Pulmonary Embolism Classification in Lung CTA

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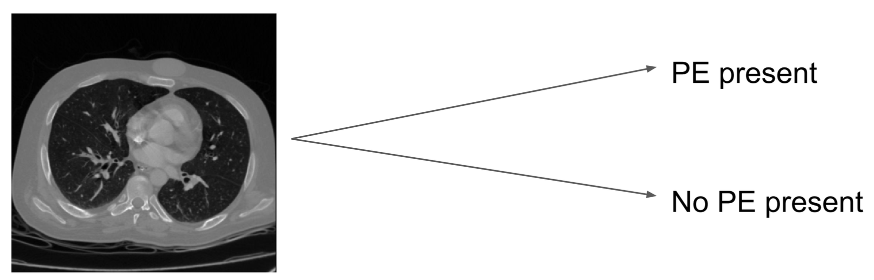
Task & Motivation

Motivation: Pulmonary Embolism (PE) is a blockage in one of the pulmonary arteries which is regularly diagnosed using computed tomography angiography (CTA). We propose a deep learning approach using ConvNets to detect the existence of PE in CTA slices within CTA scan volumes.

Task: classify the CTA slice image as showing PE or not showing PE



Dataset

Dataset: The Dataset used is the publicly available FUMPE (Ferdowsi University of Mashhad PE) dataset.

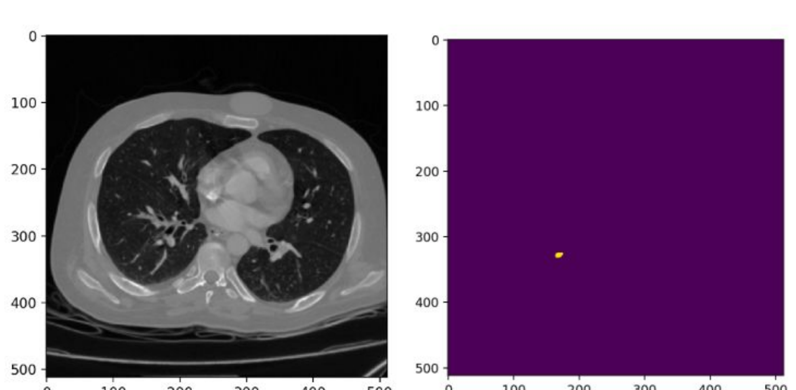
Numbers: CTA scans of 35 patients totalling 8792 slices. Each slice image is a 512px by 512px 2D image. The ground-truth images are also provided where PE regions were delineated by an expert.

Train set: 574 samples (~70%)

Dev set: 72 samples (~20%)

Test set: 72 samples (~10%)

Labeling: Each slice is labelled as showing a PE (label = 1) or not showing a PE (label = 0)



Above: Impact of Regularization Parameter on SVM accuracy

Baseline

As a baseline model we used a LeNet architecture with binary cross-entropy loss.

- Accuracy: ~75% on test set
- Predictions: the algorithm produced no PE present label most of the time
- High bias is due to simplicity of the model

Methodology

ResNet50:

To improve on the previous model we transitioned onto a deeper more sophisticated model, a ResNet with 50 layers. Binary cross-entropy loss was used.

Focal Loss:

To deal with the sparsity of positive examples in the training set, we decided to use focal loss instead of binary cross-entropy loss.

$$FL(p_t) = -(1-p_t)^\gamma log(p_t) \qquad (1)$$

$$p_t = \begin{cases} p, & \text{if y=1} \\ 1-p, & \text{otherwise} \end{cases} \qquad (2)$$

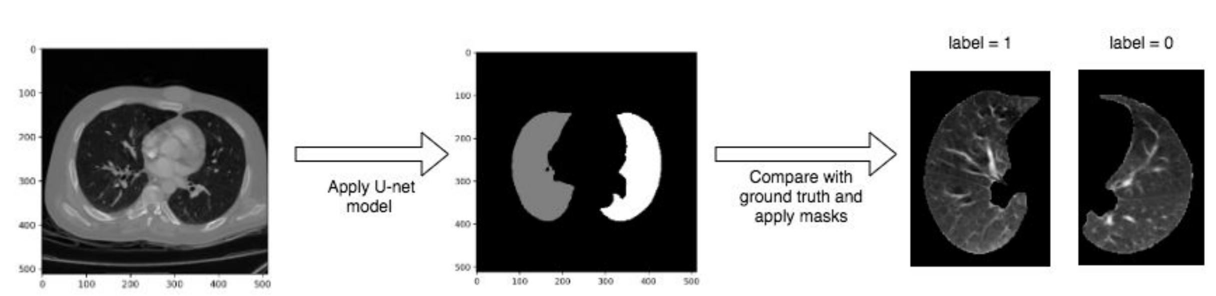
Inception V1:

After experimentation with LeNet and ResNet50 we moved onto the Inception V1 architecture.

Lung segmentation → Classification:

Finally, to further improve accuracy and sensitivity we performed lung segmentation on the CTA slice images.

Lung segmentation is performed using a pre-trained U-net model.



Above: Impact of Regularization Parameter on SVM accuracy

Results

ResNet50

train set accuracy = 82.34%

test set accuracy = 74.52%

	Predicted Positive	Predicted Negative
Actual Positive	48	184
Actual Negative	40	607

ResNet50 + Focal Loss

train set accuracy = 80.43%

test set accuracy = 77.13%

	Predicted Positive	Predicted Negative
Actual Positive	83	149
Actual Negative	52	595

Inception V1 + Focal Loss

train set accuracy = 90.51%

test set accuracy = 82.48%

	Predicted Positive	Predicted negative
Actual Positive	110	122
Actual Negative	32	615

Lung segmentation --> Classification

train set accuracy = 89.77%

test set accuracy = 82.17%

	Predicted positive	Predicted negative
Actual Positive	112	120
Actual negative	35	612

Conclusion

We obtained the best results using the Inception V1 model. This was expected since the Inception V1 model had a far greater number of layers and parameters than the other models

Lung segmentation did not make any noticeable improvement in the accuracy or sensitivity of the model.

None of the models were able to produce high enough sensitivities to be considered effective for the classification task. We hypothesise that this is due to the relatively large variability of PE shape, size and location across the different CTA images coupled with the small number of hard positive examples used during the training of the models

Future Work

- **Collect more data:** Use a much larger dataset with a wider variety of patients and larger proportion of hard positive examples
- **Use more advanced models:** Use more sophisticated ConvNet models such as Inception V3
- **3D ConvNet approach:** Once a larger dataset is procured, try a 3D ConvNet approach that takes whole volumes instead of slices into account. NNs such as 3D inflated Inception could be used.
- **ROI bounding box:** Develop a model that produces a bounding box localising the PE location within the CTA volume.

References

[1] asoudi, M., Pourreza, H., Saadatmand-Tarzjan, M., Eftekhari, N., Zargar, F. S., & Rad, M. P. (2018). A new dataset of computed-tomography angiography images for computer-aided detection of pulmonary embolism. *Scientific Data*, *5*(1).

[2] Automatic lung segmentation in routine imaging is a data diversity problem, not a methodology problem. (n.d.). arXiv.org. https://arxiv.org/abs/2001.11767