Machine Learning for Nuclear Forensics

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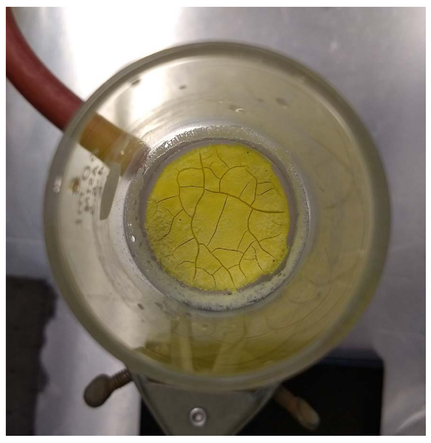
What is Nuclear Forensics?

- Goal is to prevent nuclear material trafficking
- Nuclear materials are made many different ways
- Production changes **material structure**
- Use structure to identify **where and how** material was made
- Scanning Electron Microscopy (SEM) images used for analysis

How is Machine Learning and Image Processing used?

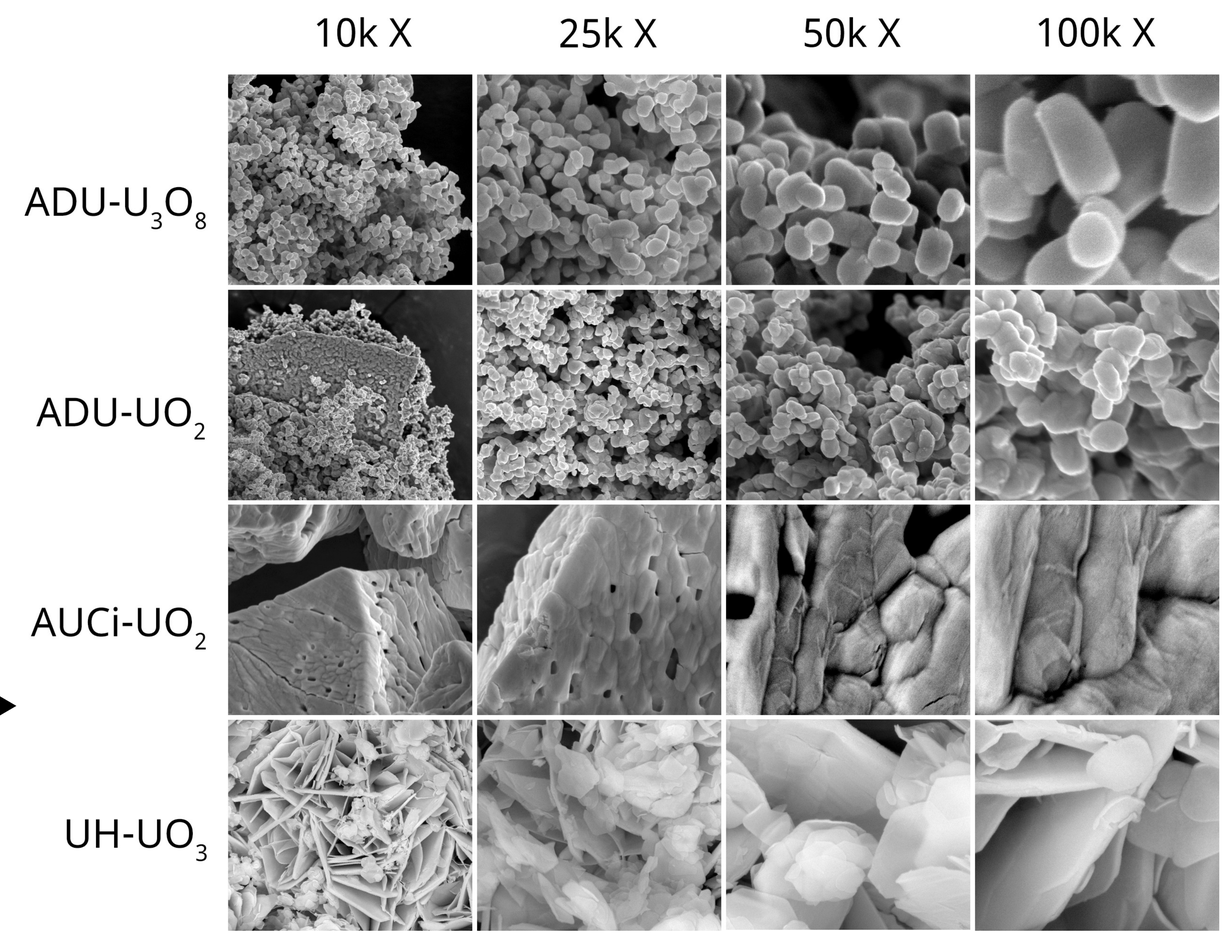
- **Segmentation** to detect particles
- **Classification** of material processing route
- **Uncertainty Quantification** needed for legal standing
- **Contrastive**, **Semi**, and **Self Supervised Learning** help with small dataset size

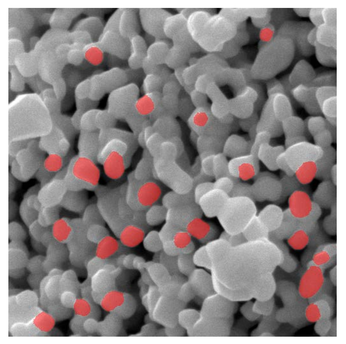


↑ Macro scale Uranium Oxide, or "Yellowcake"

Examples of variance in **processing route**, at different **magnifications** →

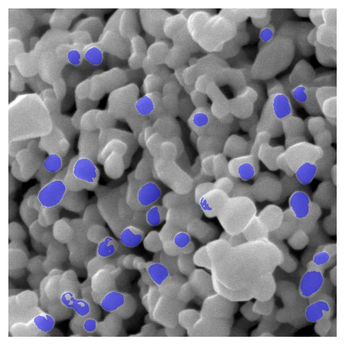
↓ **Contrastive Learning** model, Used for route classification

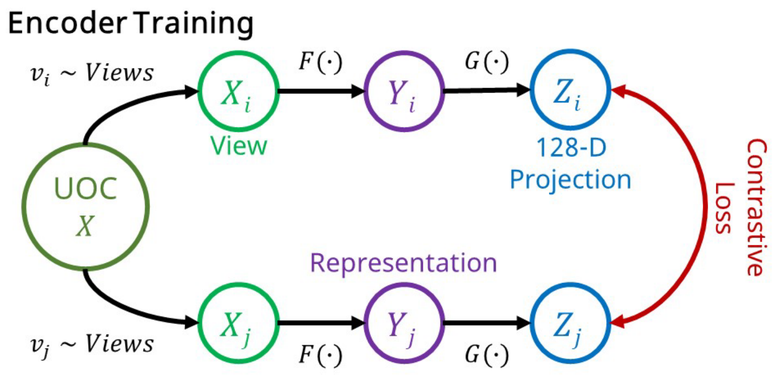




Ground Truth Particle Segmentation

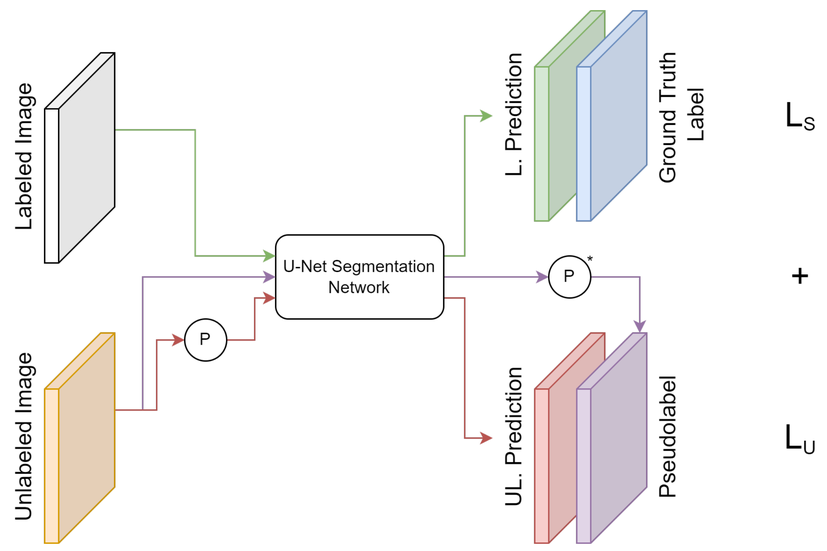
Predicted Particle Segmentation



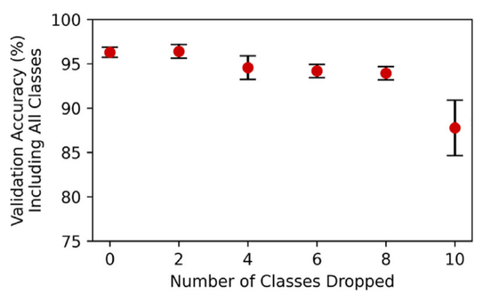


Making both **accurate** and **trustworthy** predictions is important

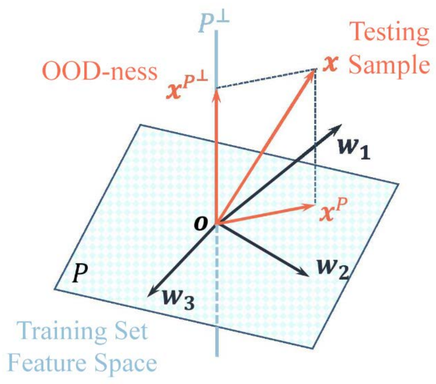
Semi-supervised Segmentation model uses **perturbations** (P) to image to allow learning from **unlabeled data**

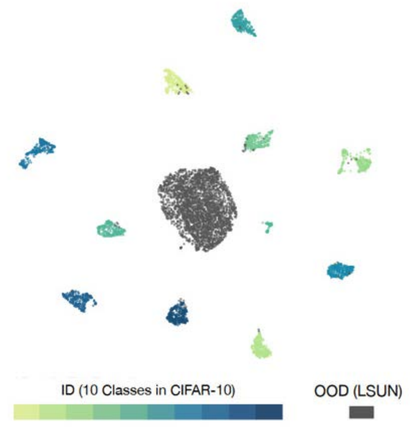


Method	Mean accuracy
Supervised ResNet50	95.6%
Supervised MISO [6]	96.4%
Unsupervised VQ-VAE [7]	81.8%
Ours	90.2%
Ours, with multi-image voting	96.2%



Accuracy (top) and Generalization (bottom) results for Contrastive Learning model.





Examples of top-performing Out-Of-Distribution detection methods. **ViM** (left) and **KNN** (right)

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