Segmentation of Ultrasound Images using Convolutional Neural Network with Noisy Activation Functions

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Motivations and Aims

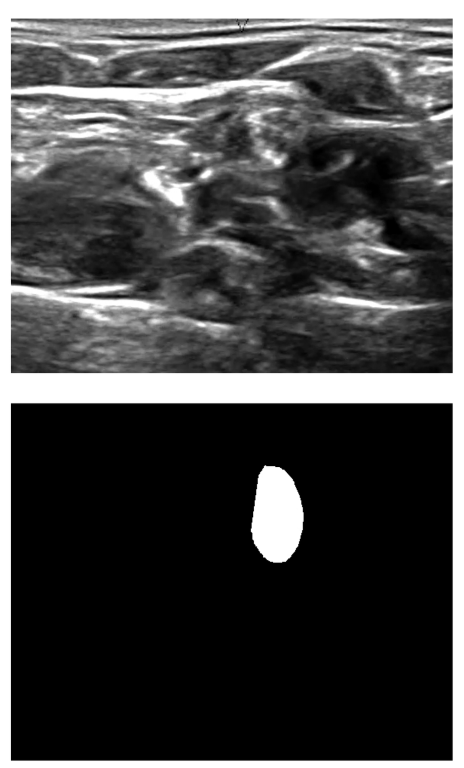
Indwelling catheters can be used to replace narcotics to mitigate pain in patients after surgery. The catheter is typically inserted into the neck of the patients at the pain source.

The catheter needs to avoid nerves in the necks. To visualize the neck structures, ultrasound images are typically used. However, in these images, the nerves are hard to identify. Therefore, we aim to detect and segment nerve structures using CNNs.

Data

Kaggle Challenge 2016: Ultrasound Nerve Segmentation

- 5635 images
- Contains nerves called the Brachial Plexus (BP)
- Human segmentation volunteers



Challenges

Inherent challenges

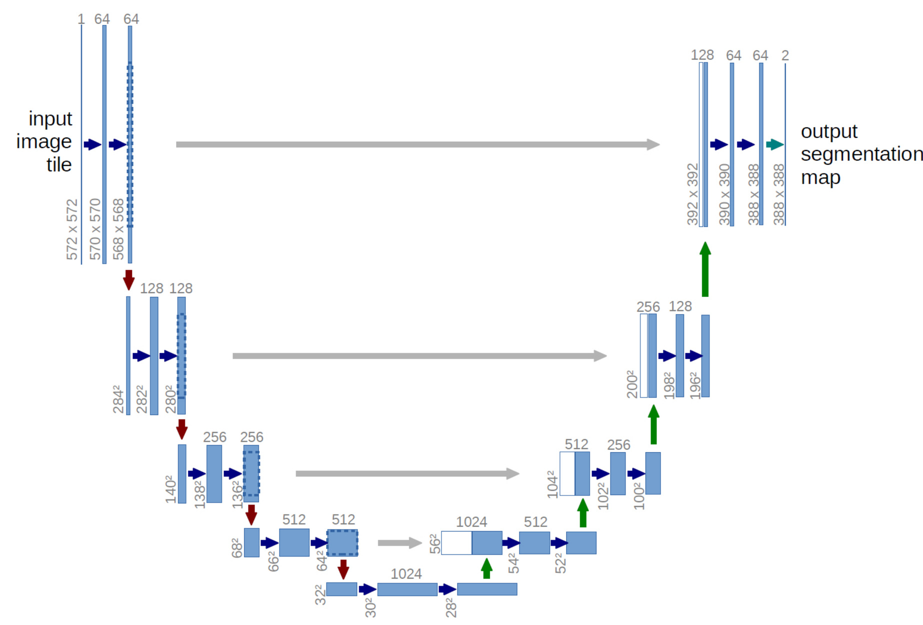
- Speckle noise
- Low SNR: 1.91
- Lower image quality than CT/MRI
- Only 2D images, no volume data

Challenges related to the data set

- No obvious structural feature
- False positive/negative reference reported
- Reduced data size

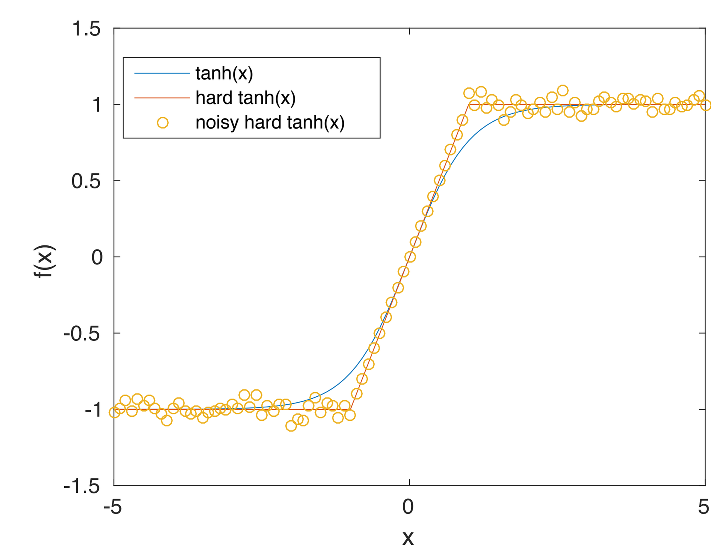
Methods

U-Net



Blue boxes: multi-channel feature maps
deep blue arrows: (noisy) activation functions
Others: Inception block, batch normalization, Dice coefficient loss functions…

Noisy Activation Functions



- Push the algorithm to explore neighborhood of local minima
- clipping the original activation function
- Adding noise to saturated zone

Training Methods

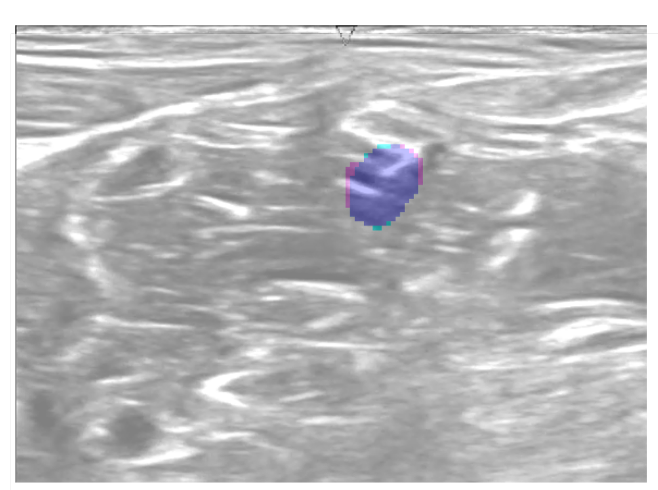
- Data size:
  - Test set: 20%
  - Training set: 64%
  - Validation set: 16%
- Noisy Activation functions: Noisy hard tanh, noisy hard sigmoid, noisy ReLU
- Implementation: Keras, Theano

Evaluation of Results

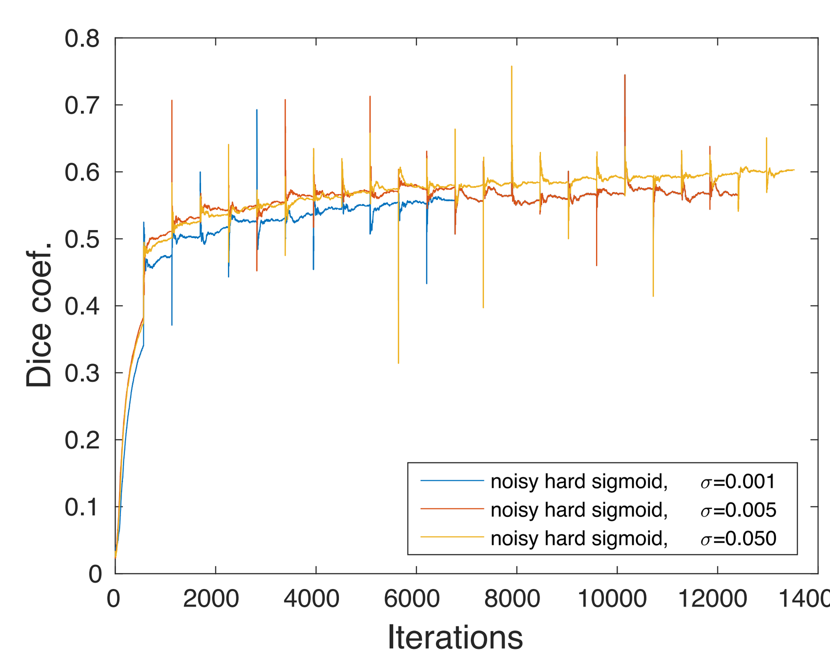
1. Dice coefficient: $\frac{2 \cdot |X \cap Y|}{|X| + |Y|}$

2. False negatives: causing injuries to patients

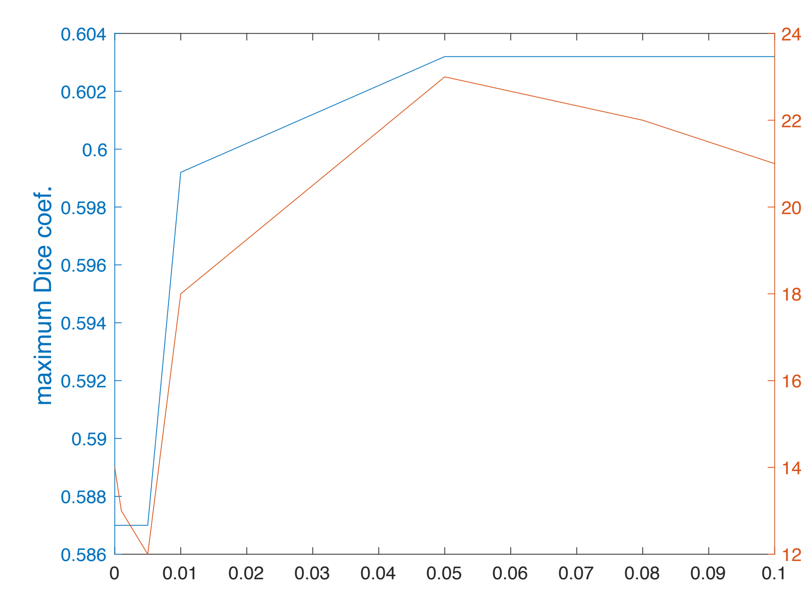
Results



Segmentation Example
Red: ground truth
Blue: predicted



Validation results



Final validation Dice coefficients and total number of epochs

- Noisy Hard Sigmoid
- Different noise levels
- Terminated at convergence

	0.000	0.001	0.005	0.010	0.050
Dice Coefficient	0.5241	0.4661	0.5031	0.5794	0.5581
False Negative	2.00	3.30	2.96	5.23	4.44
False Positives	63.77	68.00	63.77	46.96	55.08

Test results

Discussions

- Segmentation results
  - Relatively low average Dice coefficients (60%)
  - Cause: high false positive rate
  - Low false negative rate: desirable
  - High Dice coefficients in true positive predictions
- Activation functions
  - Push the algorithms away from local minima
  - Increase Dice coefficients
  - Cost: more time to achieve convergence
  - Saturation thresholds exist
- Comparison
  - Noisy hard sigmoid performs better than noisy hard tanh and noisy ReLU

References

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3. https://www.kaggle.com/c/ultrasound-nerve-segmentation
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5. Vinod Nair and Geoffrey E Hinton. 2010. Rectified linear units improve restricted boltzmann machines. In Proceedings of the 27th International Conference on Machine Learning (ICML-10). 807–814.