Building a Geological Cyber-infrastructure: Classifying Clasts in Photomicrographs

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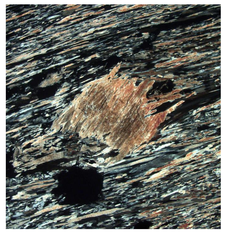
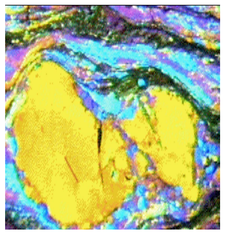
Introduction

- Goal: Incentivize the participation and contribution to the growth of an earth-science-based cyberinfrastructure.
- Build: Analytical environment that allow automatic analysis and classification of data from connected data repositories
- Develop a system for automatic classification of photomicrographs as containing asymmetric, shear-sense-indicating clasts or not.

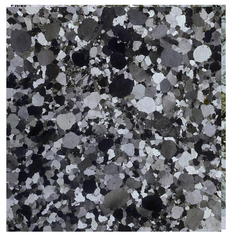
Dataset (photomicrographs with sigma-clasts, without sigma clasts)



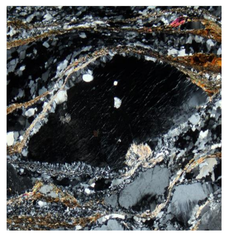
Sigma-Clast
Confidence Score: 0:99



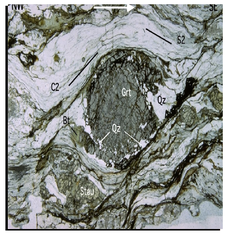
Sigma-Clast
Confidence Score: 0.74



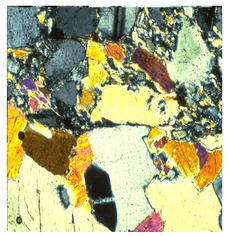
Non-Sigma-Clast
Confidence Score: 0.98



Sigma-Clast
Confidence Score: 0.98



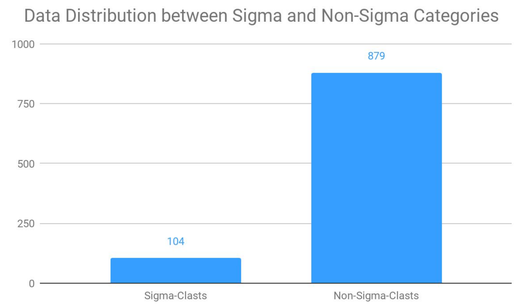
Sigma-Clast
Confidence Score: 0.81



Non-Sigma-Clast
Confidence Score: 0.94

Data Distribution

- 983 images of photomicrographs were selected by an expert.

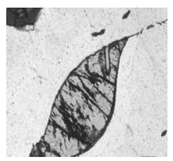


Addressing Data Imbalance

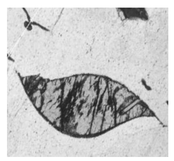
- Oversampling: Duplicates images in smaller dataset to match larger one.
- Data augmentation: Transforms images in smaller dataset.

Transformations utilized:

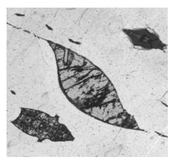
Rotation range: 40˚
Height/width shift: 10%
Shear range: 0.2 rad ccw
Zoom: 30%
Horizontal flipping: true
Fill mode : “reflect”



Counterclockwise **R**otation **Z**oom



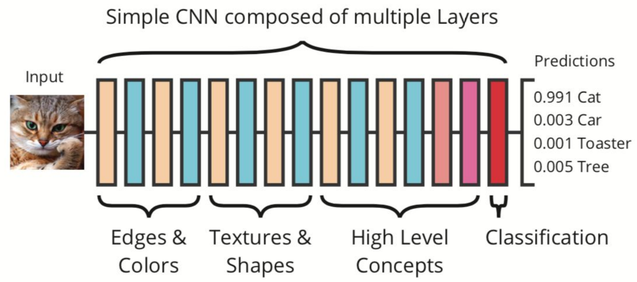
Height Shift Width Shift **Z**oom



Horizontal Flip Clockwise **R**otation **F**illed

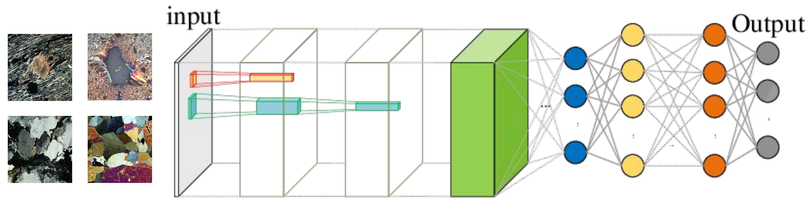
Convolutional Neural Networks (CNN)

- CNNs are a class of neural networks that model how the brain works.
- It compromises of convolutional layers, which are trained by large amounts of data.
- Takes as input an image and outputs the confidence scores for each output category.



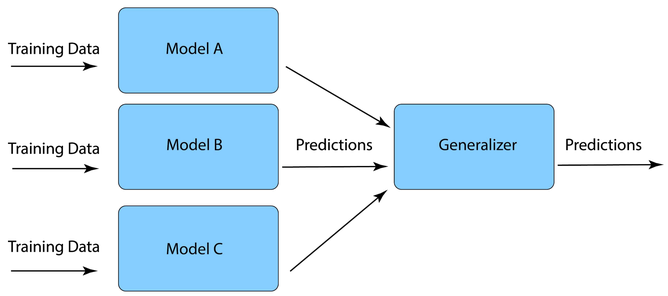
Transfer Learning and Fine Tuning a Pre-Trained CNN

- Allows a CNN to learn over a small image dataset such as photomicrographs.
- Instead of re-training the CNN from scratch, it takes a pre-trained CNN and adds few layers to it and trains them.
  - Fine tuning further modifies last few layers of the pre-trained CNN.



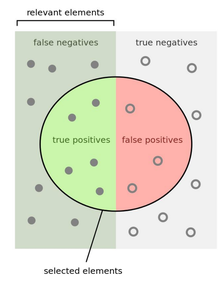
Ensemble Learning

- Use few different CNN models and combine their results to predict new results.



Evaluation

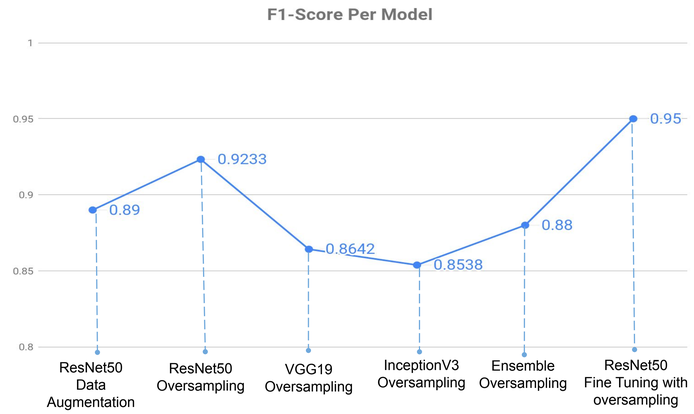
- Compute F1-score



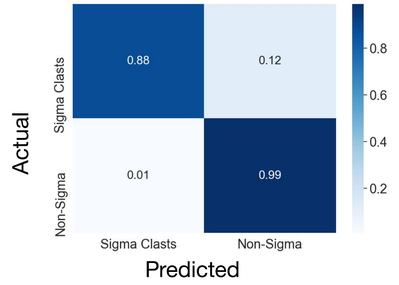
F1 score = 2*TP/(2*TP + FP + FN)

- Perform K-Fold Cross Validation

Results

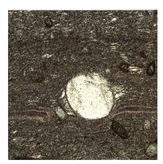


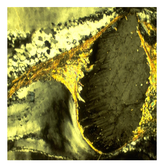
ResNet50 Fine Tuning Oversampling Confusion Matrix

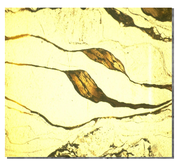


Average Accuracy & Std. Dev.	0.9828	0.0136
Average F1 Score overall & Std. Dev.	0.9523	0.0381
Average F1 Score by class	0.91425344	0.99040706

Result Analysis







ResNet50	✓	✗	✓
InceptionV3	✗	✓	✓
ResNet50 with Fine Tuning	✓	✓	✓
Ensemble Network	✓	✓	✓

Conclusion and Future Research Questions

- CNNs are able to classify photomicrographs as containing asymmetric, shear-sense-indicating clasts or not, by training on a very small dataset
- Framework addresses data imbalance and allows combining models.
- Can it be further trained to determine the shear sense (i.e., sinistral (CCW) or dextral (CW) shearing)?
- Can a CNN be trained from scratch instead of using a pre-trained one?
- Can a “heatmap” indicate which regions of an image are used to make the prediction?

Acknowledgements

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