

## Abstract

After surgery patients are typically prescribed opioids in order to alleviate pain and aid in the recovery process. Opioids however have many adverse health effects such as nausea and vomiting, liver damage, and physical dependence [1]. Alternatives to mitigating pain exist but require radiologists to locate nerve clusters in ultrasound images so that a catheter can be placed to treat pain at the source by preventing pain signals from propagating to the brain. Our goal is to be able to accurately locate these nerve clusters using a convolutional neural network so that this alternate pain management solution can be more available by not needing a radiologist to locate nerve clusters.

## Dataset and Image Preprocessing

Our dataset was obtained from Halyard Health and consists of 5635 ultrasound images from a total of 47 patients [2]. Mask images corresponding to the Brachial Plexus in the ultrasounds were hand labeled by a radiologist observing an ultrasound image. Due to the way the acquisition machine generates image frames from the ultrasound video, there are nearly identical images in the dataset. With these duplicate images, there are occurrences when the radiologist assigned contradicting masks. As a preprocessing procedure we remove the duplicate image and mask pair that does not include a mask. This choice of removing the empty mask stems from trusting that the radiologist only labels the image when they are sure there is a mask.

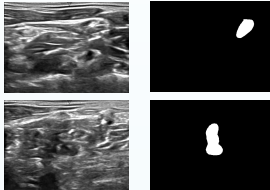


Fig. 2: Examples from the dataset

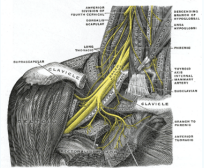


Fig. 1: Brachial Plexus in the neck

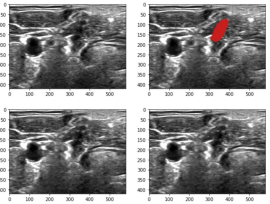


Fig. 3: Duplicate images with contradicting masks

## Method

### Architecture

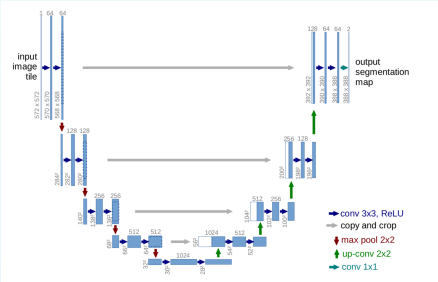


Fig. 4: U-net architecture - 31,030,593 trainable parameters [3]

### Augmentation

- Horizontal flip
- Vertical flip
- random degree rotations

### Data split

- 9012 training
- 2256 validation
- 2818 test

### Metrics

$$DC = \frac{2|X \cap Y|}{|X| + |Y|}$$

Eq. 7: Dice coefficient [4]

### Activation

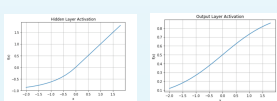


Fig. 5: ELU activation

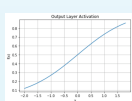


Fig. 6: Sigmoid activation

### Post-processing

1. Map output predicted mask to binary scale
  - $\geq 0.6 \rightarrow 1$
  - $< 0.6 \rightarrow 0$
2. Zero out masks whose sizes aren't feasible

## Results

### Examples

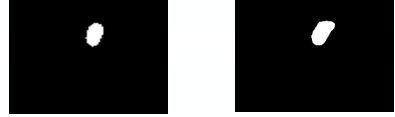


Fig. 8: Desirable result



Fig. 9: Result that may be filtered with refined post-processing



Fig. 10: Undesirable result

### Metrics

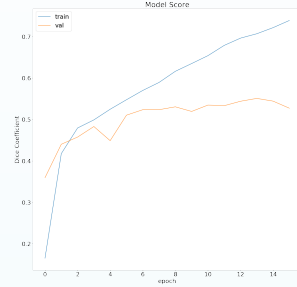


Fig. 11: Score at training stage

	Predicted: Negative	Predicted: Positive
Actual: Negative	TN = 99.62%	FP = 0.3785%
Actual: Positive	FN = 44.56%	TP = 55.44%

Fig. 12: Pixel-wise confusion matrix

### 5-fold verification score

- Mean: 0.689
- Variance: 0.0004

## Discussion

From Fig. 8-10 you may see variations of our result when there is a nerve present in the ultrasound our model performs extremely well (high dice coefficient); however, if there is no nerve present our model doesn't always predict correctly. The result in Fig. 9 is an example of a mask that can be zeroed out by refining the threshold of feasibility in our post-processing technique 2. However, there are some occasions where our model simply provides us with a poor prediction which is undesirable and these occurrence shall be minimized in further implementation.

## Further Implementation

- Expand network and dataset to allow for classification of a wider variety of nerve clusters. This will allow broader implementation of Halyard Health's pain management solution.
- Apply the model to video stream input rather than single image to allow for real time image labeling. This will allow a medical professional to accurately insert catheter during the procedure.

## References

[1] Schug, S.A., Zech, D. & Grond, S. Drug-Safety (1992) 7: 200. <https://doi.org/10.2165/00002018-199207030-00005>

[2] Ultrasound Nerve Segmentation." Kaggle, Halyard Health, 2016, [www.kaggle.com/c/ultrasound-nerve-segmentation/](http://www.kaggle.com/c/ultrasound-nerve-segmentation/).

[3] Ronneberger, Olaf, et al. "U-Net: Convolutional Networks for Biomedical Image Segmentation." ArXiv.org, 18 May 2015, [arxiv.org/abs/1505.04597](http://arxiv.org/abs/1505.04597).

[4] Dice, Lee R. (1945). "Measures of the Amount of Ecologic Association Between Species". Ecology. 26 (3): 297-302. doi:10.2307/1932409. JSTOR 1932409.