

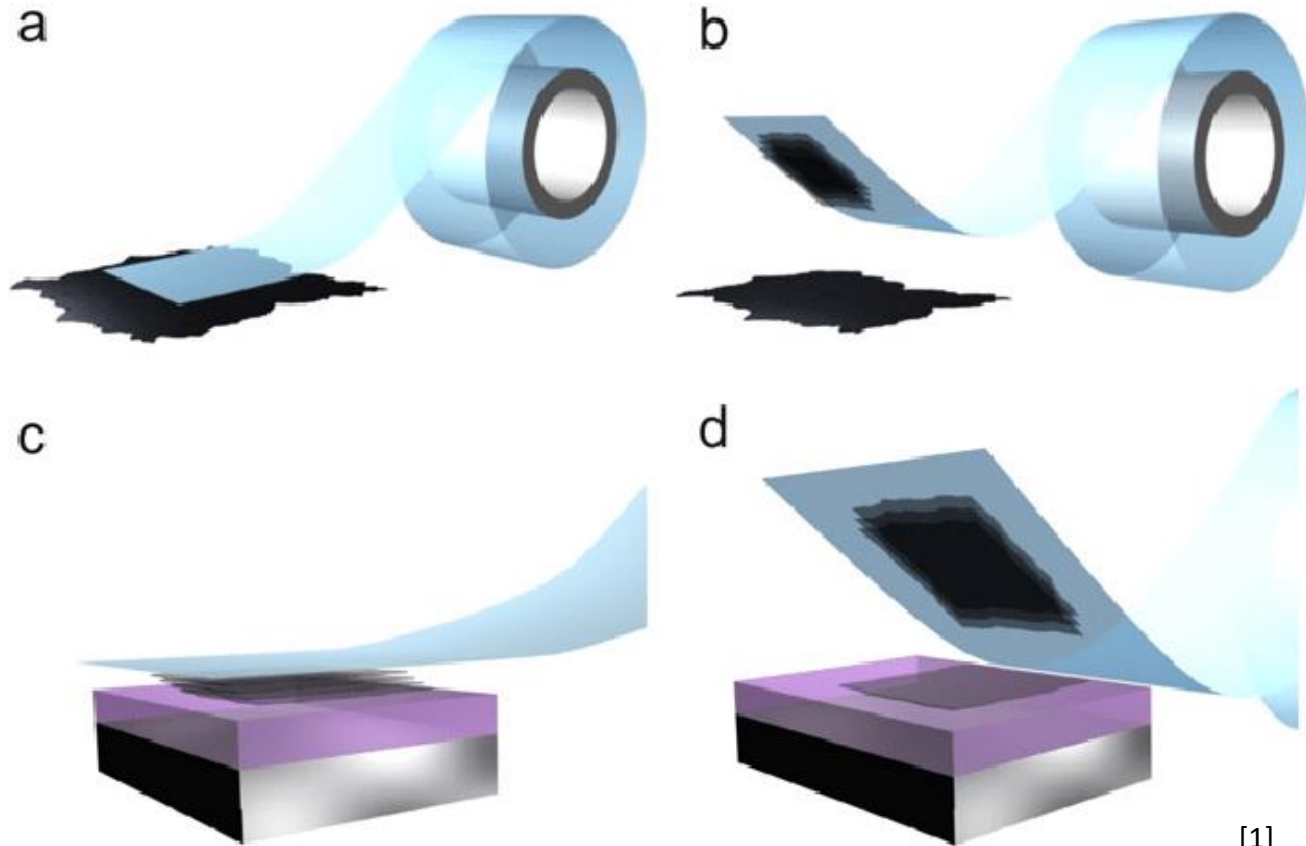


Automated recognition of exfoliated two-dimensional materials using python OpenCV library

By Daniil Ivannikov



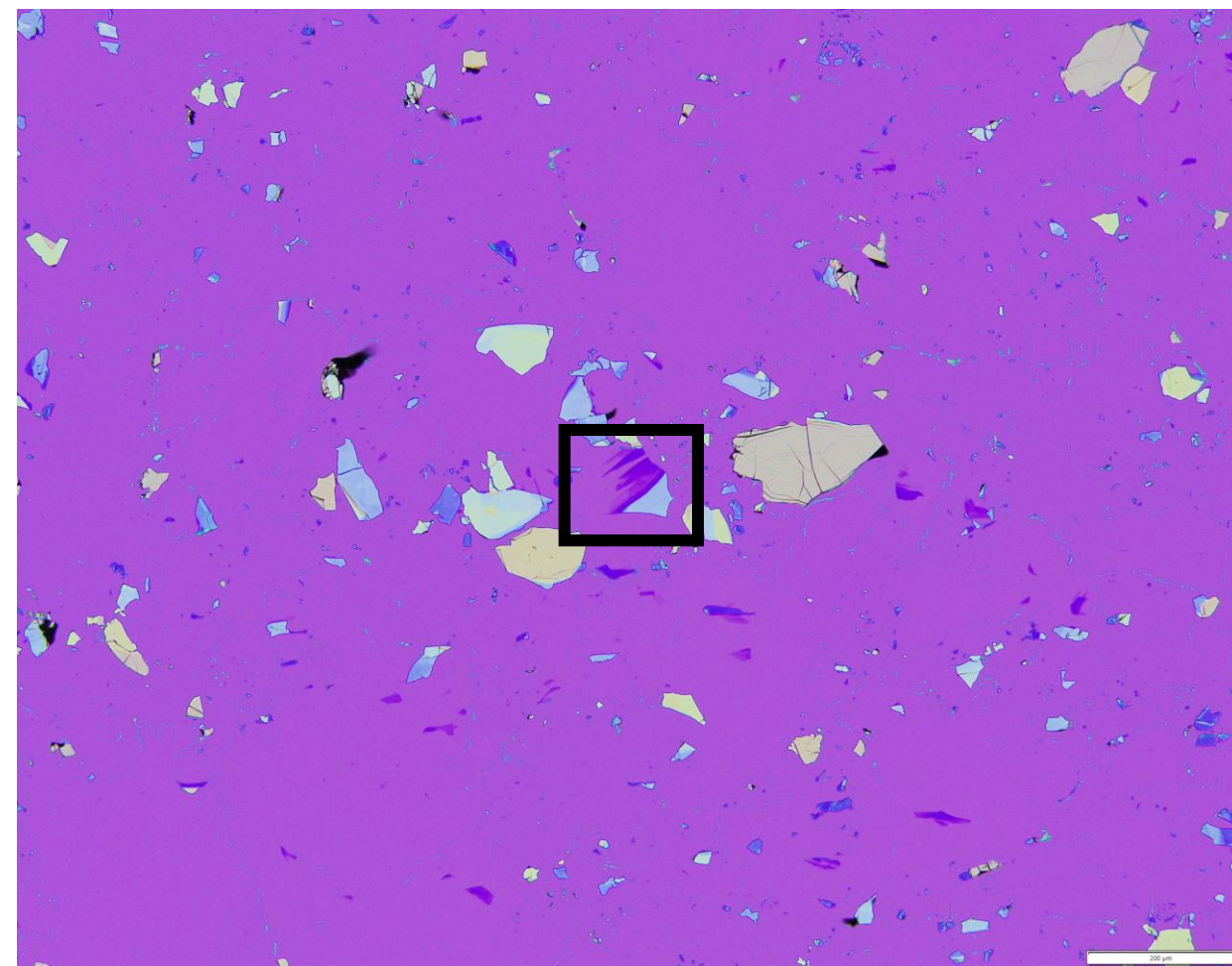
Two-Dimensional Materials Exfoliation



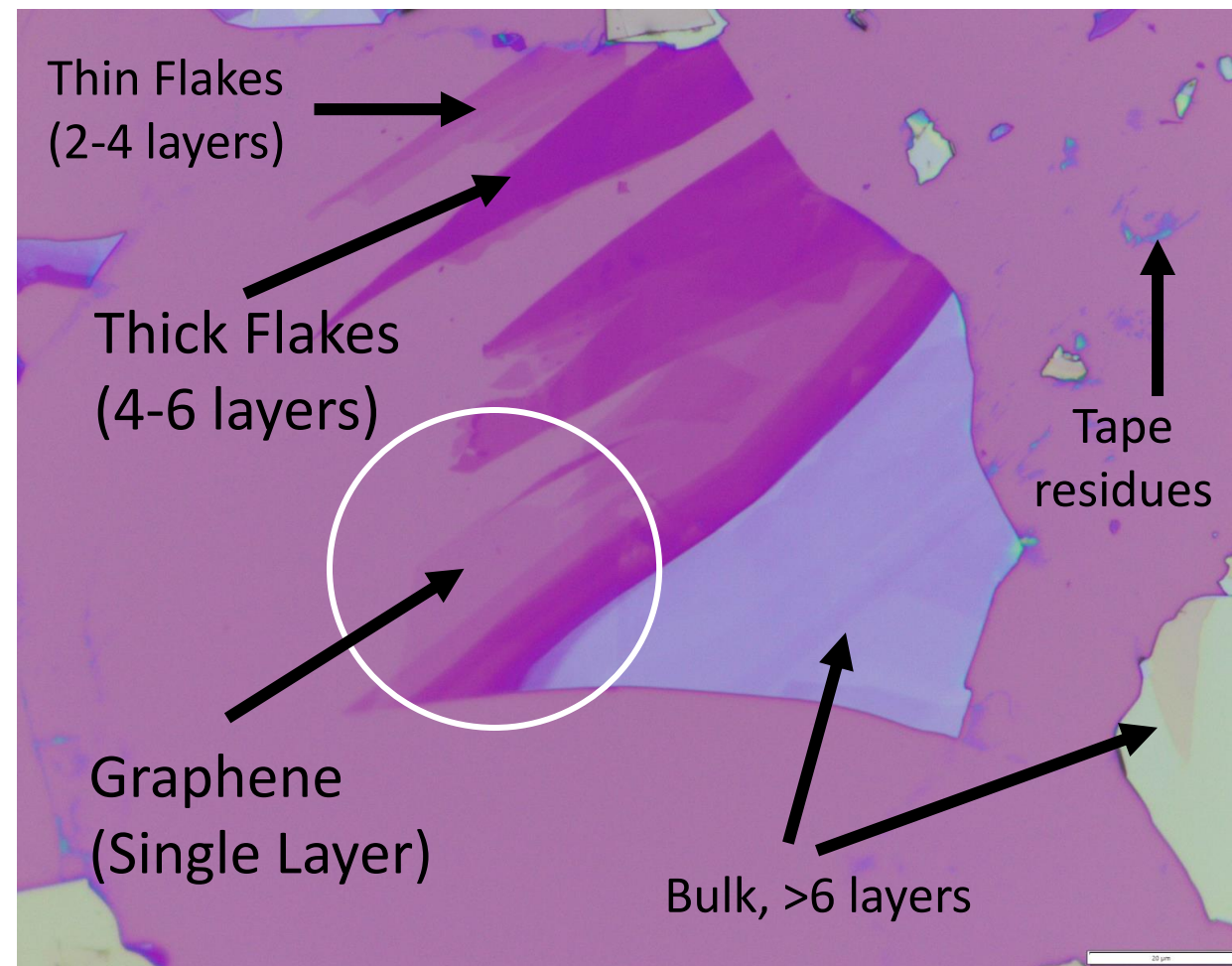
Micromechanical exfoliation of 2D crystals:

- (a) Stick tape to the bulk of material
- (b) Peel the tape
- (c) Stick tape to substrate
- (d) Peel the tape, leaving monolayer of material

Two-Dimensional Materials Exfoliation



Exfoliated Graphene on Silicon substrate, 10x magnification (approx. pic. size 1.2 x 1.2 mm) [4]



Exfoliated Graphene on Silicon substrate, 100x magnification (approx.. pic. Size 0.12 x 0.12 mm) [4]

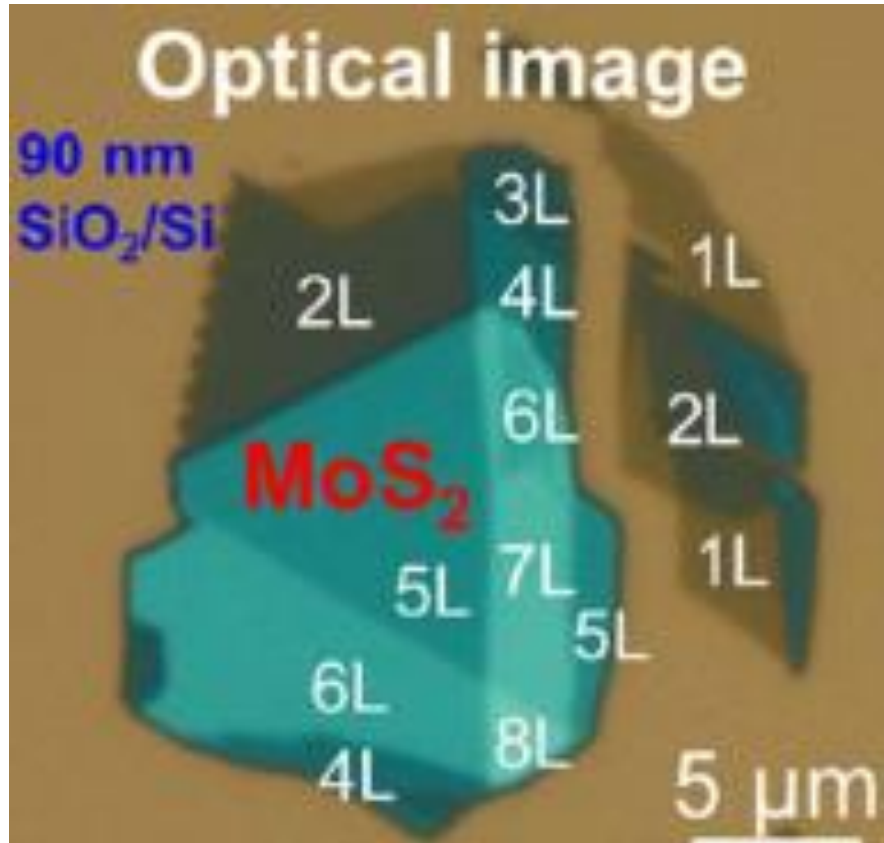
Current Solution: Using AI for characterization ⁴

- Requires lots of images to train on
- Training a model takes a long time
- Analysis process takes prolonged time



Alternative solution: Using non-AI generic algorithm

5



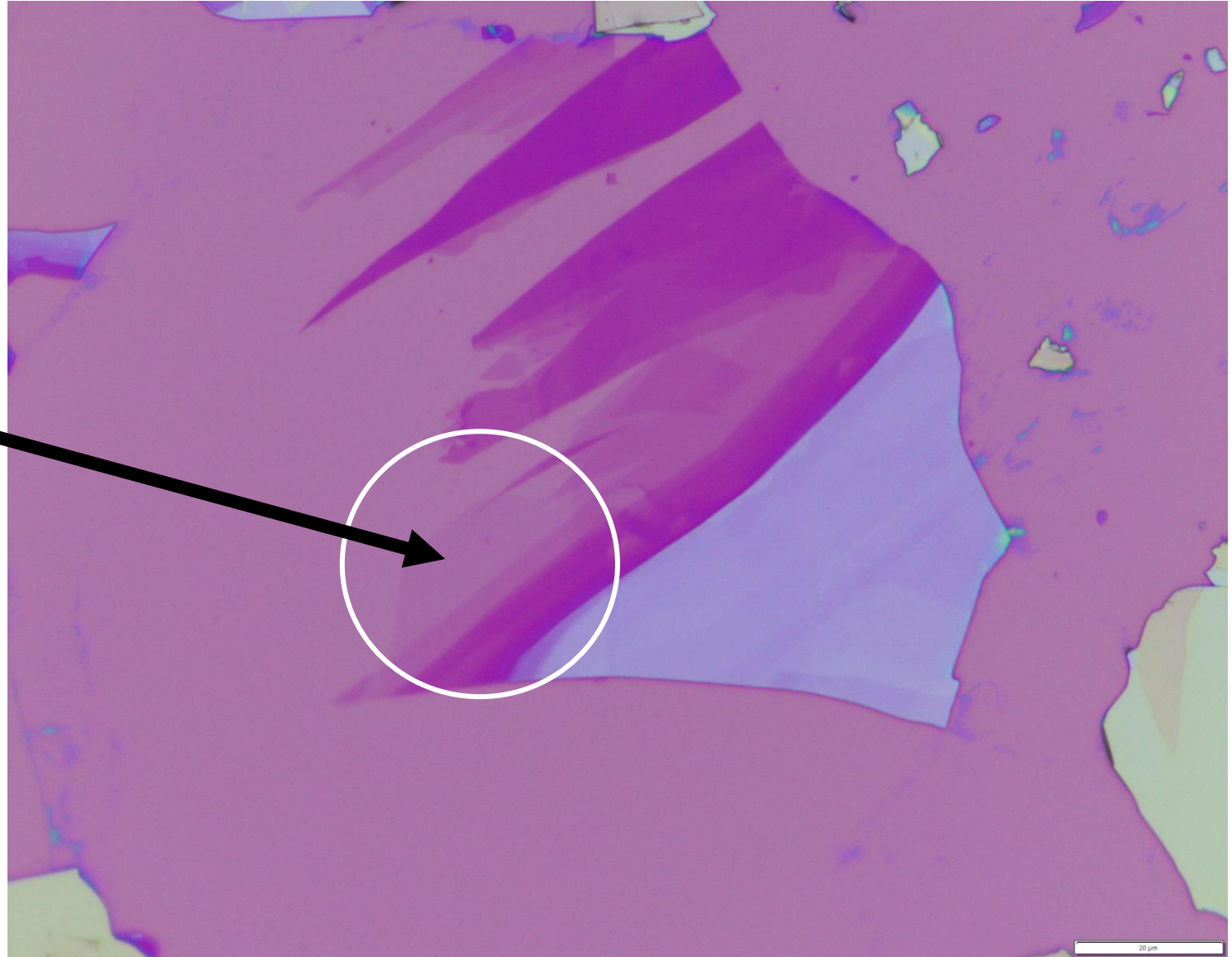
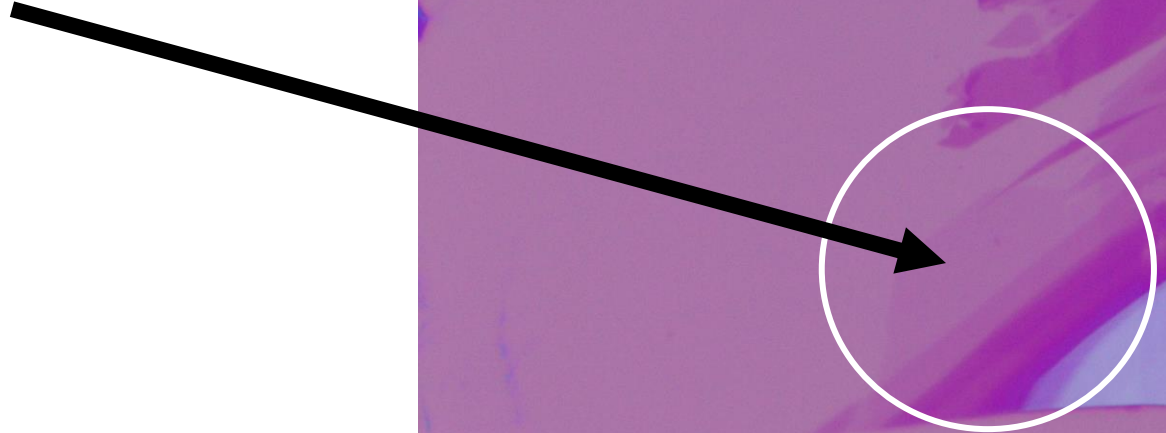
Difference between apparent color between areas of different thickness (number of layers) of Molybdenum Disulfide (MoS₂) [2].

Impact:

Algorithm aims to make characterization of Two-Dimensional materials more streamlined by using limited user input rather than fully trained AI model.

How Algorithm Works

The Goal is to detect this thin part of flake.



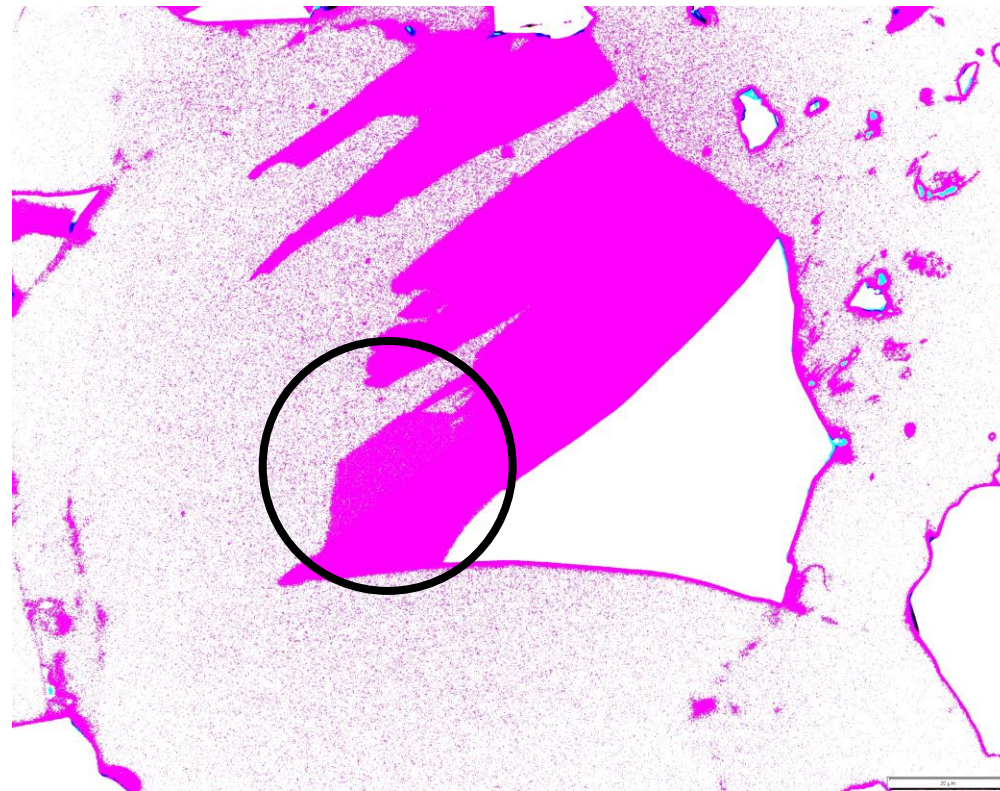
Original Image

How Algorithm Works: Continue

Two Binary Thresholds
Subtraction



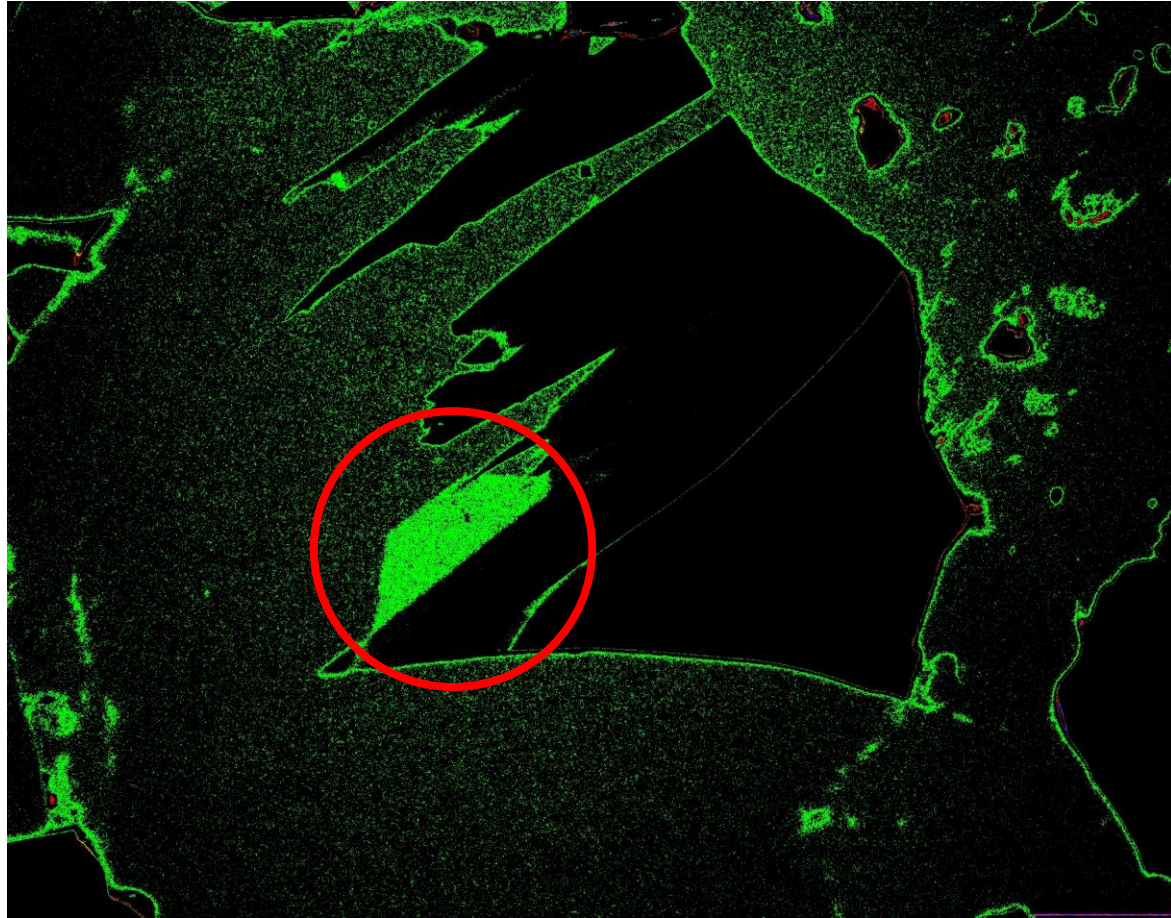
Lower Threshold



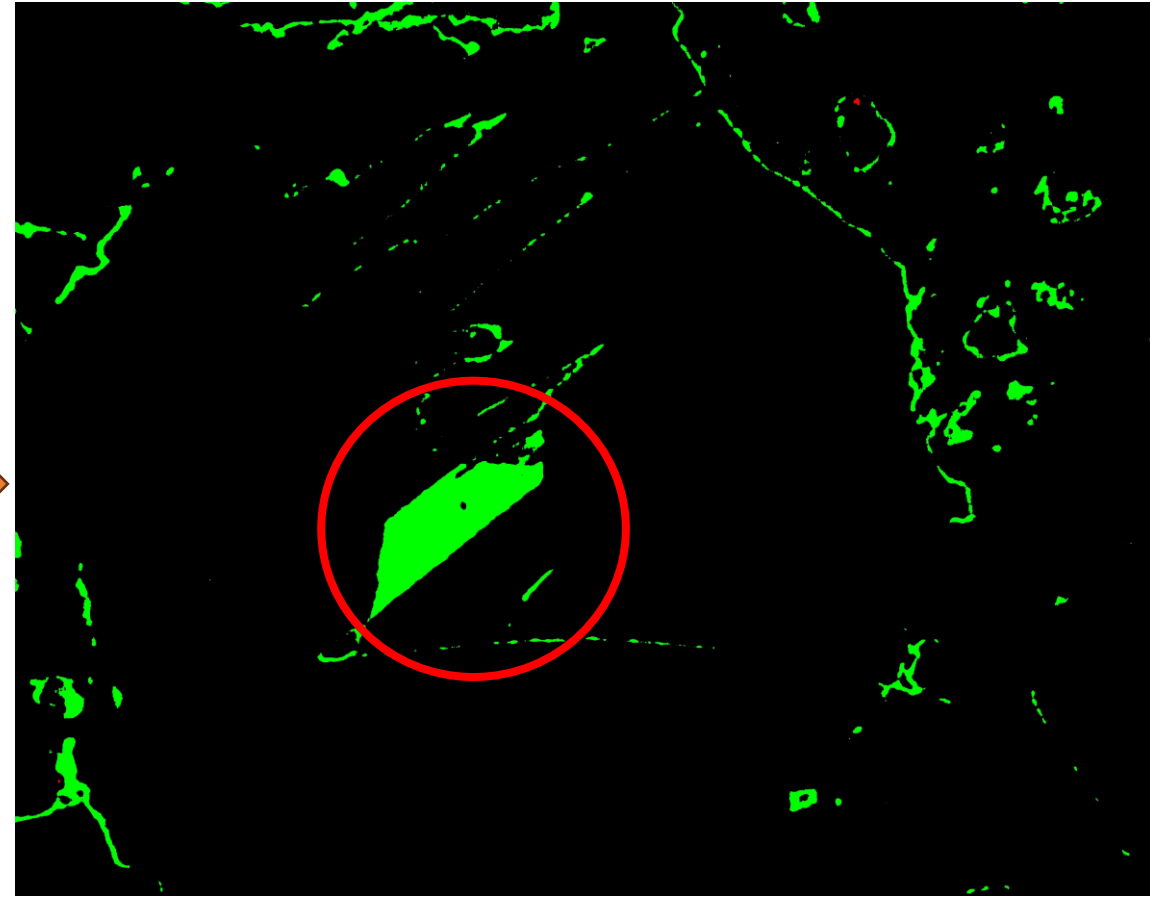
Higher Threshold



How Algorithm Works: Continue

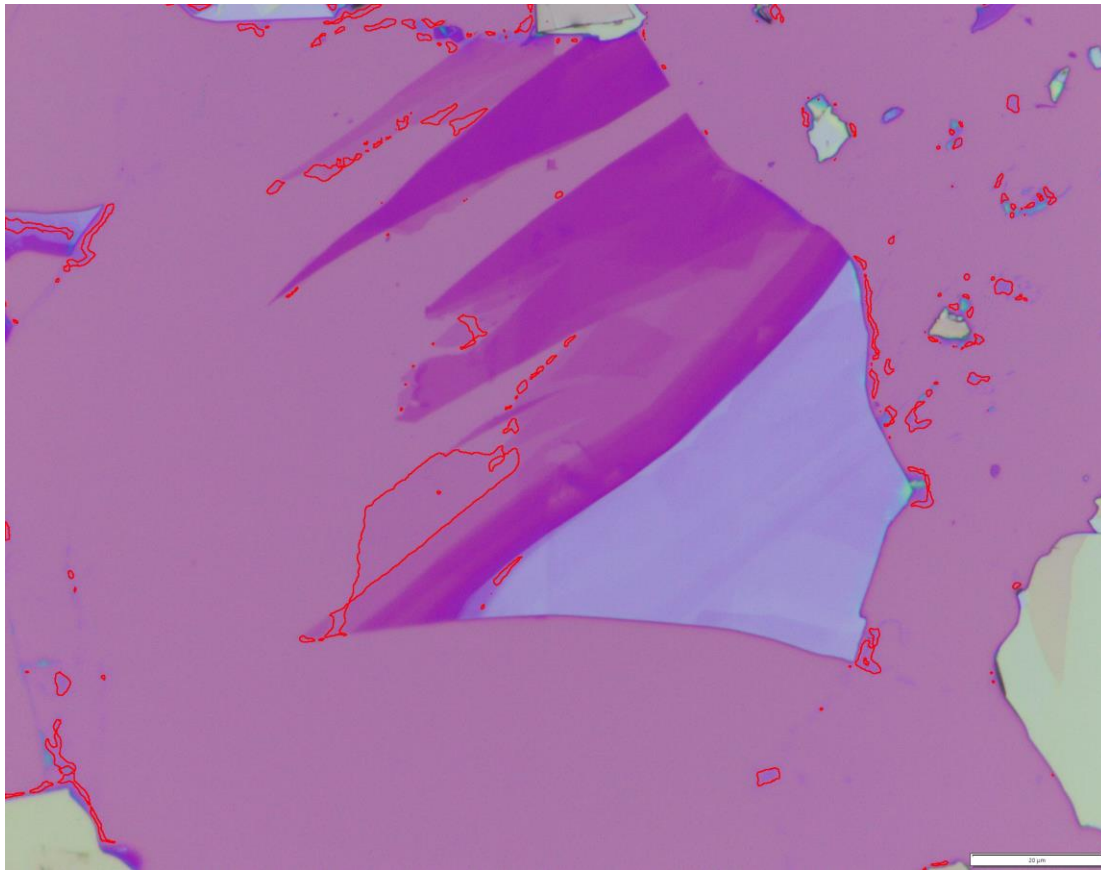


Threshold
Subtraction Result

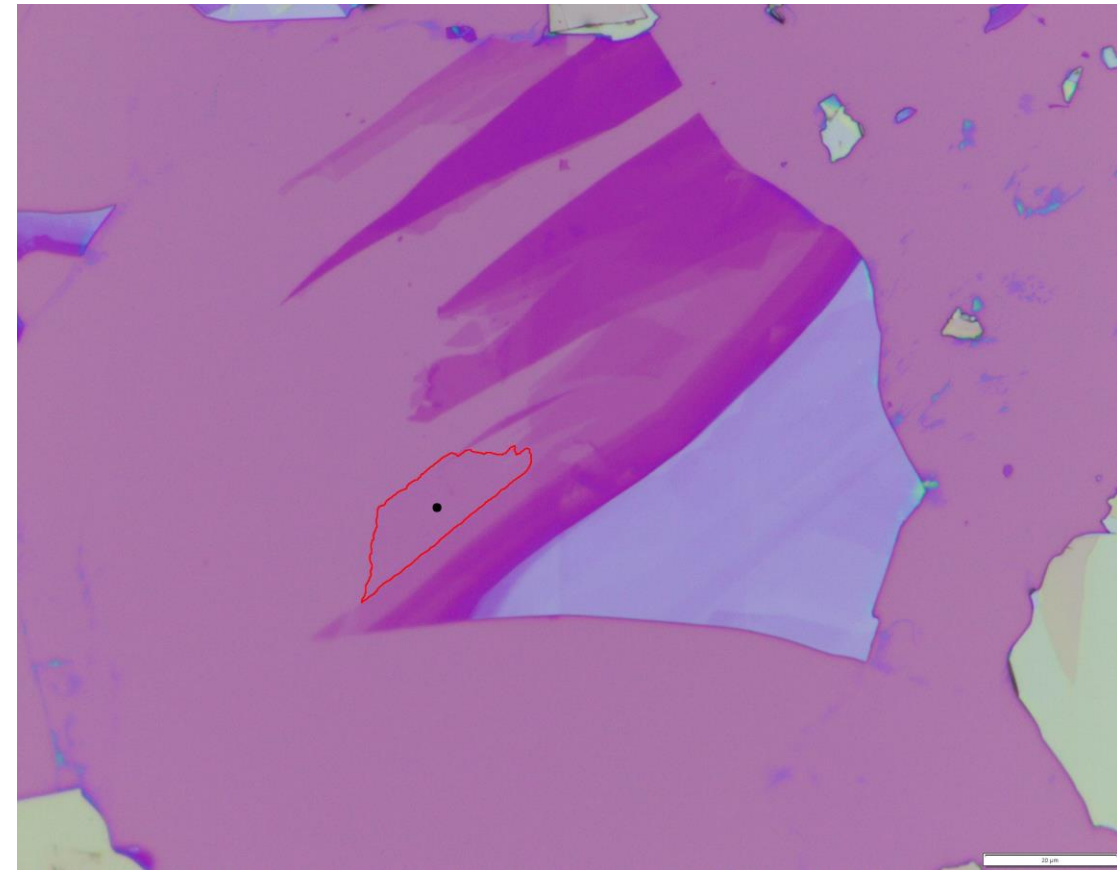


Median Blur
(Denoising)

How Algorithm Works: Results



Contour Detection, all contours



Sorting Contours and Finding Centers

Accomplishments/Future work

- Algorithm was successful in identifying flakes correctly with minimal user input
- To convert code into downloadable app and improving user interface
- To explore ways to automate image collection with generic microscope camera

References

- [1] K. S. Novoselov and A. H. Castro Neto, *Two-Dimensional Crystals-Based Heterostructures: Materials with Tailored Properties*, Phys. Scr. **T146**, 014006 (2012).

- [2] H. Li, J. Wu, X. Huang, G. Lu, J. Yang, X. Lu, Q. Xiong, and H. Zhang, *Rapid and Reliable Thickness Identification of Two-Dimensional Nanosheets Using Optical Microscopy*, ACS Nano **7**, 10344 (2013).

- [3] S. Lerner, *AI Failure Example: Widespread across the Enterprise*, <https://www.enterprisedigi.com/artificial-intelligence-machine-learning/articles/ai-failure-example>.

- [4] Son Le, 2020, Physical Measurement Laboratory, NIST

Binary Thresholding Explained

- Function accepts two values (threshold value, maximum value)
- Checks pixel color
- If color is less than threshold makes pixel color 0
- If color is greater than threshold makes pixel color = to maximum value

Threshold Value increasing
(maximum value =255)

