CNN Development for Emphysema Detection

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Emphysema Detection: The Problem

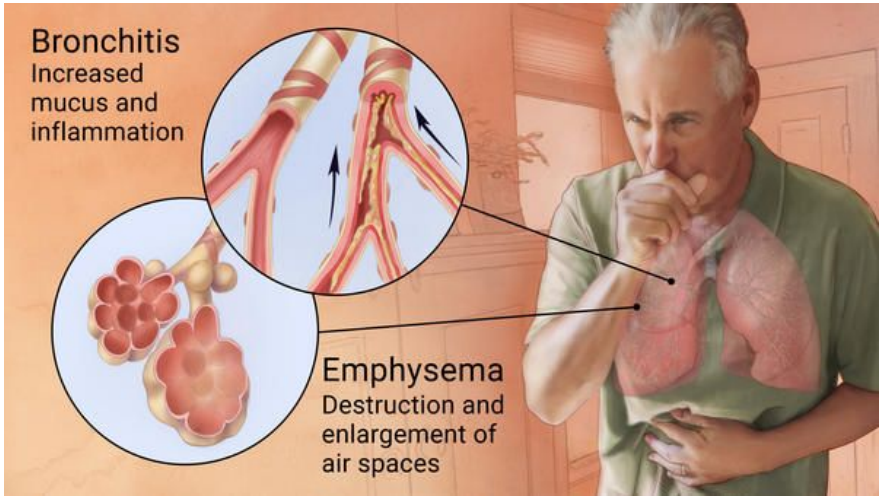
Emphysema is a widespread chronic lung disease:

- 3M patients per year
- $3B in treatment costs per year

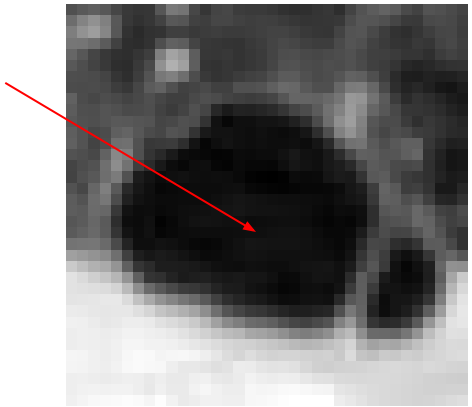
Symptoms:

- Difficulty Breathing
- Chronic Cough
- Deterioration of lung tissue

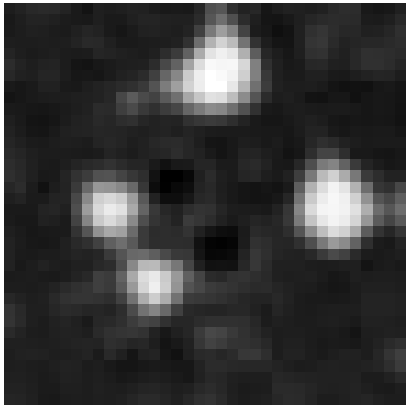
Diagnosed using Lung CT Scans



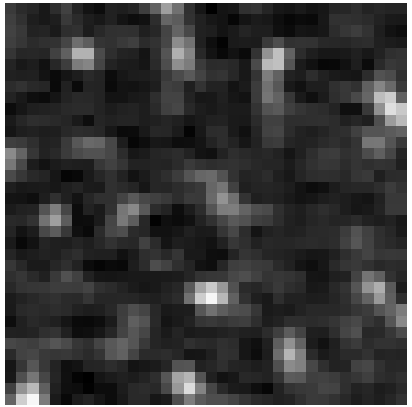
Emphysema Detection: Lung CTs



Emphysema



Airway



Normal

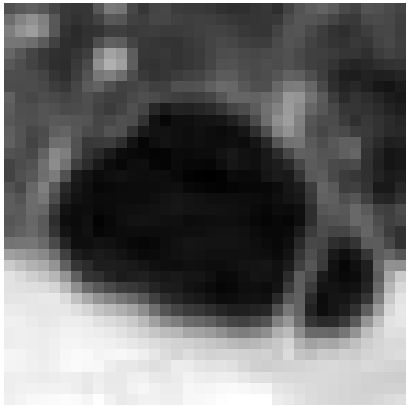
Lung CTs that show signs of emphysema are characterized by large dark patches.

Dataset: Annotated Emphysema Images

Provided by the Li Lab at MGH's Radiology Department

~10000 annotated images, one third emphysema:

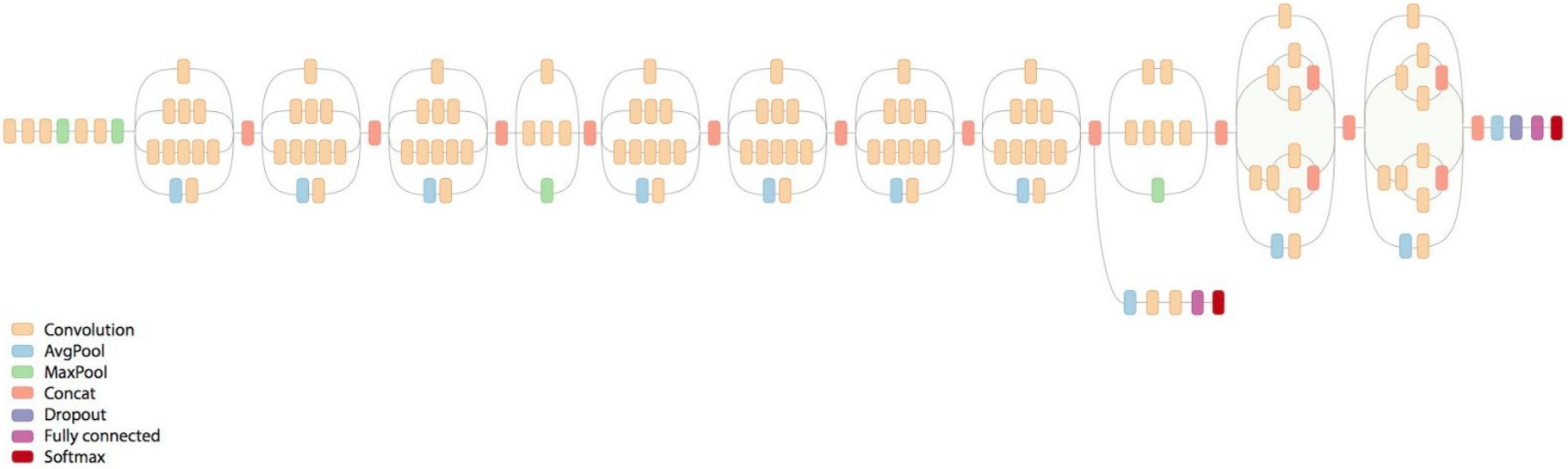
1. 9000 Training
2. 600 Validation
3. 900 Test



Split evenly across three classes (emphysema, normal, airway)

Challenges: Low resolution (36x36), black and white images

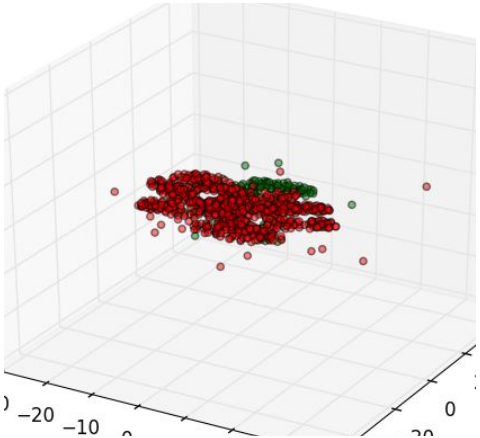
Approach - Convolutional Neural Networks



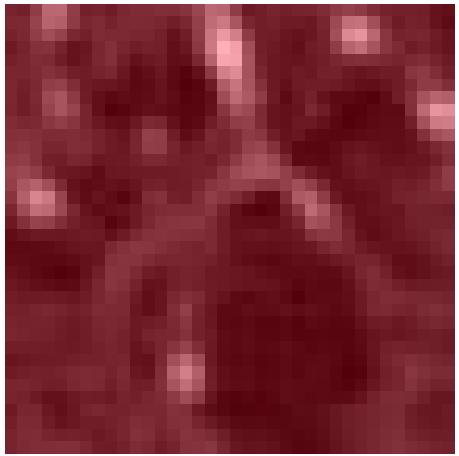
Szegedy et al. [arXiv:1512.00567]

Baseline CNN for Emphysema

Training a VGG-16 Implementation from scratch: AUC: 0.78, Accuracy: 0.79



t-SNE 3D Embeddings



Class Activations

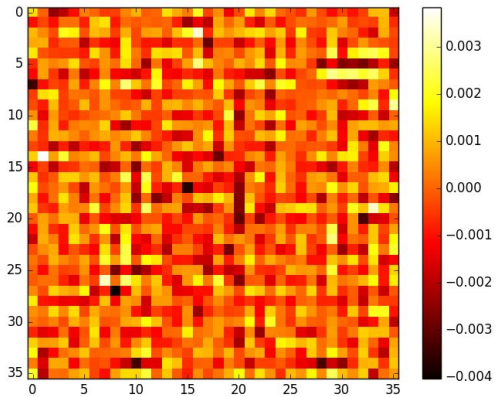
Key takeaway: unclear if we are learning any meaningful structures

What if we measure the darkness of the image instead?

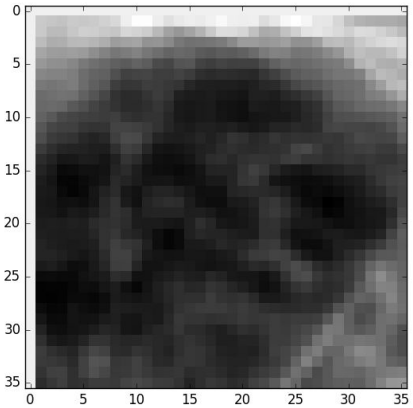
Issues: small dataset, low resolution

Baseline CNN for Emphysema: Explanation

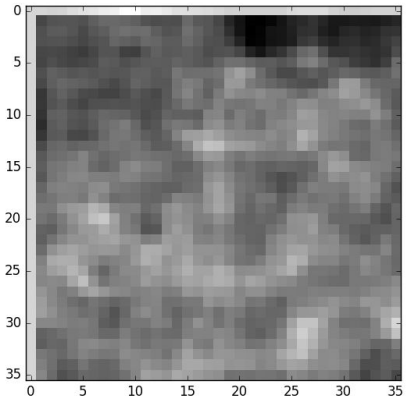
Training a Logistic Regression on the 36x36 images: AUC 0.71



Heatmap of Logistic Beta Values



“Average Image”: Emph



“Average Image”: No emph

The Logistic is likely fitting the darkness of the image.

Next Step: Transfer Learning

- The improvement of learning a new task through the transfer of knowledge from a related task that's already been learned
- Hard to apply convnets with small image datasets - ImageNet
- Training entire convnets from scratch is computationally intensive - weeks!
- Use pre-trained convnets and retrain last few layers for new classifications

For emphysema: allow the model to elicit more feature structure

Transfer Learn from: ImageNet and Luna16 (Lung Nodule Detection)

Transfer Learning from ImageNet

Retrain fully connected layer of Inception-v3 trained on ImageNet on Emphysema classifications

Accuracy: 96.7%

Sensitivity: 96.75%

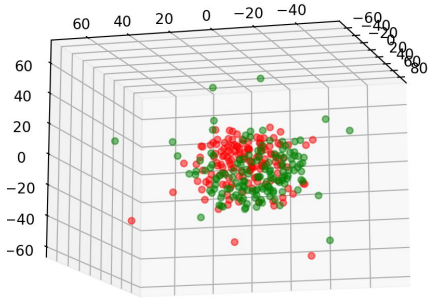
Specificity: 95.55%

But are we missing Lung-specific feature structure?

Lung Nodule Detection (Luna16)

- 3D Lung CT scans for 400 patients with annotated lung nodules
- Data Processing: Sliced 3D images, zoomed in and patched into 36x36 pixel patches with nodule existence annotations
- CNNs Developed on Nodule Data:
  - Baseline CNN for lung nodule detection - 2-layer architecture for MNIST, AUC: 0.76
  - Retrained VGG-16, AUC: 0.89

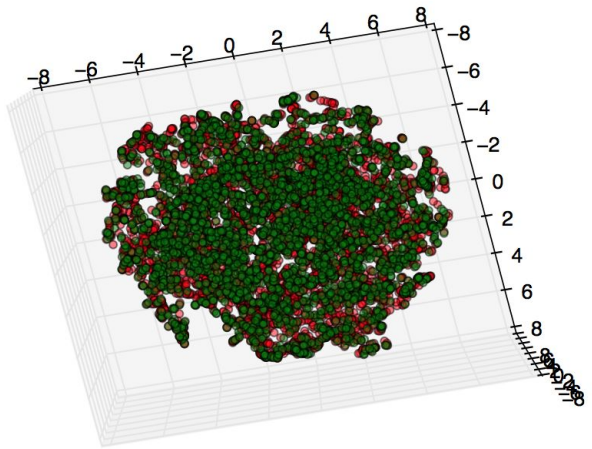
512x512 CT Scan for Nodule Detection



t-SNE 3D of Retrained VGG

Transfer Learning: VGG → Lung Nodule → Emph

- Fit the Emphysema data on the 0.89 AUC Classifier on Lung Nodule Data
- Retrained the final weights for the Emphysema task using Logistic Regression
- AUC: 0.76, Accuracy: 0.80



Results: Overfitting, different imaging scale for lung nodule data.

Future Work

1. Focus on interpretability: class activation maps for each of the CNNs
2. Inception → LUNA → Emphysema Transfer Learning
3. Revisit the preprocessing of the LUNA dataset to see if alternative inputs could be generated

Conclusion

1. Developed a CNN for emphysema detection
2. Saw improvement when using transfer learning approaches for emphysema detection
3. Example of using domain-specific data sources to augment transfer learning