Salt Segmentation using U-shaped Residual Convolution Neural Network

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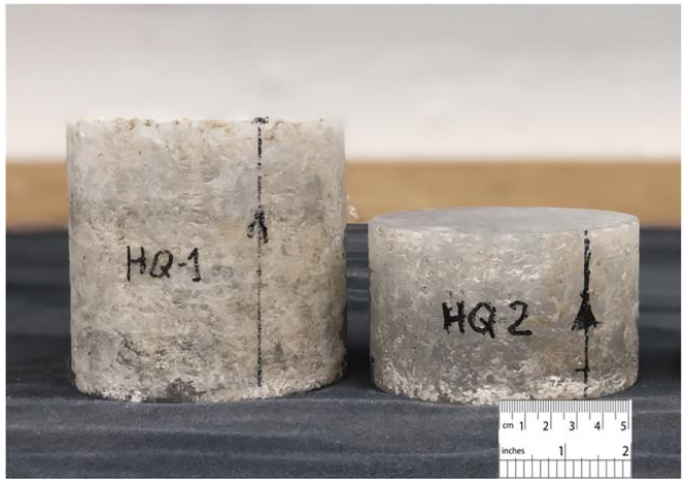
Outline

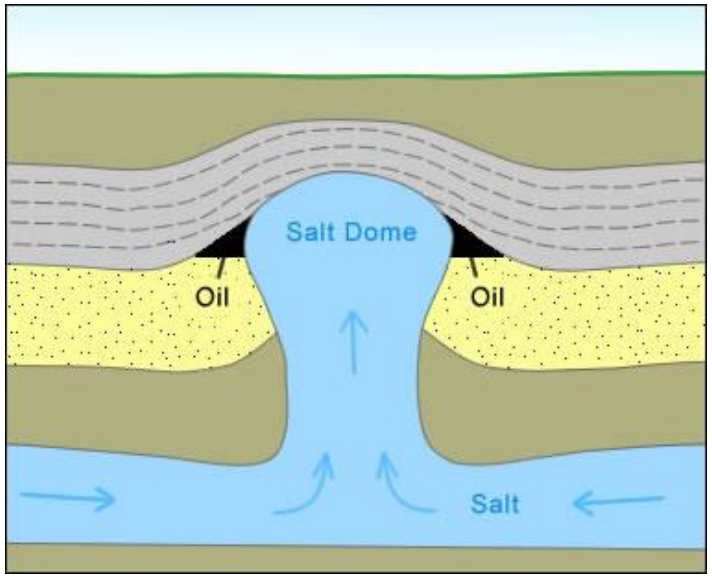
- Introduction
  - Salt background
  - Seismic imaging
- Methods
  - U-net
  - ResNet
- Results
- Concluding remarks

Background: Subsurface salt

- Unique physical properties
  - Relatively light density
  - High wave speed
  - Flow under stress
- Economic importance
  - Oil and gas trap
  - Storage site for helium and hydrogen
  - Disposal site for hazardous waste



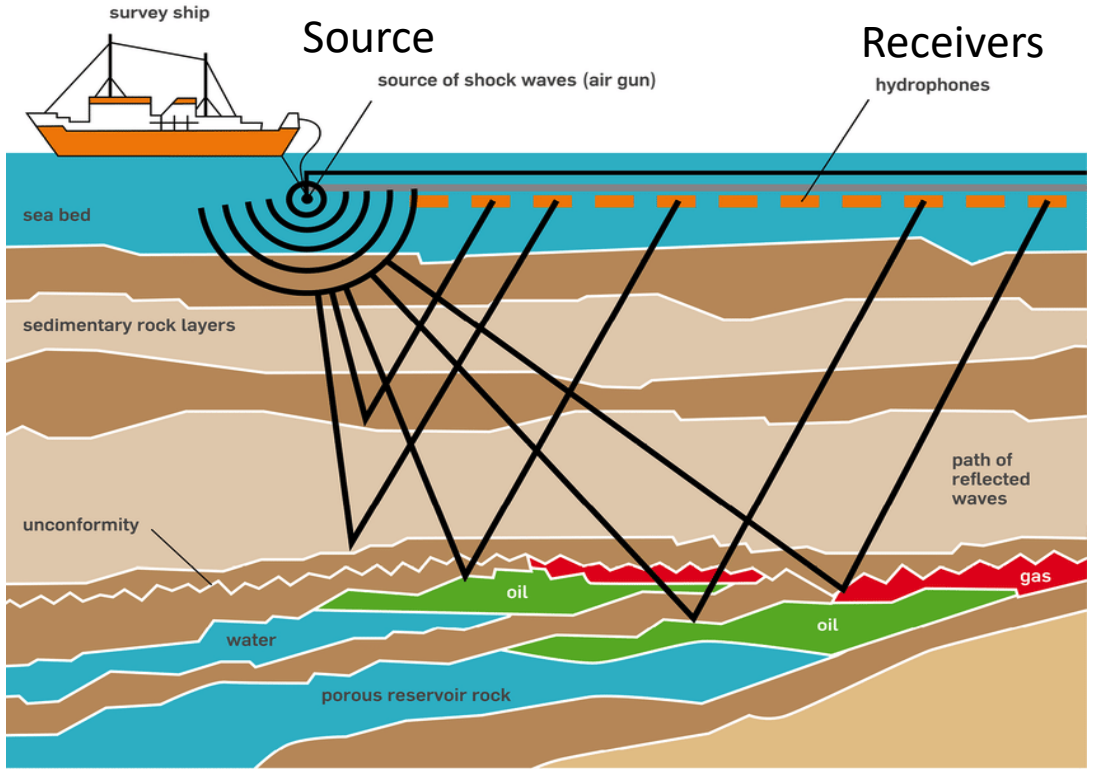
Laboratory specimens of salt (halite) from Zong et al. (2020)



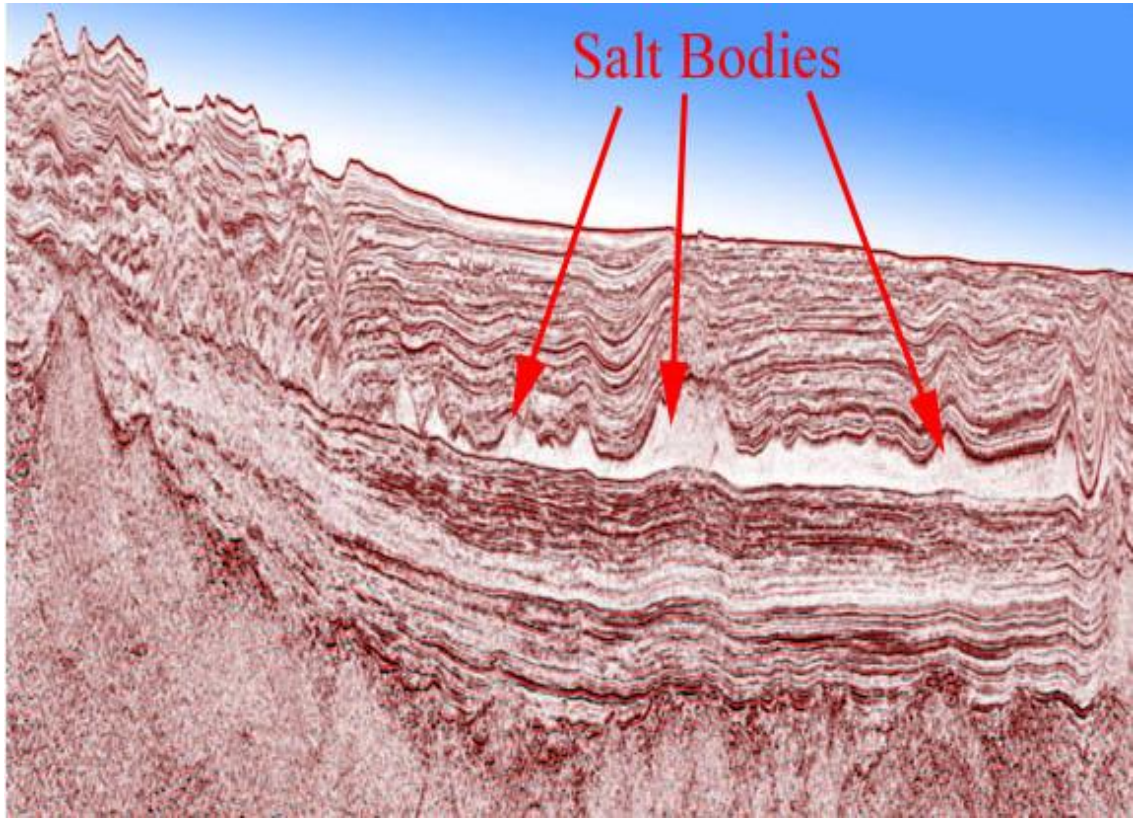
A salt dome trap

https://geology.com/stories/13/salt-domes/

How to find salt: Seismic imaging



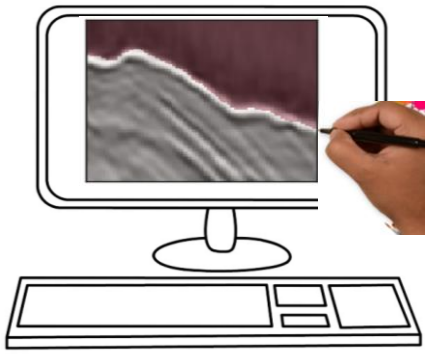
Reflection seismology is widely used to image the subsurface; Seismic events are expected at boundaries of different layers.



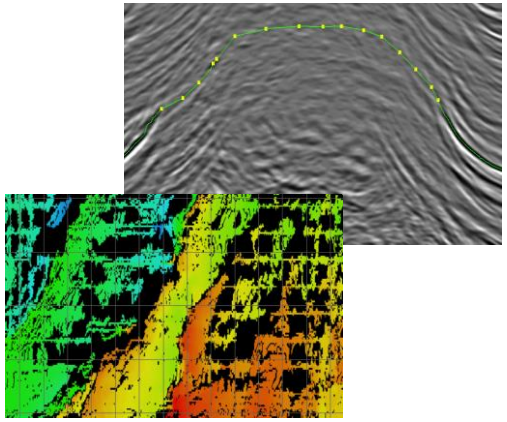
Salt body identification is critical but time-consuming and biased. Therefore, automation is highly desired.

Evolution of salt identification

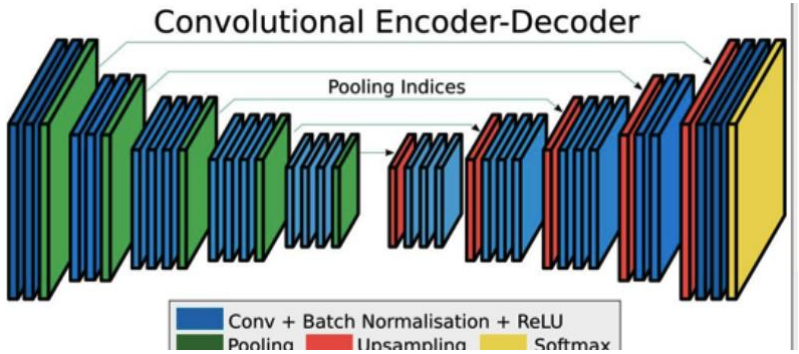
Conventional hand-engineered horizon picking



Auto Seed Tracking
Based on correlation



When computer vision
Meets seismic images



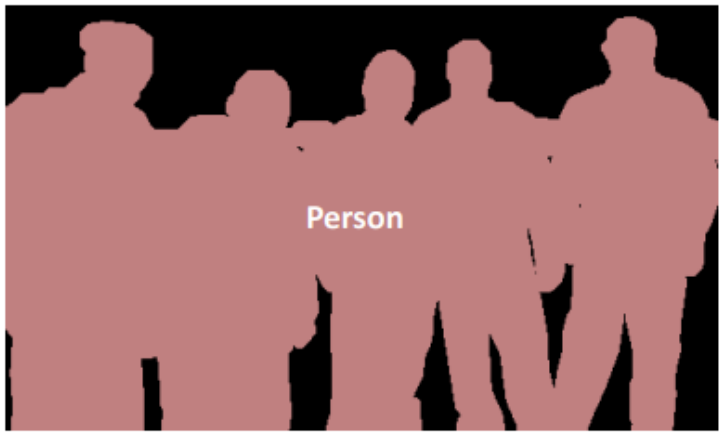
Who should concern?

- Geophysicists and computer vision experts
- Government agencies and National Geological Survey
- Oil and service companies

(Donadei and SönkeSchneider, 2002, book chapter)

Objective

- Implement semantic segmentation to label salt in each pixel of 18,000 test images by learning 4,000 seismic images and masks
- Determine the threshold of the binary classification in each pixel to yield the best metric of Intersection over Union (IoU)



Semantic Segmentation

	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

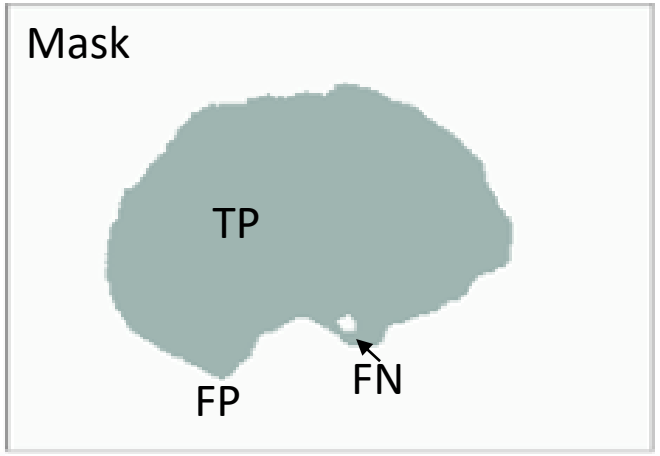
Metric: Intersection Over Union (IoU)

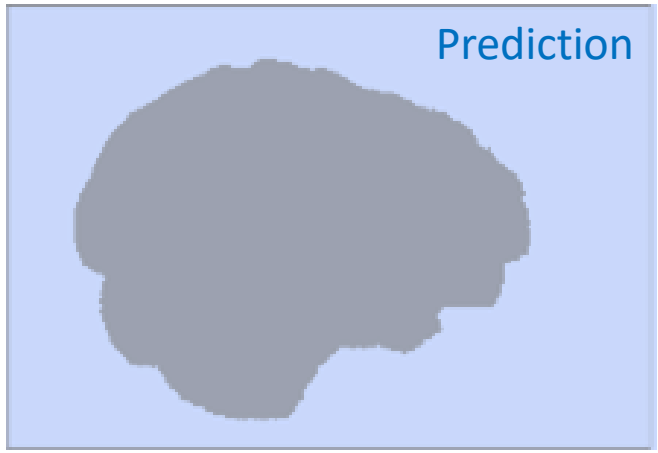
IoU compares the corresponding pixel between the ground truth and prediction:

$$IoU = \frac{I_1 \cap I_2}{I_1 \cup I_2}$$

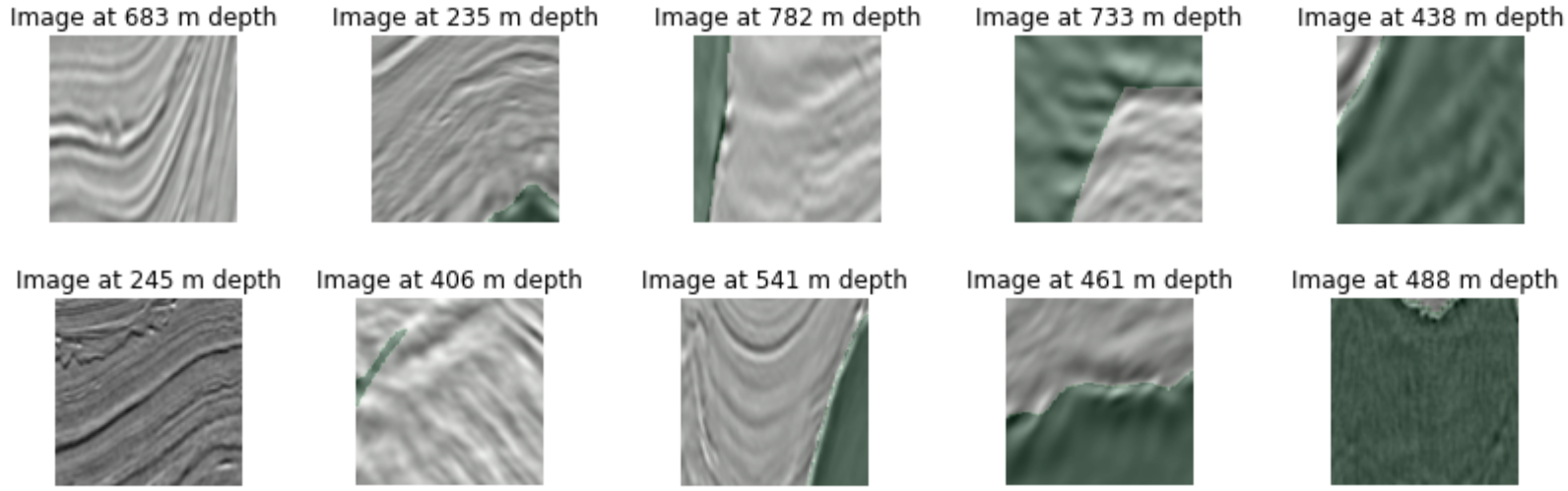
Calculate IoU for different threshold (t) and find the best threshold of Mean IoU

$$\frac{TP(t)}{TP(t) + FP(t) + FN(t)}$$



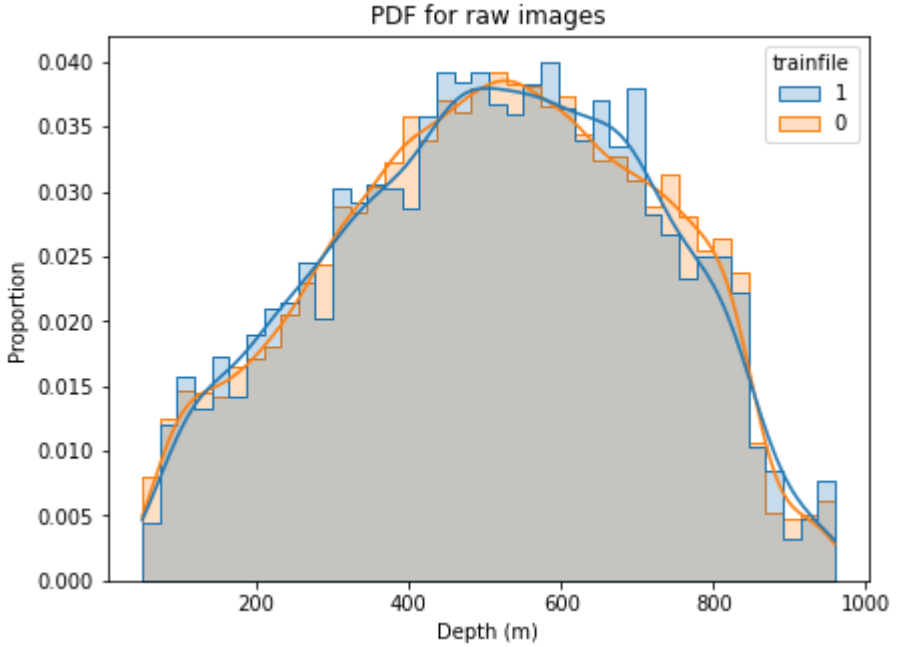


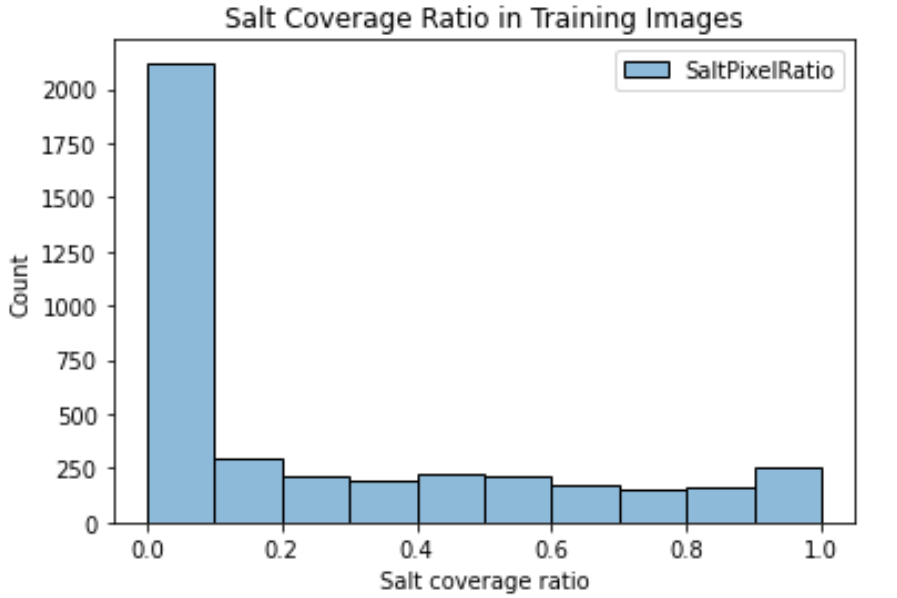
Data wrangling



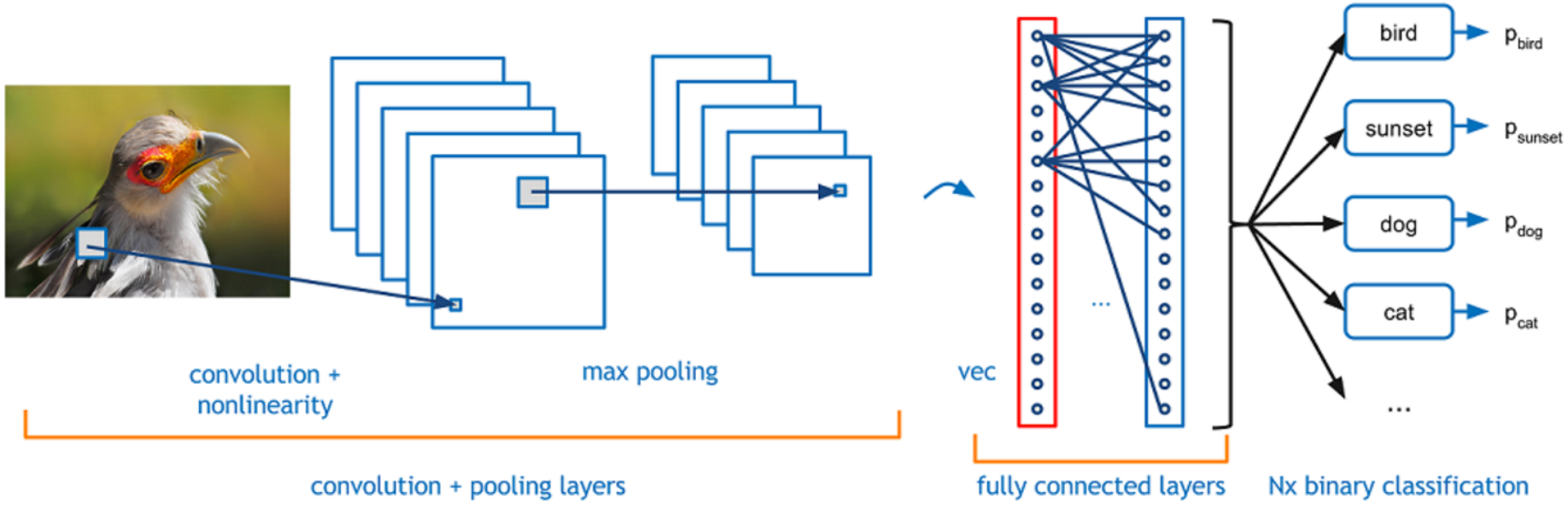
Grey: seismic image; Green: salt mask

- 4000 images with masks available, much less than 18,000 test images
- Image depths range from 50 to 950 m for both training and testing sets
- Salt coverage indicates imbalanced labels



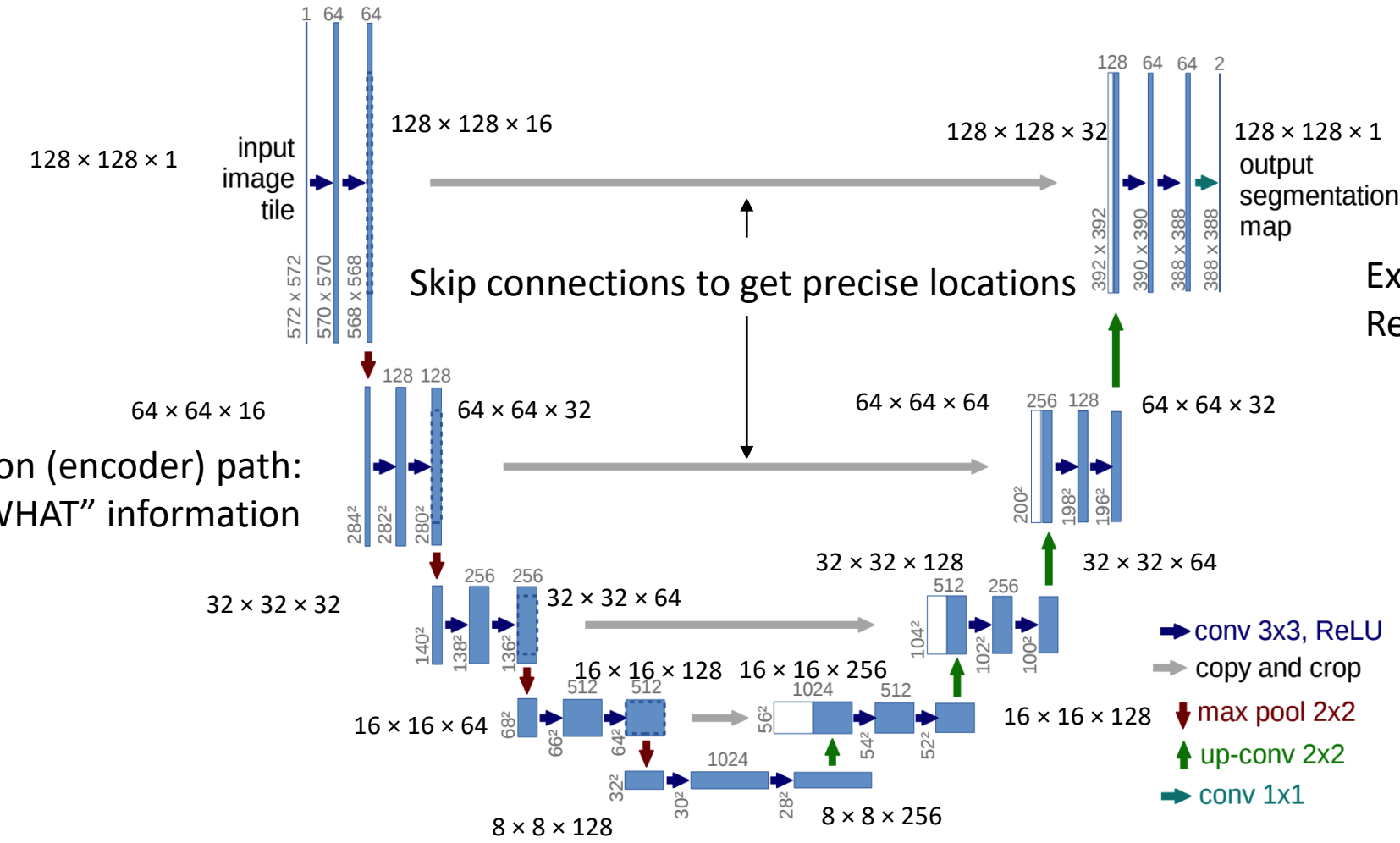


Convolution Neural Network



https://adeshpande3.github.io/adeshpande3.github.io/A-Beginner's-Guide-To-Understanding-Convolutional-Neural-Networks/

U-net for semantic segmentation



Contraction (encoder) path:
Learns "WHAT" information

Expansion (Decoder) path:
Recovers the "WHERE" information

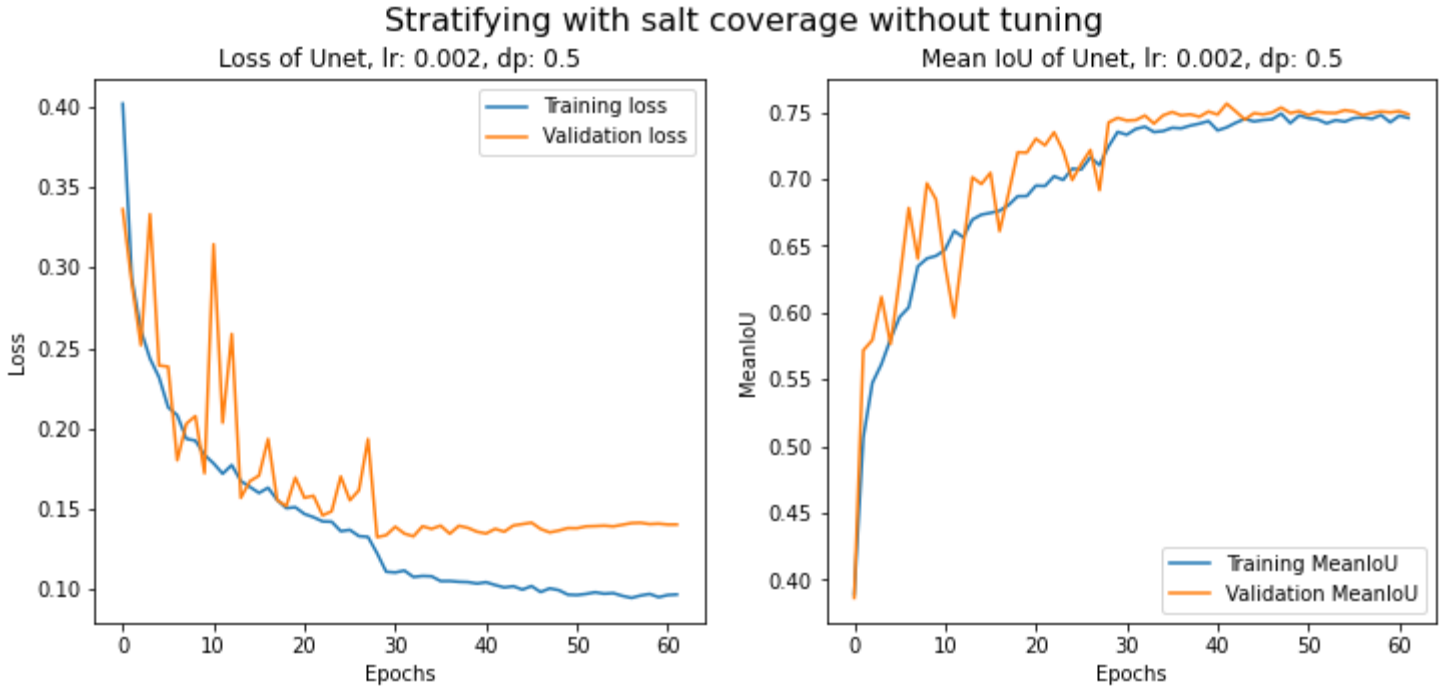
Max pooling: Decrease image dimension (downsample)

For up-sampling: Transposed Convolutional layers are used

Vanilla U-net by Ronneberger et al. (2015)

https://towardsdatascience.com/understanding-semantic-segmentation-with-unet-6be4f42d4b47

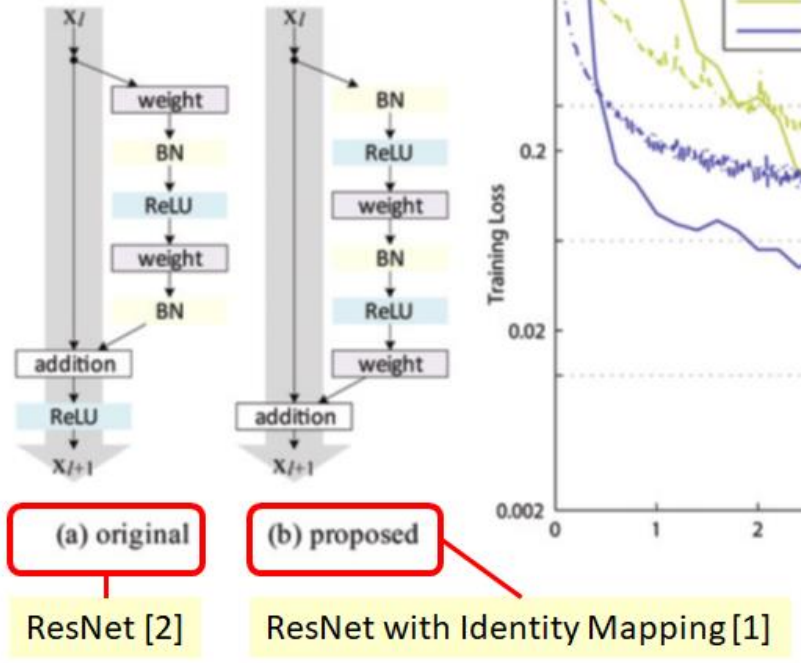
U-net training history

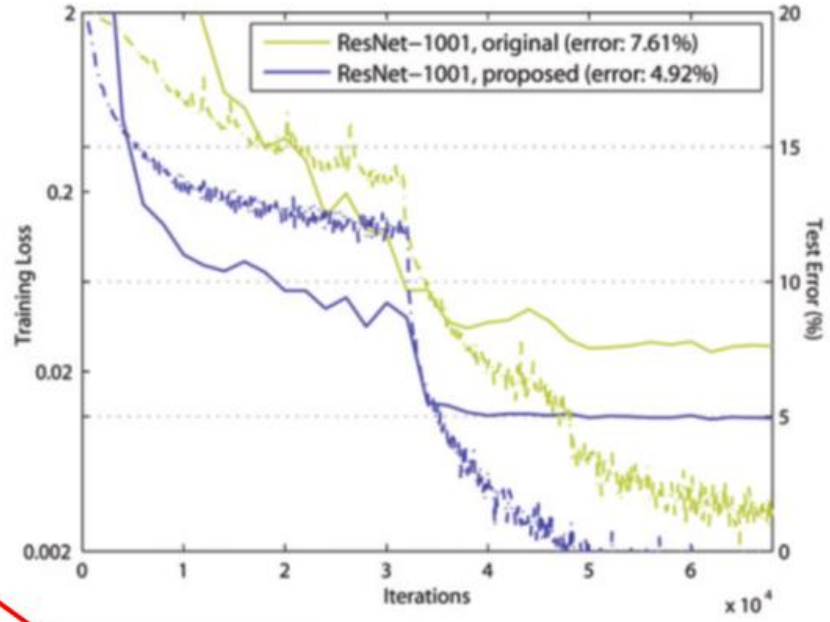


- Unet has over 2.1 M trainable parameters
- Split the training images to training(0.8) and validation(0.2) sets
- Stratify the splitting based on 10 categories of salt coverage

Building block of ResNet

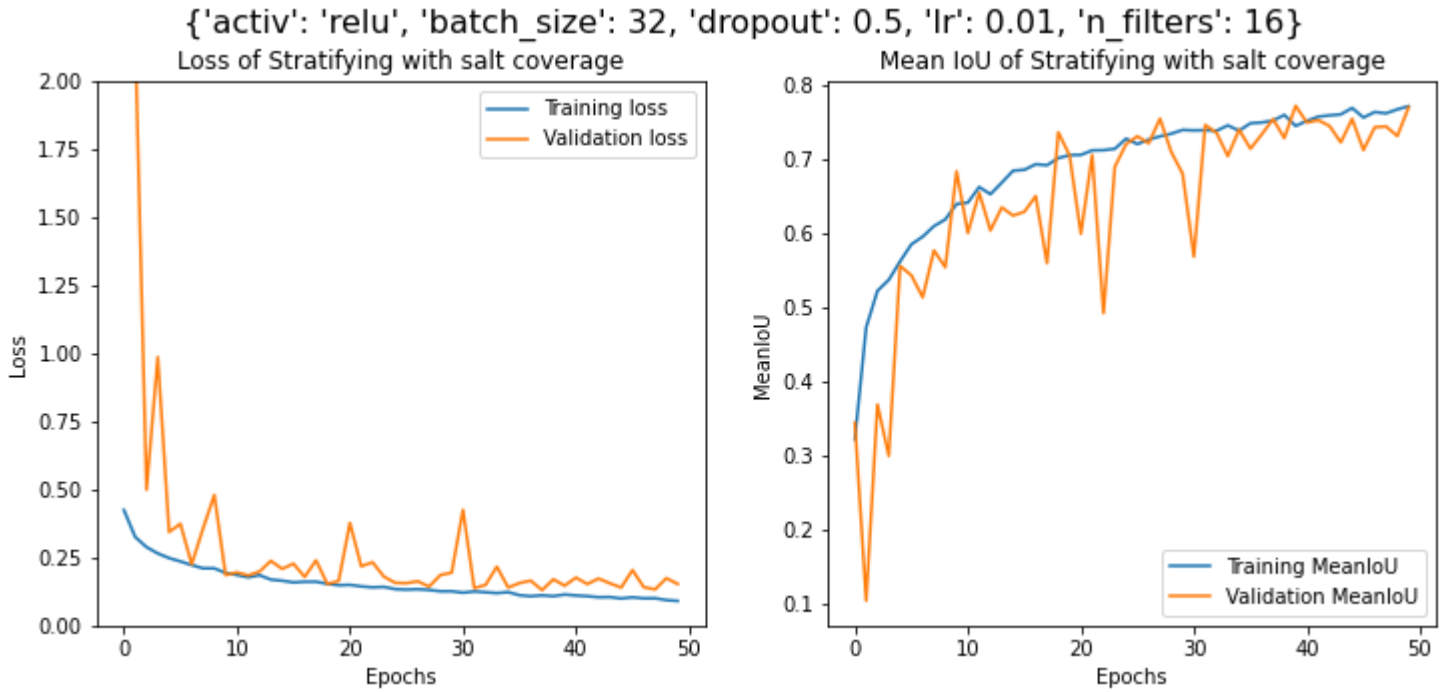
- Vanishing gradient problem
- Residual neural networks
  - Reintroduce outputs from shallower layers

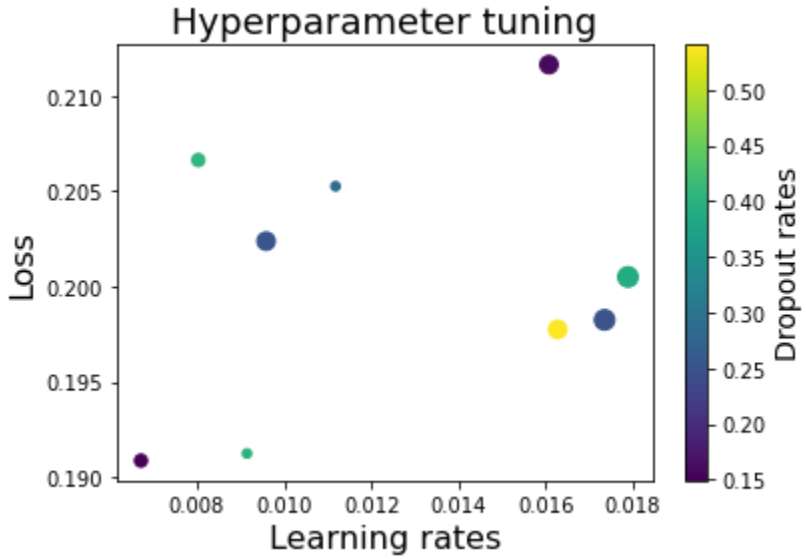




ResBlock with Full Pre-Activation

ResNet training history

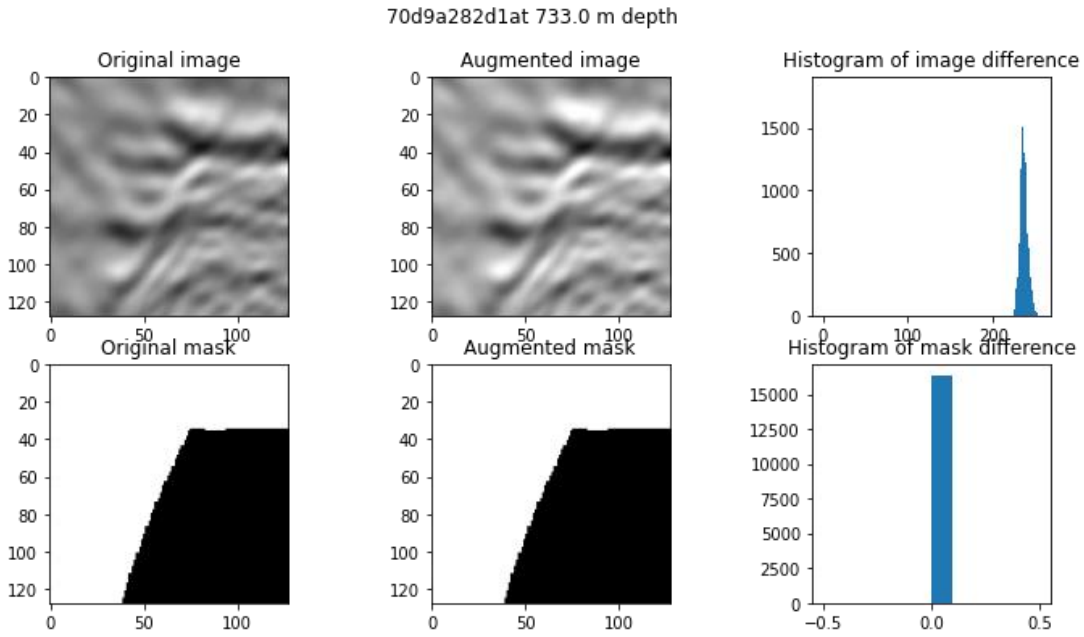




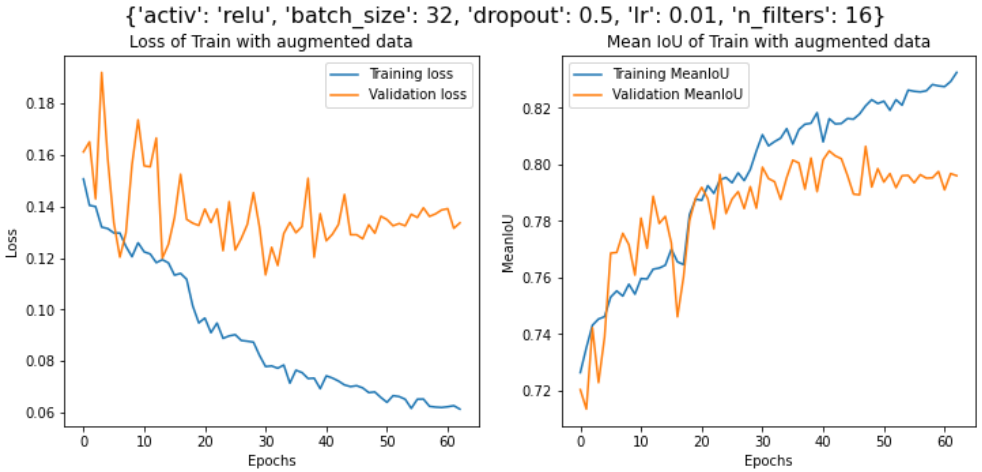
- ResNet has over 5.1 M trainable parameters
- Tune hyperparameter via tree-based Parzen Esimtors (TPE) in Hyperopt library

Data augmentation

- Horizontal flipping
- Sequentially augment images
  - Affine, including translation and rotation, scaling
  - Crop and pad
  - Gaussian noise/blur
  - Multiply to make darker/brighter
  - Add to shift the greyness
- Randomly generate augmentation in each batch and epoch

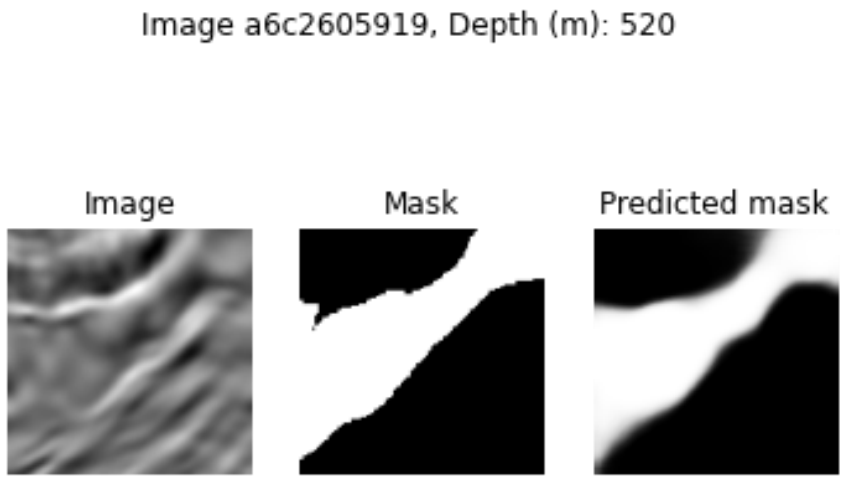


(Augment the image and mask)

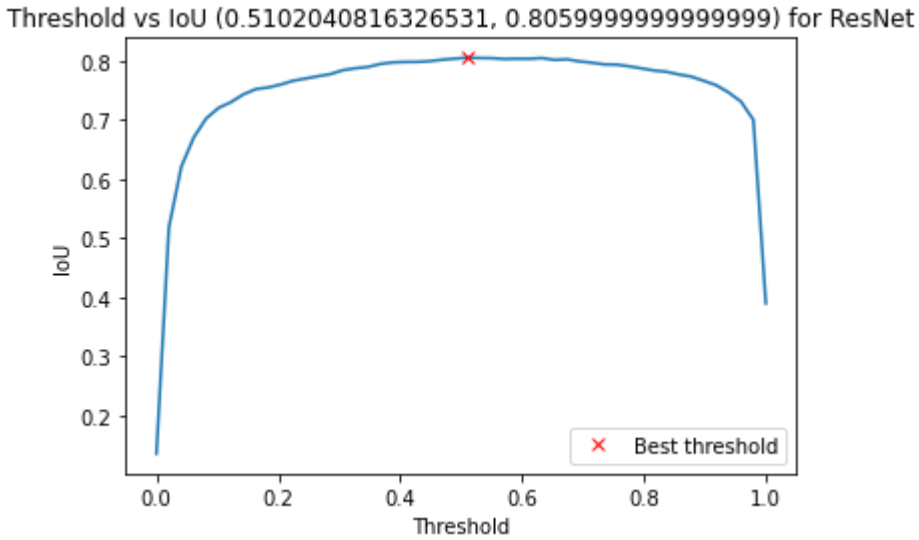


(Further improve the training/validation metrics)

Optimize the threshold IoU

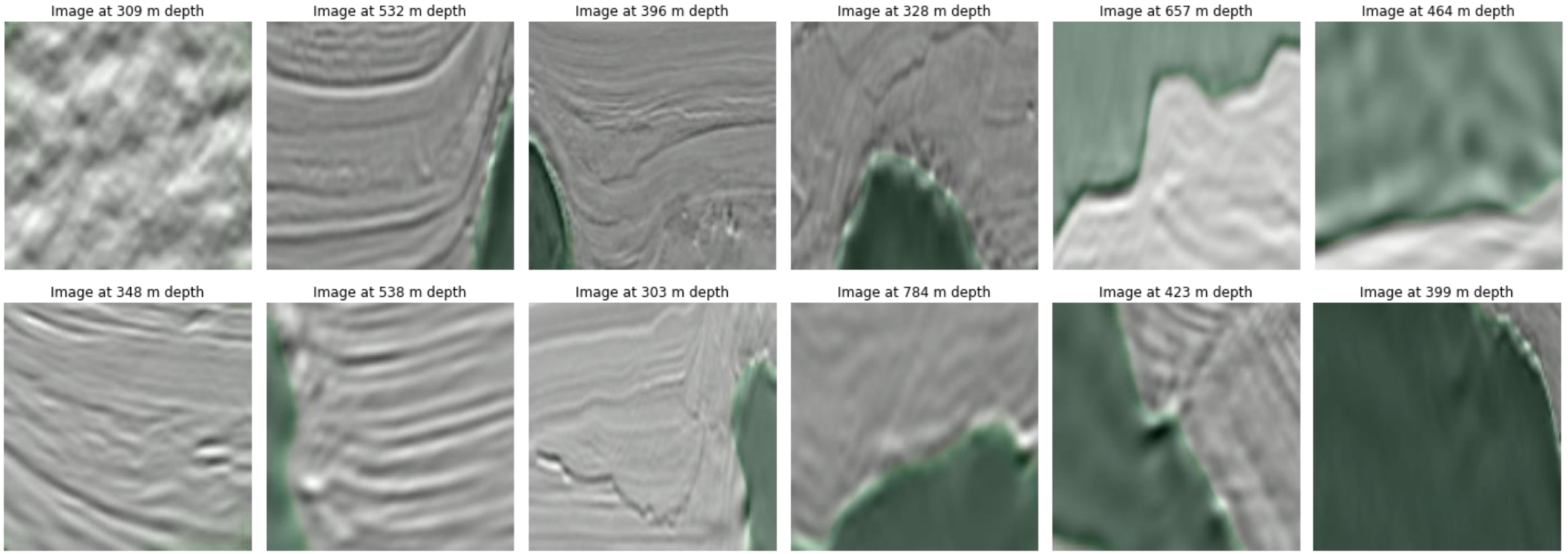


The last layer uses ‘sigmoid’ as the activation, generating a probability from 0 to 1 for each pixcel.



Select the threshold based on the validation sets

Examples of predicting the test images



Submission and Description

Private Score

ResNet_binary_crossentropy_notune_lr01.csv

Complete (after deadline) · 1d ago · ResNet (correct): no scale, 82 split, iaa ResNet_binary_crossentropy_notune_lr01_iaa.h5

0.8258

Future work

- Improve the model
  - Data augmentation with domain knowledge
  - Ensemble
  - Long-short circuit ResNet (bottleneck block)
  - Use Lovász Hinge as the loss function for binary segmentation
  - Attention module
- Build an API for convenient usage

Concluding remarks

- U-shaped network can solve image segmentation tasks using contraction and expansion paths
- Adding residual blocks further improves the segmentation task, assisting the automation of seismic interpretation
- Data augmentation improves the training/validation metrics and prevents from the overfitting

Acknowledgement

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Thank you!