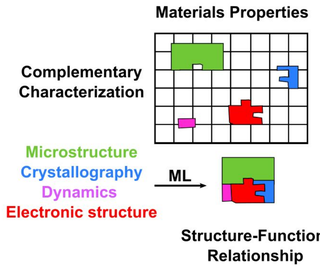
Few-Shot Electron Microscopy GUI

UW DIRECT Students: Shweta Bhushan, Wenya Chen, Wenqi Cui, Christina Doty, and Shaun Gallagher
PNNL Researchers: Sarah Akers, Marjolein T. Oostrom, and Steven R. Spurgeon

Harmony between Data Science and Electron Microscopy[1]

Modern Scanning Transmission Electron microscopy (STEM) provides near atomic resolution, enabling new insights about material structures, but analyzing features manually is time consuming and difficult.



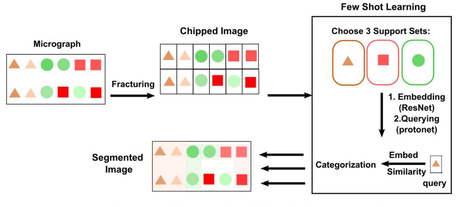
Want to use Machine Learning to assist in processing micrograph data, to benefit both experienced and non-expert users

Few Shot Approach → pyCHIP [2]

-In Electron Microscopy have very limited data, want a mode that is specialized for small data sets (i.e. Few Shot)

-Despite this few shot ML is relatively uncommon in electron microscopy

PNNL Approach: Semantic Segmentation

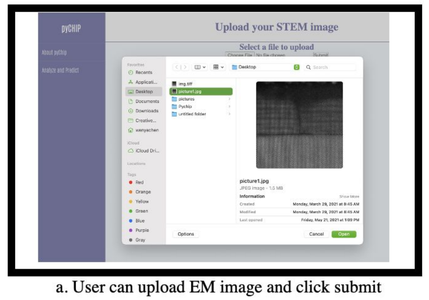


Our Goal: GUI Interface

Challenges

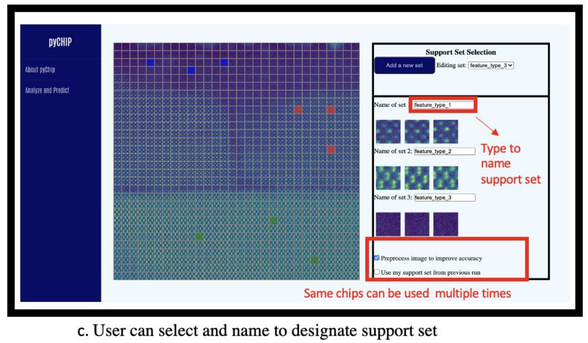
1. Making an accessible model that can be widely used requires a GUI-based approach
2. ML still requires some level of prior knowledge on the image segmentation side
3. Ensuring good communication between pages of the UI as well as between the different tools incorporated in this web app (Python flask, Html, D3, Vega-Lite, and JavaScript) proved challenging.

Web Application pyCHIP

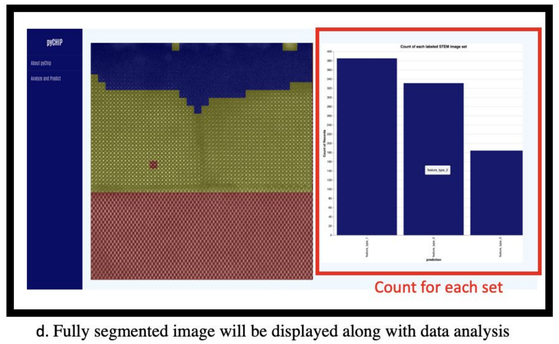


a. User can upload EM image and click submit

b. The chip size can be easily adjusted by using slider



c. User can select and name to designate support set



d. Fully segmented image will be displayed along with data analysis

GUI features and advantages

- The user can upload their own images to analyze.
- The chip size is easy to modify with a slider function
- The user can create multiple support sets and observe the chips that they have selected under the name of each set.
- The support set is saved in a folder that the ML model can access to use as a training set.
- The user can see the breakdown of features highlighted on the original image, shortly after saving their support sets.
- The bar chart of features is available for the user to make a quantitative estimate of the microstructural properties.

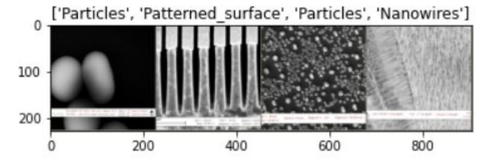
Technology Options

- **Python Flask**: easily customizable for adding data analysis and visualization in a web app
- **D3**: helpful design for the gridding function, chip sizing, and chip selection
- **VegaLite:** tool for building the bar chart depicting features
- **HTML/JavaScript:** languages used in building the app layout and assigning selected chips to their respective support sets
- **Plotly Dash**: an alternative tool for building interactive plots and charts in a flask or dash app

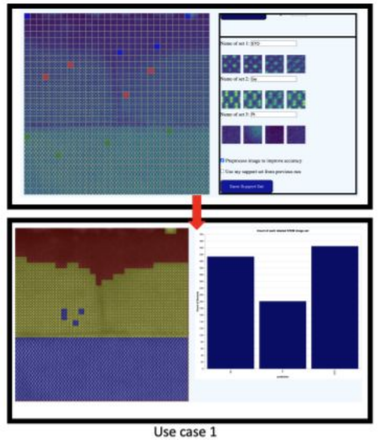
Few-shot ML Model

Few Shot learning is a desirable approach for microscopy applications via Transfer Learning

- The premise of this few-shot learning model is to use very few labeled examples (< 10) per class for classification.
- To avoid over-fitting on few samples, formulate prototype to be a set of inductive bias
- Prototypes are obtained from the support set with labels
- Few-shot learning is implemented by calculating the Euclidean distance from the prototypes
- We train a resnet for extracting features from images. Open-source SEM Dataset is employed for training



Example: Oxide Heterostructures



Use case 1

References

(1) **Spurgeon, S. R.**; Ophus, C.; Jones, L.; Petford-Long, A.; Kalinin, S. V.; Olszta, M. J.; Dunin-Borkowski, R. E.; Salmon, N.; Hattar, K.; Yang, W. C. D.; et al. Towards Data-Driven next-Generation Transmission Electron Microscopy. *Nat. Mater.* **2021**, *20* (3), 274–279. https://doi.org/10.1038/s41563-020-00833-z.

(2) **Akers, S.**; Kautz, E.; Trevino-gavito, A.; Olszta, M.; Wang, L.; Du, Y.; **Spurgeon, S. R**. Rapid and Flexible Semantic Segmentation of Electron Microscopy Data Using Few-Shot Machine Learning. **2021**, 0.21203/rs.3.rs-346102/v1