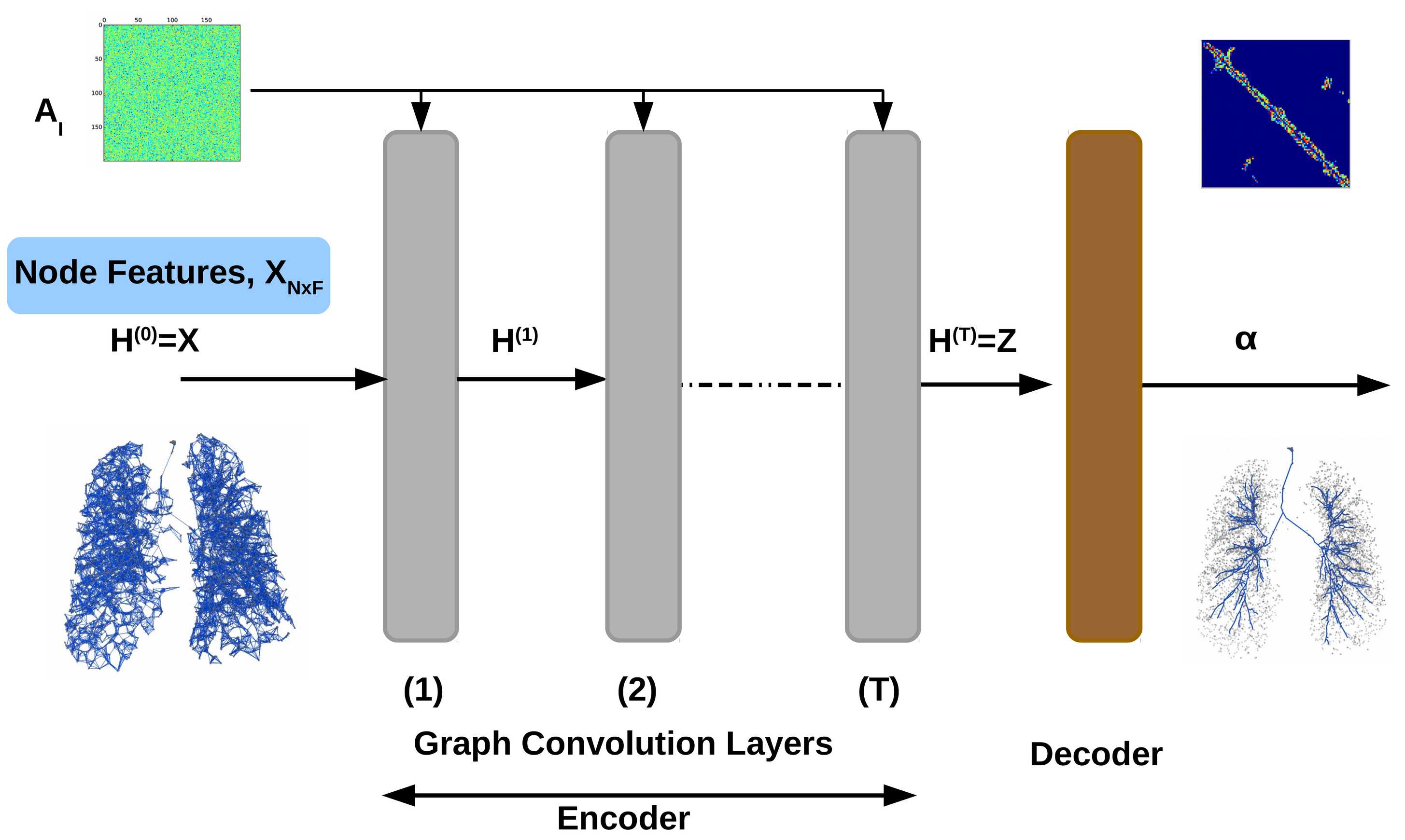
Graph Neural Networks

- Neural networks directly operating on graph structured data
- Generalisation of message passing algorithms
- End-to-end trainable using message passing
- Learn node embeddings for inductive and transductive tasks

Graph Refinement Model using GNN

Objective: Predict output adjacency matrix corresponding to the underlying airway tree based on node features

- Graph auto-encoder based model [1]
- Encoders comprised of Graph Convolution Layers
- Radial basis decoder outputs predicted adjacency from learnt embedding



GNN Model for Airway extraction posed as a graph refinement task

Encoder: $\mathbf{H}^{(l+1)} = \sigma\Big(\mathbf{H}^{(l)}\mathbf{W}_0^{(l)} + \mathbf{D}^{-1}\mathbf{A}_l\mathbf{H}^{(l)}\mathbf{W}_1^{(l)}\Big)$

Decoder: $\alpha_{ij} = \exp\big(-\frac{1}{2}(\mathbf{z}_i - \mathbf{z}_j)^2\big), \quad \forall(i,j)$

Data

- 3-D chest CT scans from Danish Lung Cancer Screening Trial
- $24 + 8$ scans for training and test, respectively
- Manually verified reference segmentations
- Bayesian smoothing based pre-processing [2]

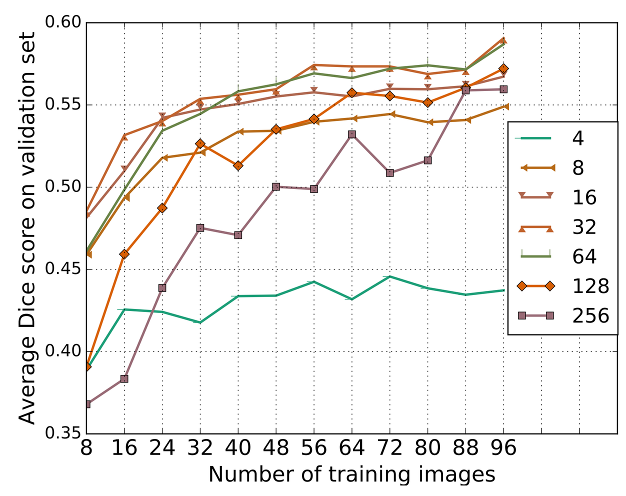
Pre-processing pipeline of CT images to obtain graph-like input.

Experiments & Results

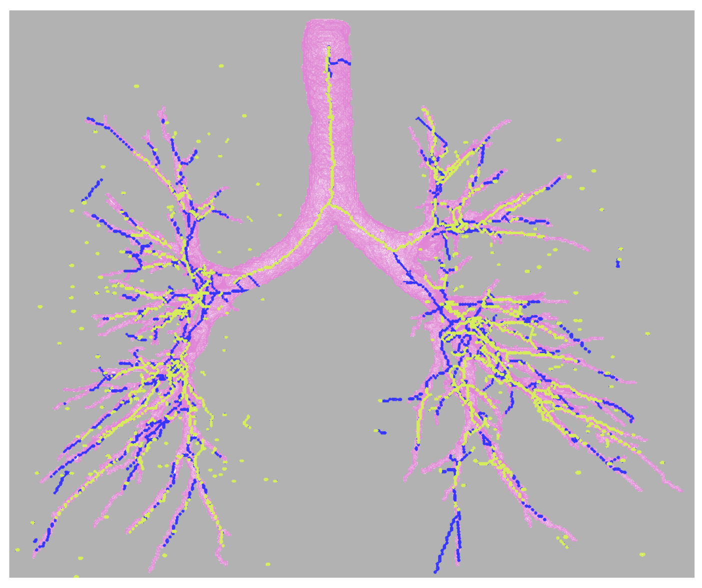
- Compared with Mean-field Networks (MFNs) [3]
- Coarse segmentations from output graphs to extract centerlines
- Centerline distance as error measure

Method	d_{FN}(mm)	d_{FP}(mm)	d_{err} (mm)
MFN	2.571	0.835	1.703 ± 0.186
GNN	2.890	3.913	3.402 ± 0.386
GNN+MFN	2.014	3.345	2.679 ± 0.264

Performance comparison using centerline distance with MFNs



Plot showing the influence of increasing training set size on average dice score on the validation set for different hidden units per GNN layer.



Airway tree centerlines for one of the test cases obtained from MFN predictions (blue) overlaid with the reference segmentations (pink surface) and the centerlines from GNN model (yellow).

Conclusion

- Preliminary work on using graph refinement for airway extraction
- GNN+MFN predictions show improvements over MFN
- GNN model currently suffers from higher false positives
- Improvements are seen with additional data

Future Work:

- Data augmentation
- Attention layers to focus on specific node neighbours
- Use edge representation based GNN

Contact

raghav@di.ku.dk

Paper ArXiv Id.:1804.04436

Acknowledgements

This work was funded by the Independent Research Fund Denmark (DFF) and SAP SE Berlin.

References

[1] Thomas N Kipf and Max Welling. “Semi-supervised classification with graph convolutional networks”. ICLR, 2017.
[2] Selvan, Raghavendra, et al. “Extraction of airways with probabilistic state-space models and Bayesian smoothing”. GRAIL, 2017
[3] Selvan, Raghavendra, et al. “Mean field network based graph refinement with application to airway tree extraction.” MICCAI, 2018 (Accepted)