# GEOSPATIAL DATA UNDERSTANDING:

## *A Peek into Historical Maps and Contemporary Geospatial Databases*

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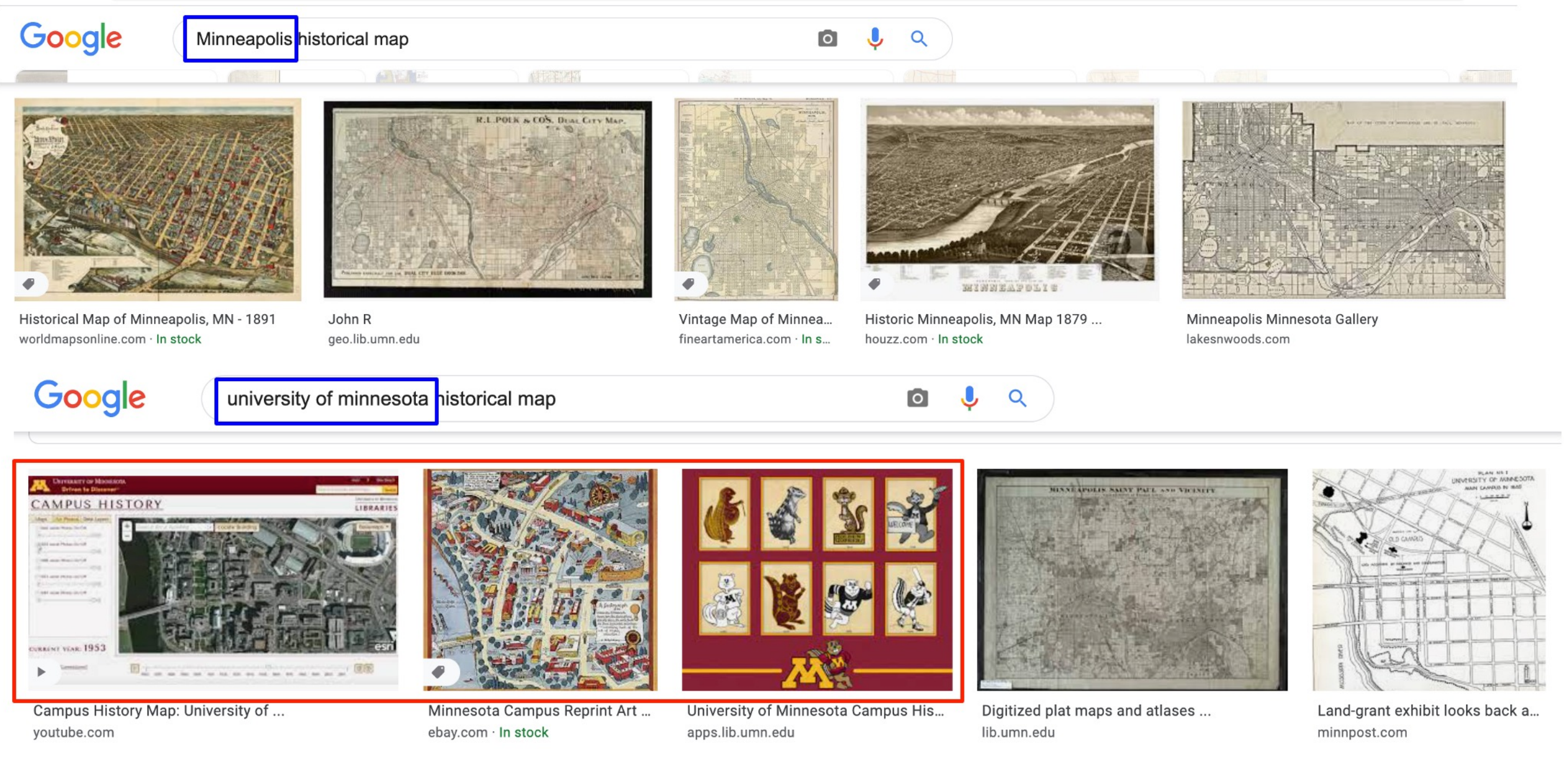
**Driven to Discover®**

## Introduction

- Historical maps offer a wealth of valuable information of our past, **millions** of scanned maps are made widely **available** nowadays.
- But most of the maps remain **unanalyzed**
- **Reason:** map processing is **time-consuming** and **costly**


Google
Minneapolis historical map
Historical Map of Minneapolis, MN - 1891
worldmapsonline.com · In stock
John R
geo.lib.umn.edu
Vintage Map of Minnea...
fineartamerica.com · In s...
Historic Minneapolis, MN Map 1879 ...
houzz.com · In stock
Minneapolis Minnesota Gallery
lakesnwoods.com
Google
university of minnesota historical map
Campus History Map: University of ...
youtube.com
Minnesota Campus Reprint Art ...
ebay.com · In stock
University of Minnesota Campus His...
apps.lib.umn.edu
Digitized plat maps and atlases ...
lib.umn.edu
Land-grant exhibit looks back a...
minnpost.com

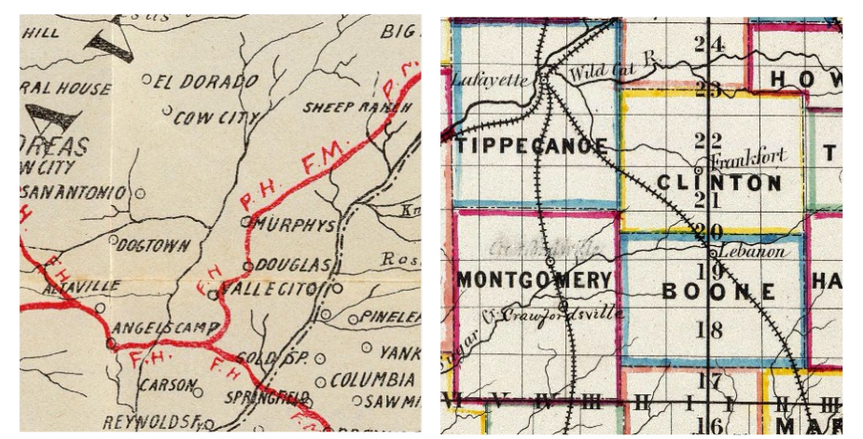
Search result of "Minneapolis historical map" is reasonable, but result for "**University of Minnesota**" is **erroneous**

We want to develop a machine-learning method to **read the historical map** and **establish connections to** contemporary geospatial databases!

## Challenges

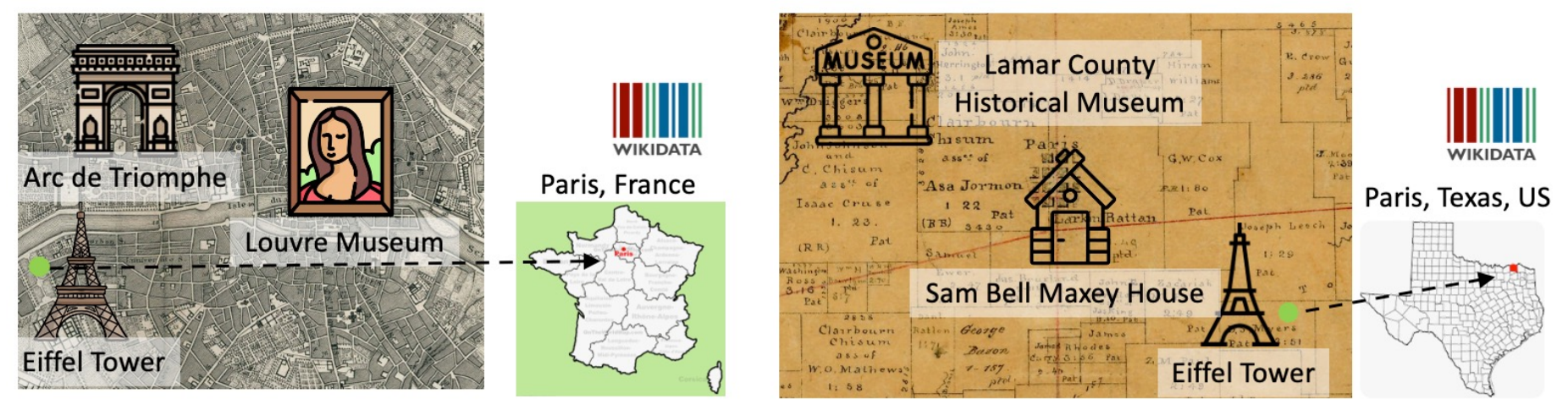
- Historical maps looks quite **different from natural scene images**, spotting models trained on general domain data does not perform well on maps

Sample images from ICDAR 15 dataset



Sample image patches from David Rumsey historical map collection

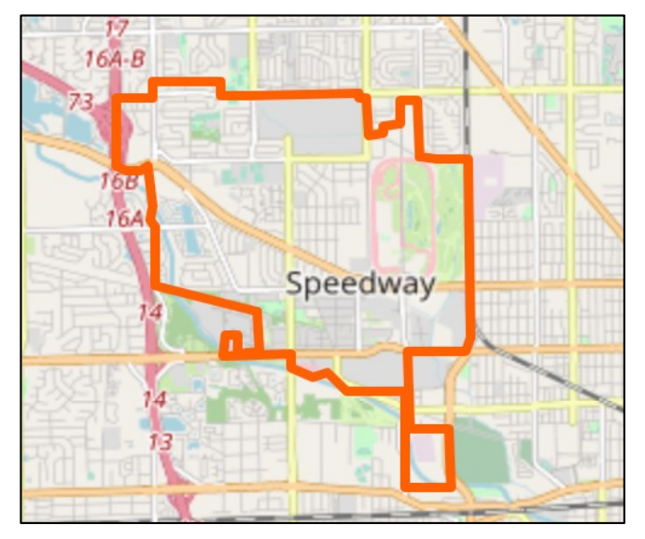
- Linking to contemporary geospatial database can be challenging due to the usage of **same places names** in different locations



## SpaBERT: Geo-entity Feature Representation

- Most geo-entities exist as **point** data (e.g. GeoNames).
- Geo-entity names can be **ambiguous** without knowing the geometry

SpaBERT Repo



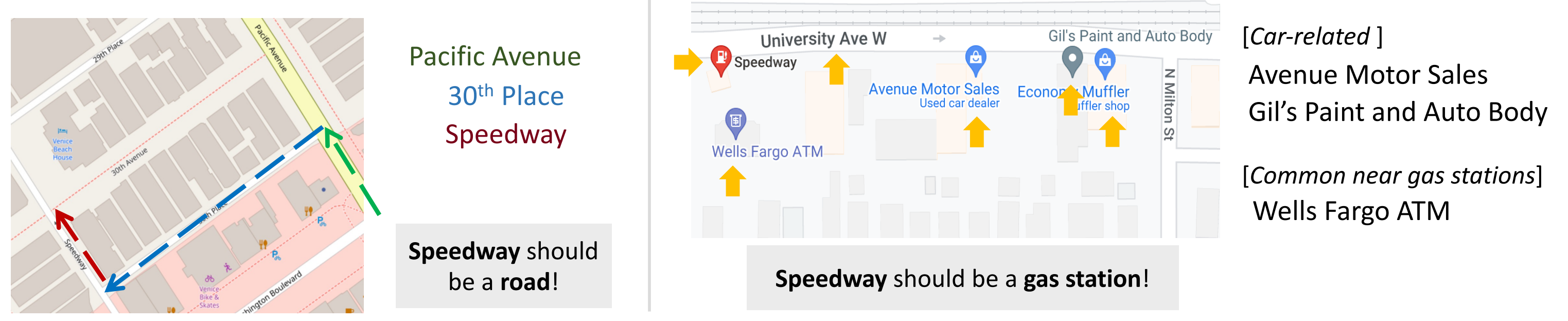
A **town** in Marion County, Indiana

A **road** in Los Angeles, California

A **gas station** in Minneapolis, Minnesota

Q: What is **Speedway?**

We shall know the **characteristics** of a geo-entity by its **surrounding entities**, similar to knowing word meanings by their linguistic context.



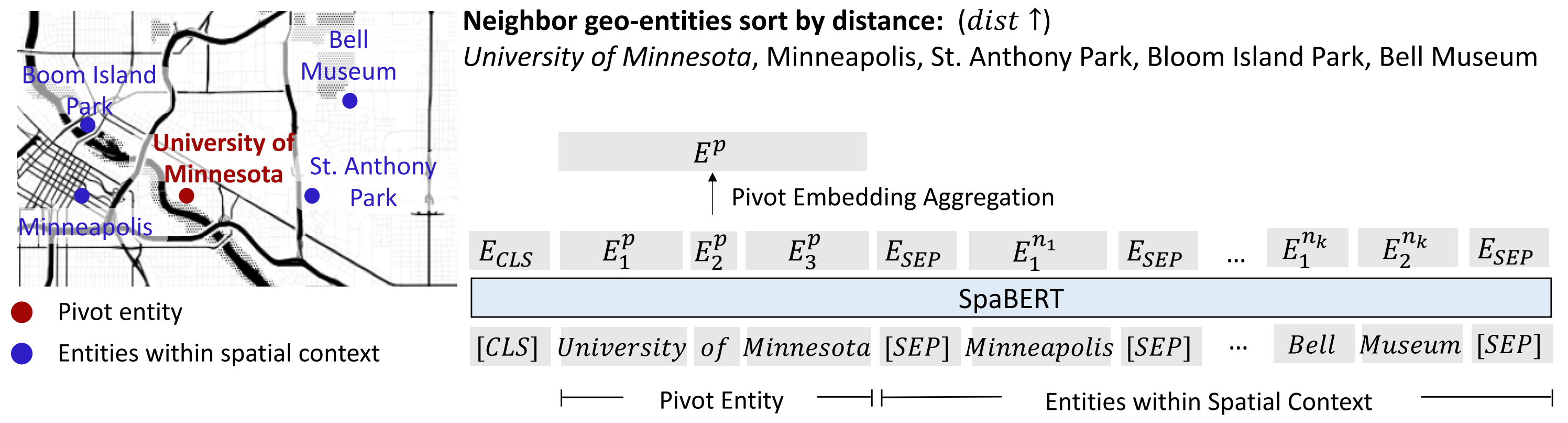
**Speedway** should be a **road**!

**Speedway** should be a **gas station**!

*[Car-related ]*
Avenue Motor Sales
Gil's Paint and Auto Body

*[Common near gas stations]*
Wells Fargo ATM

- Problem Setting & Approach
  - Input: Geo-entity **name** and **point location** (image coord. or geo-coord.)
  - Goal: Produce **general-purpose** geo-entity feature representation



**Neighbor geo-entities sort by distance:** ($dist \uparrow$)
*University of Minnesota*, Minneapolis, St. Anthony Park, Bloom Island Park, Bell Museum

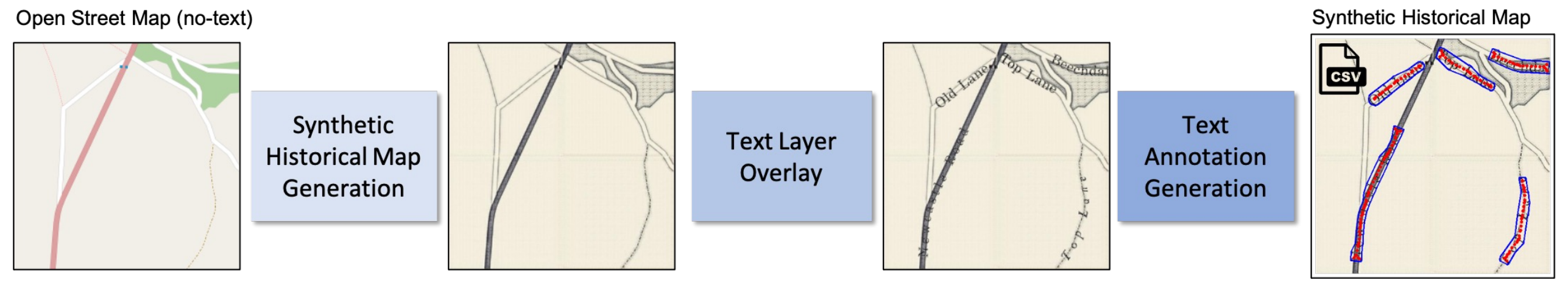
- Downstream task: **Geo-entity Linking**
  - **Task**: Link geo-entities in scanned historical maps (USGS) to Wikidata
  - ***Setting***: USGS map entities are associated with **pixel** coordinates; Wikidata entities are associated with **geo-coordinates**

| Model | MRR | R@1 | R@5 | R@10 |
|---|---|---|---|---|
| BERT$_{Base}$ | .400 | .289 | <u>.559</u> | <u>.635</u> |
| RoBERTa$_{Base}$ | .326 | .232 | .446 | .540 |
| SpanBERT$_{Base}$ | .164 | .138 | .201 | .213 |
| LUKE$_{Base}$ | .306 | .188 | .440 | .547 |
| SimCSE$_{BERT\text{-}Base}$ | <u>.453</u> | <u>**.371**</u> | .547 | .628 |
| SimCSE$_{RoBERTa\text{-}Base}$ | .227 | .188 | .264 | .301 |
| SpaBERT$_{Base}$ | **.515** | .338 | **.744** | **.850** |

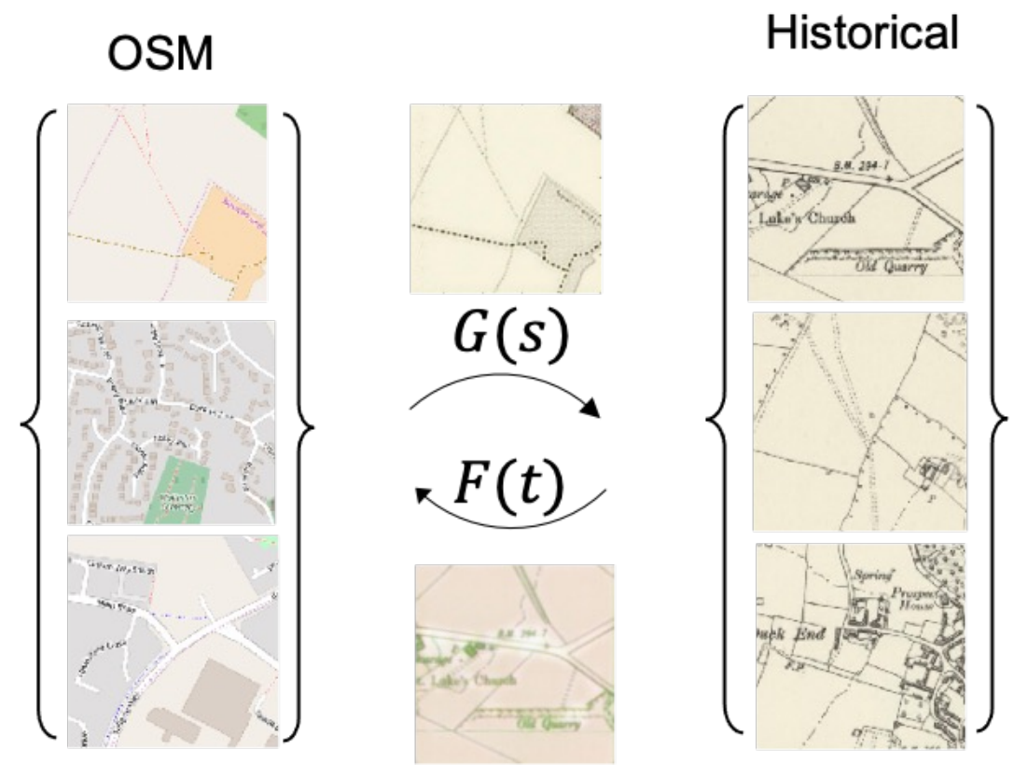
## Synthmap: Generate Synthetic Historical Maps

- Gathering **training data** for historical maps is important, while manual annotation takes a lot of time and effort
- We propose to generate **synthetic historical maps** to aid the training of text detection models
- **General Idea:**
  - Create synthetic map **background without** any **text labels**
  - Automatically **place text labels** and compute ground-truth annotation (of text bounding polygon)

SynthMap Demo


Open Street Map (no-text)
Synthetic Historical Map Generation
Text Layer Overlay
Text Annotation Generation
Synthetic Historical Map
CSV

- **Source** map: Clean (no text) OpenStreetMap tiles to provide background
- **Target** map style: **Ordnance Survey** 6-inch map during year 1888-1913
- **Model**: CycleGAN to efficiently perform **style transfer**



**Adversarial Loss:**

$$\mathcal{L}_{\text{GAN}}(G, D_Y, X, Y) = \mathbb{E}_{y\sim p_{\text{data}}(y)}[\log D_Y(y)] + \mathbb{E}_{x\sim p_{\text{data}}(x)}[\log(1 - D_Y(G(x)))]$$

**Cycle Consistency Loss:**

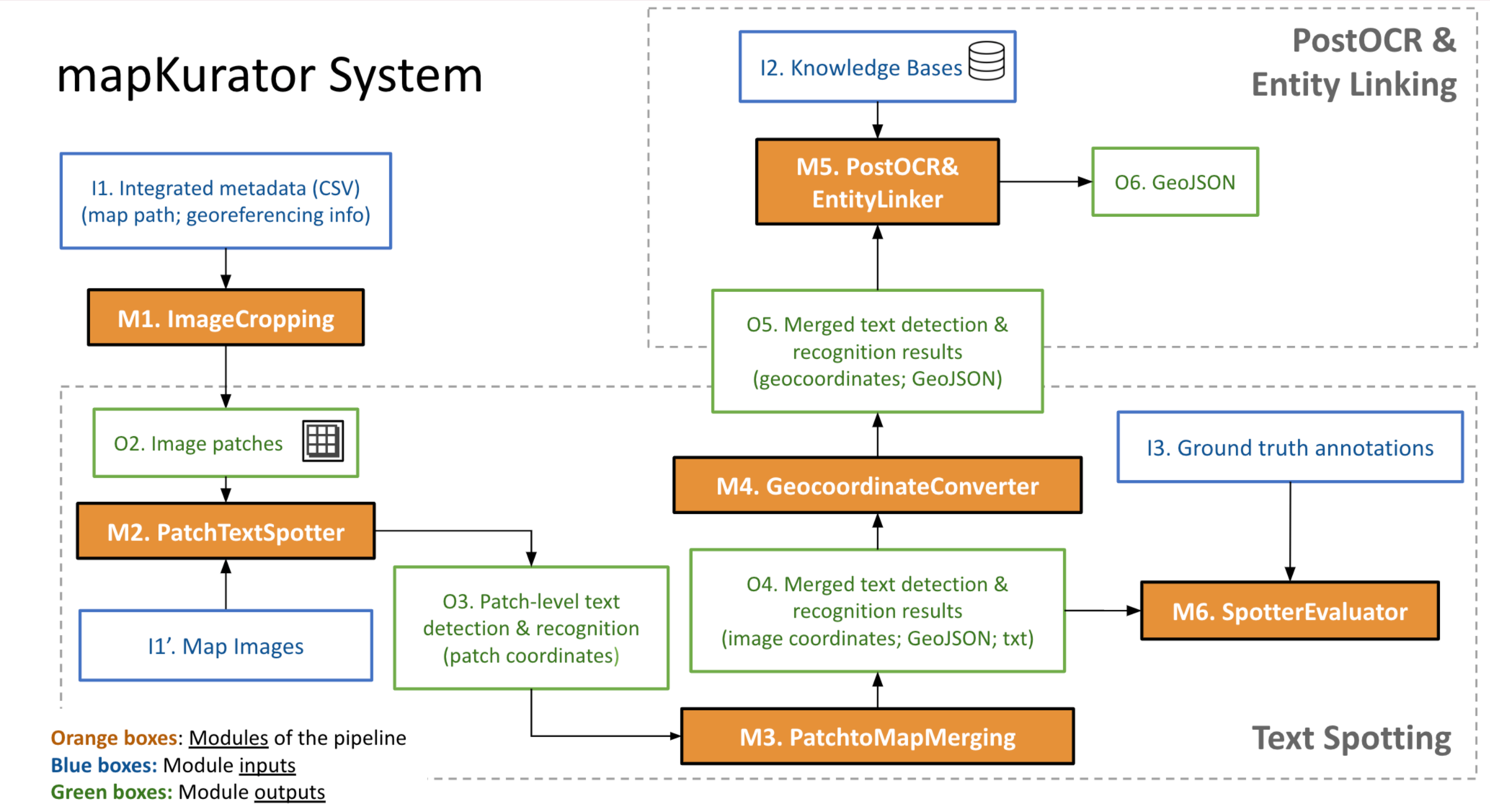
$$\mathcal{L}_{\text{cyc}}(G, F) = \mathbb{E}_{x\sim p_{\text{data}}(x)}[\|F(G(x)) - x\|_1] + \mathbb{E}_{y\sim p_{\text{data}}(y)}[\|G(F(y)) - y\|_1].$$

Input OSM map tiles
Output synthetic historical map tiles

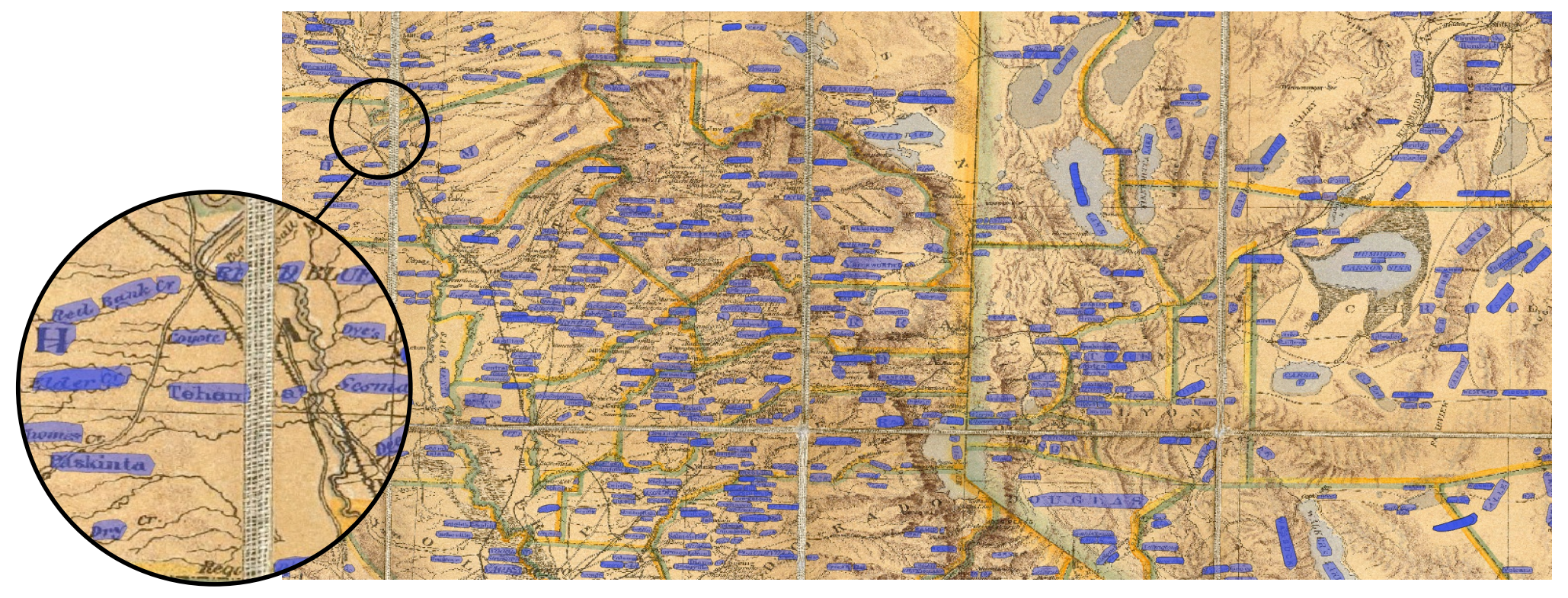
Complete map after overlaying text

*Details for automatically computing the annotation info can be found in the paper

## mapKurator: Historical Map Understanding

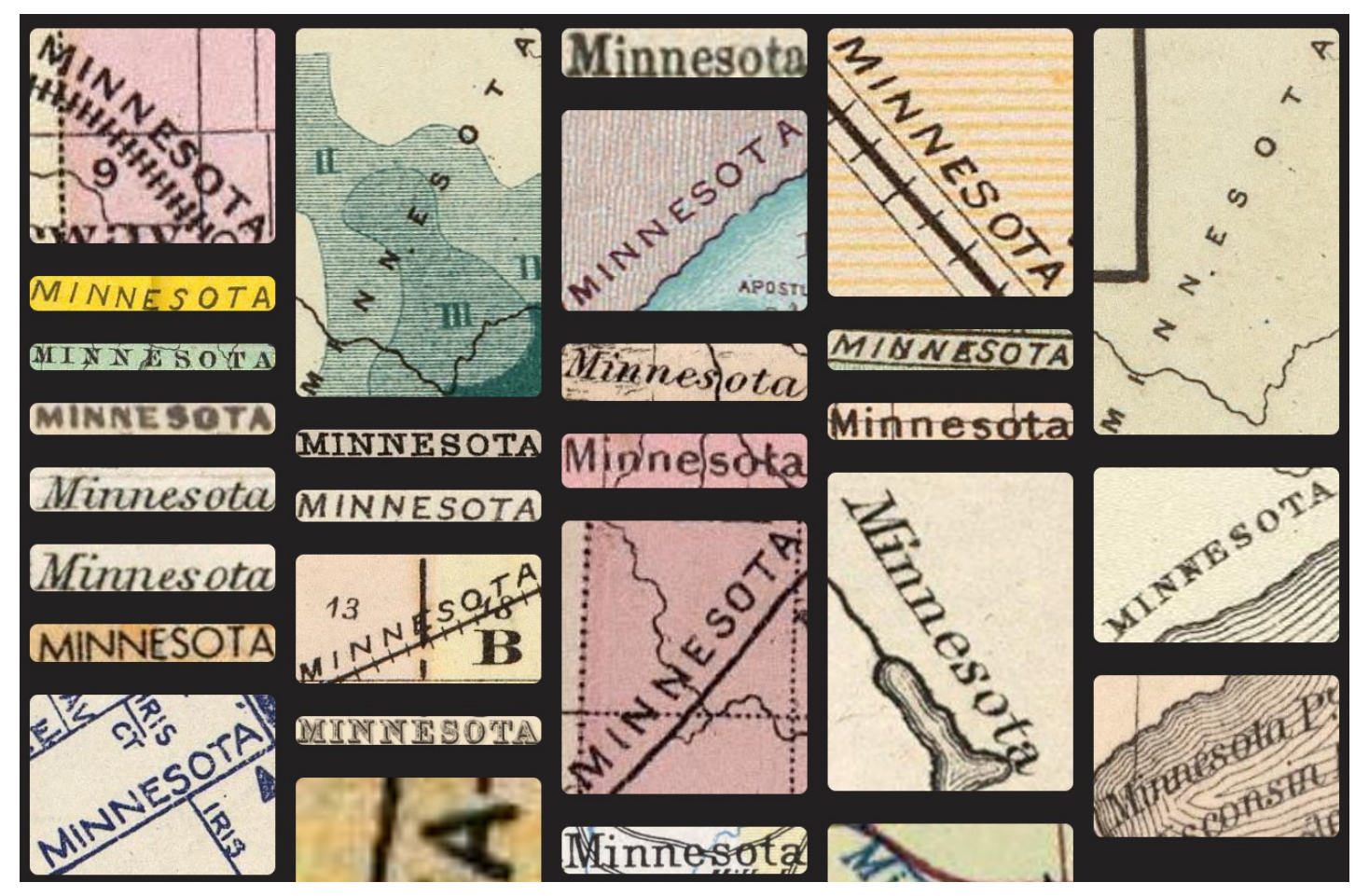

mapKurator System
PostOCR & Entity Linking
I2. Knowledge Bases
M5. PostOCR& EntityLinker
O6. GeoJSON
I1. Integrated metadata (CSV) (map path; georeferencing info)
M1. ImageCropping
O5. Merged text detection & recognition results (geocoordinates; GeoJSON)
O2. Image patches
M4. GeocoordinateConverter
I3. Ground truth annotations
M2. PatchTextSpotter
O3. Patch-level text detection & recognition (patch coordinates)
O4. Merged text detection & recognition results (image coordinates; GeoJSON; txt)
M6. SpotterEvaluator
I1'. Map Images
M3. PatchtoMapMerging
Text Spotting
Orange boxes: Modules of the pipeline
Blue boxes: Module inputs
Green boxes: Module outputs

- **Inputs:** Historical map images (.png/.geotiff) **or** metadata providing map path
- **Outputs:** Recognized text labels **&** label bounding polygons **&** Identifier to OSM

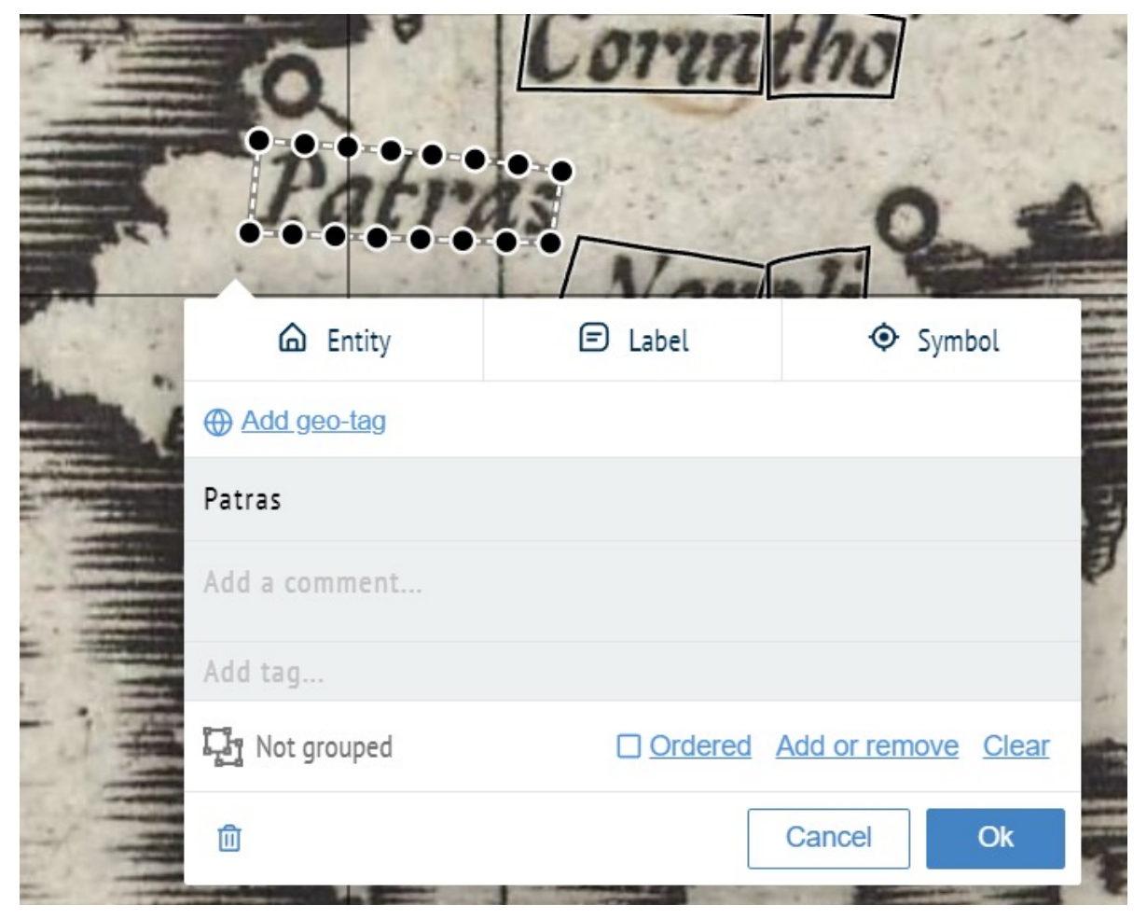


mapKurator Website

Recognized text labels from "*Map Of California And Nevada*" by *Geological Survey of California*



Search result of "Minnesota" from 57K maps in Rumsey Map Collection



Patras

Display mapKurator spotting result in Recogito web interface

## Conclusion

- **SynthMap**, a dataset of synthetic historical map images generated from OSM tiles using cycleGAN to help improve text detection.
- **SpaBERT**, a BERT-based language model to capture the relations between 2D geo-entities and produce spatial-context-aware features.
- **mapKurator**, a machine learning system for historical map understanding.

## References

[1] Li, Zekun. "Generating historical maps from online maps." *Proceedings of the 27th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*. 2019.

[2] Li, Zekun, et al. "Synthetic map generation to provide unlimited training data for historical map text detection." *Proceedings of the 4th ACM SIGSPATIAL GeoAI Workshop*. 2021.

[3] Li, Zekun, et al. "SpaBERT: A Pretrained Language Model from Geographic Data for Geo-Entity Representation." *Proceedings of the EMNLP*. 2022.

[4] Li, Zekun, et al. "An automatic approach for generating rich, linked geo-metadata from historical map images." *Proceedings of the 26th ACM SIGKDD*. 2020.

## Acknowledgement

NATIONAL ENDOWMENT FOR THE HUMANITIES

*David Rumsey Map Collection*
CARTOGRAPHY ASSOCIATES · POWERED BY LUNA IMAGING

The Alan Turing Institute

Recogito | partner of the Pelagios network

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