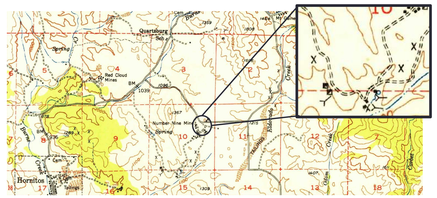
Unearthing Hidden Treasures:
Detecting Critical Minerals from Historical Maps

Zekun Li [1], **Weiwei Duan** [2], **Yijun Lin** [1], **Fandel Lin** [2], **Yao-Yi Chiang** [1] and **Craig Knoblock** [2]
[1] University of Minnesota, [2] University of Southern California

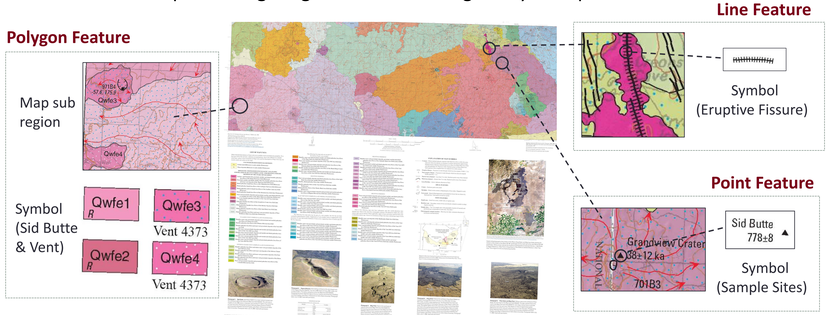
CRITICAL MINERAL DETECTION TASK

- The United States Geological Survey (USGS) collects large volumes of historical maps to **assess the availability of critical minerals**
  - Detect the mineral deposit on the maps (Figure 1)
  - However, manually reviewing these maps is time-consuming



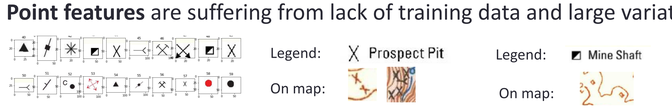
The locations of mineral deposit on a map

- **Task: Given a target symbol, automatically and accurately identify its appearances on the historical maps**
  - Three types of features: lines, polygons, and points
  - The output is image segmention indicating the symbol positions



CHALLENGES IN FEATURE DETECTION

- **Computational** challenge: Need to build individual models for every symbol from the provided map scans
- Some **line features** are similar, easily causing false detection. Also, the detected lines need to be continuous in the segmentation results
- **Polygon features** have various colors, texts, and textures. Simple color-based methods do not handle the symbols within the polygons. Some target symbols are hard to distinguish
- **Point features** are suffering from lack of training data and large variations



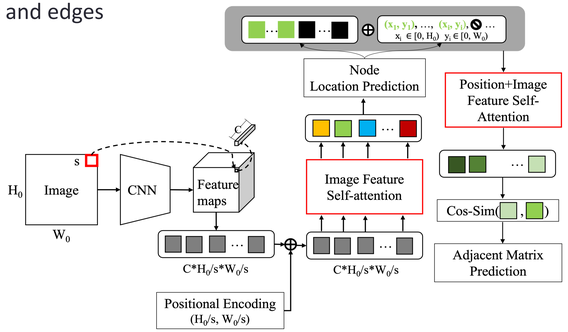
Samples of point feature symbols

Color mismatch

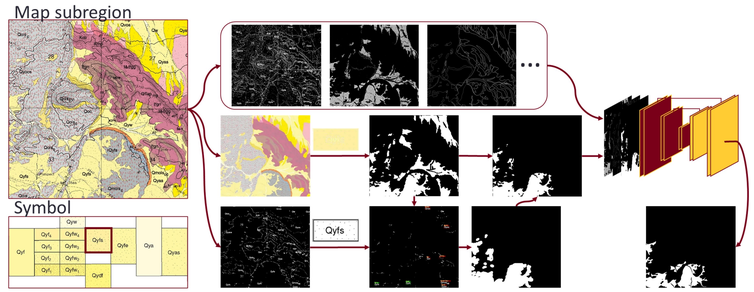
Extreme Size Variation

SYMBOL DETECTION

- The **line feature detection** model takes a map image as an input, and leverages attention mechanism to predict the line vectors, consisting of nodes and edges



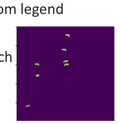
- The **polygon feature detection** model synergizes the color, pattern of text, and map texture for extracting polygons



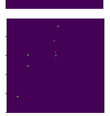
- The **point feature detection** module involves three models to handle large variations of symbols: a color-based model, a deep neural network (DNN) model, and a shape-based template matching model.

1) Find **mode color** from legend

2) Get **segmentation mask** with color search



3) Compute **mass center** of the contour



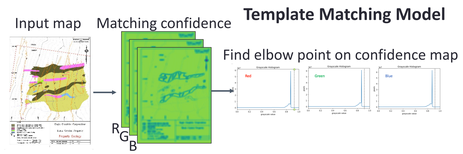
Color-based Model

Binary-classification DNN

- Train a NN classifier for **each** symbol
- **Positive**: Crop around the ground-truth (GT) location
- **Negative**:
  - **Hard negative: (p=0.25)** other symbols in the same map
  - **Random negative: (p=0.75)** randomly crop from foreground region which does not overlap with positive samples

Loss function: $L_{CE} = -\sum_{i=1}^{n} t_i \log(p_i)$ t_i: Ground-truth {0,1} for sample i; p_i: Predicted probability for sample i

Template Matching Model



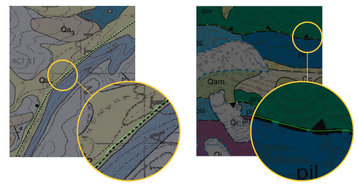
MSI HPC RESOURCES FOR TASKS

- We store the provided large-scale scanned maps (283 in total with a size of ~100G) and large volumes of intermediate results on the **MSI High Performance Storage**.
- We leverage the **MSI high-performance machines** to preprocess these maps in parallel, e.g., image cropping and generating training samples
- We take advantage of the **GPU resources** (a100 machines) on MSI for training various deep neural networks.
- We **train models** for more than 30 types of line features and 15 types of point features, respectively.

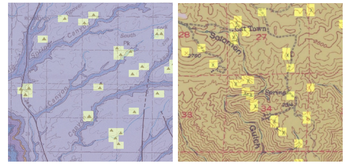
EVAL METRICS & RESULTS

Polygon Detection	Median Precision	Median Recall	Median Macro F-1
Color	0.680	**0.971**	0.737
Color + Text	0.747	0.967	0.780
Color + Text + Texture	**0.866**	0.937	**0.823**

Line Detection Visualization (green lines)



Point Detection Visualization



CONCLUSION & ACKNOWLEDGEMENT

- **Our team (ISI-UMN) won the First Place in DARPA Map Feature Extraction Challenge** (https://criticalminerals.darpa.mil/)
- The proposed system automatically detects line, polygon, point features on the historical map scans, which helps critical mineral assessments
- We thank USGS and DAPAR for providing the high-resolution historical maps and organizing the competition
- We acknowledge MSI and Research Computing for providing powerful computational resources that significantly benefit the research

DARPA
USGS science for a changing world
KNOWLEDGE COMPUTING LAB
UNIVERSITY OF MINNESOTA
MINNESOTA SUPERCOMPUTING INSTITUTE
UNIVERSITY OF MINNESOTA
Driven to Discover℠
RESEARCH COMPUTING
UNIVERSITY OF MINNESOTA
Driven to Discover℠