Application of Deep Learning in Subsurface Faults Detection With Seismic Data

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Introduction

Seismic fault interpretation is a significant part of modeling of the subsurface processes of any scale. Currently, seismic interpreters utilizes manual faults detection. It is entirely guided by domain experts and often looks "geologically correct", but is biased, extremely time-consuming and not repeatable.

In this work, we employed faults classification and detection by means of Convolutional Neural Networks (CNN), which have been extensively utilized in identifying faces,

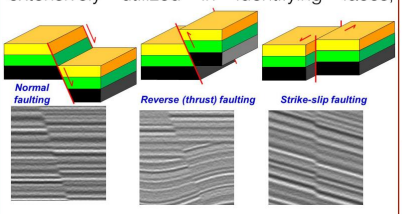
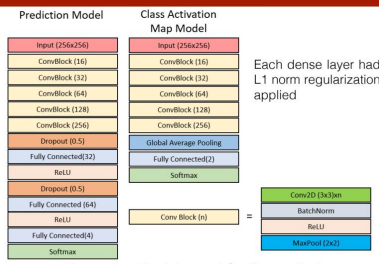


Figure 1 – Simplified classification of the faults and their corresponding seismic images (bottom)

Models



Each dense layer had L1 norm regularization applied

Figure 2 – Models used for the project

Dataset

- **4 image classes** – No Fault; Normal Fault, Reverse Fault and Strike Slip Fault:
  - ✓ Synthetic simulation of 50K images (256 x 256)
  - ✓ Manual collecting 3K images from real seismic datasets (New Zealand and Norway)
  - ✓ Data augmented using Keras ImageDataGenerator
- **Train/validation/test** -> 90/5/5
- Real data: No Fault and Normal Fault only

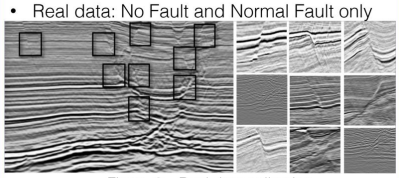


Figure 3 – Real data collection

Accuracy and Misclassification

Synthetic/real sets accuracy

Metrics	NoFault	Normal	Reverse	Strike Slip
Precision	1/0.93	0.92/0.87	0.97/0	1/0
Recall	1/0.93	0.97/0.89	0.91/0	0.1/0
F1	1/0.93	0.95/0.88	0.94/0	1/0

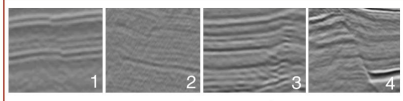


Figure 4 – Misclassified normal fault real data

Sample	NoFault	Normal	Reverse	Strike Slip
1	0.6937	0.2962	0.0101	6.11E-06
2	0.7201	0.2706	0.0093	1.17E-05
3	0.66	0.3256	0.0145	1.89E-05
4	0.0033	0.414	0.58	3.00E-03

Neural Style Transfer for Faking Reverse Faulted Seismic Images

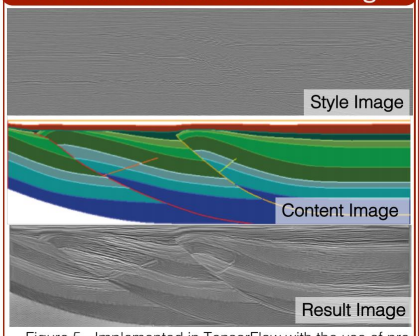


Figure 5 - Implemented in TensorFlow with the use of pre-trained VGG 19 network

Discussion

1. Synthetic set accuracy (f1=0.95) is close to domain expert level
2. A lack of real reverse and strike slip data did not allow to test real data accuracy for these classes
3. Strike slip accuracy metric is characterized by low recall, i.e. by abundance of false negatives.
4. Neural Style Transfer can be utilized for faking reverse or strike slip seismic sections
5. Fault detection using activation maps demonstrates good performance in identification of faults on seismic sections

Future Work

1. Gather more real reverse fault and strike slip data to validate model over those classes
2. Form an implementation on full 3D seismic sections to exploit 3D locality

Class Activation Maps

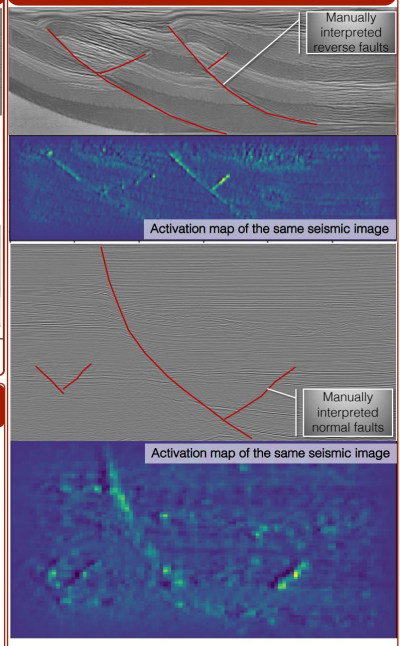


Figure 6 – Full seismic images with fault activation maps

References

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2. Xiong, W., X. Ji, Y. Ma, Y. Wang, N. M. BenHassan, M. N. Ali, and Y. Luo, 2018, Seismic fault detection with convolutional neural network: Geophysics, doi:10.1190/geo2017-0666.1
3. https://github.com/dhale/ipf