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Implementing the Concept of Geographic Context for Efficient Recognition from Large-Scale Topographic Map Series

Johannes H. Uhl[1]

Research Team: Stefan Leyk[1], Yao-Yi Chiang[2], Weiwei Duan[3], Vinil Jain[2], Dan Feldman[2], Craig Knoblock[3]

[1] Department of Geography
University of Colorado Boulder

[2] Spatial Sciences Institute
University of Southern California

[3] Computer Science Department
University of Southern California

Outline

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I Map Processing: Impact & Challenges

II The Principle of Geographic Context

III Case Study:

Recognition of Buildings and Urban Areas in Historical Topographic Maps

I Map Processing: Impact & Challenges

The Impact of Map Processing

(a) Military Geographical Institute, Poland 1930, 1:25K

(b) Royal Prussian Surveying Unit, Map of Western Russia, 1915, 1:100K

(c) Imperial and Royal Military Geographical Institute, Austria, Map of the Austrian-Hungarian Monarchy and foreign map pages, Russia, 1878, 1:75K

(d) Swiss Federal Topographic Bureau, Swiss Topographic Map (Siegfried Map), 1912, 1:25K

→Preserving unique witnesses of the past

→unlocking geographic information

The Impact of Map Processing

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- Map processing = Recognition + Extraction
- Pattern recognition, computer vision, machine learning...
- Creating GIS-readable data from scanned map archives
- Retrospective Landscape Analysis
- Historians, Geographers, Demographers, Landscape Ecologists, etc…

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- Complexity, graphical quality, data volume
- User interaction → Low levels of automation in information extraction

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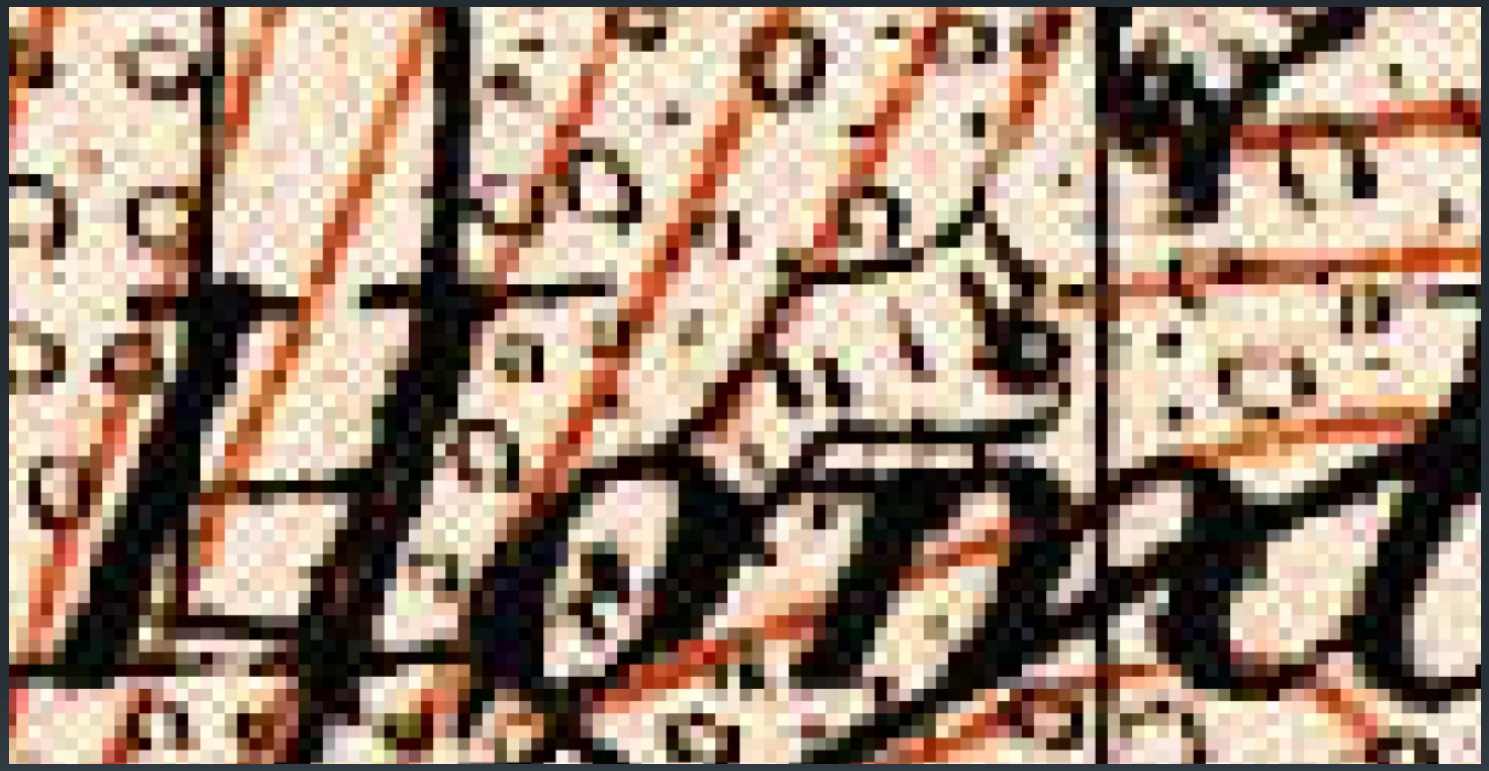

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Map recognition involving user interaction:

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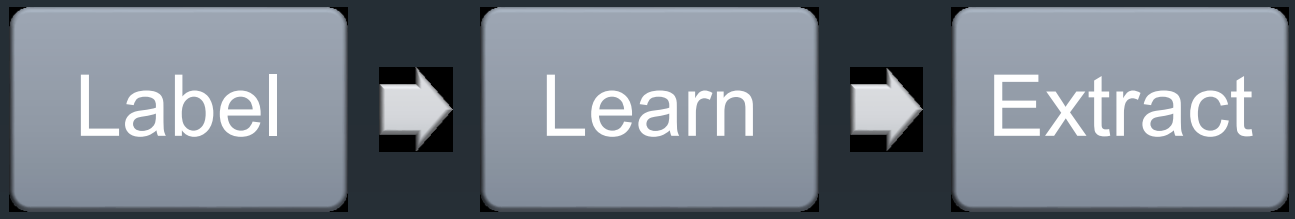

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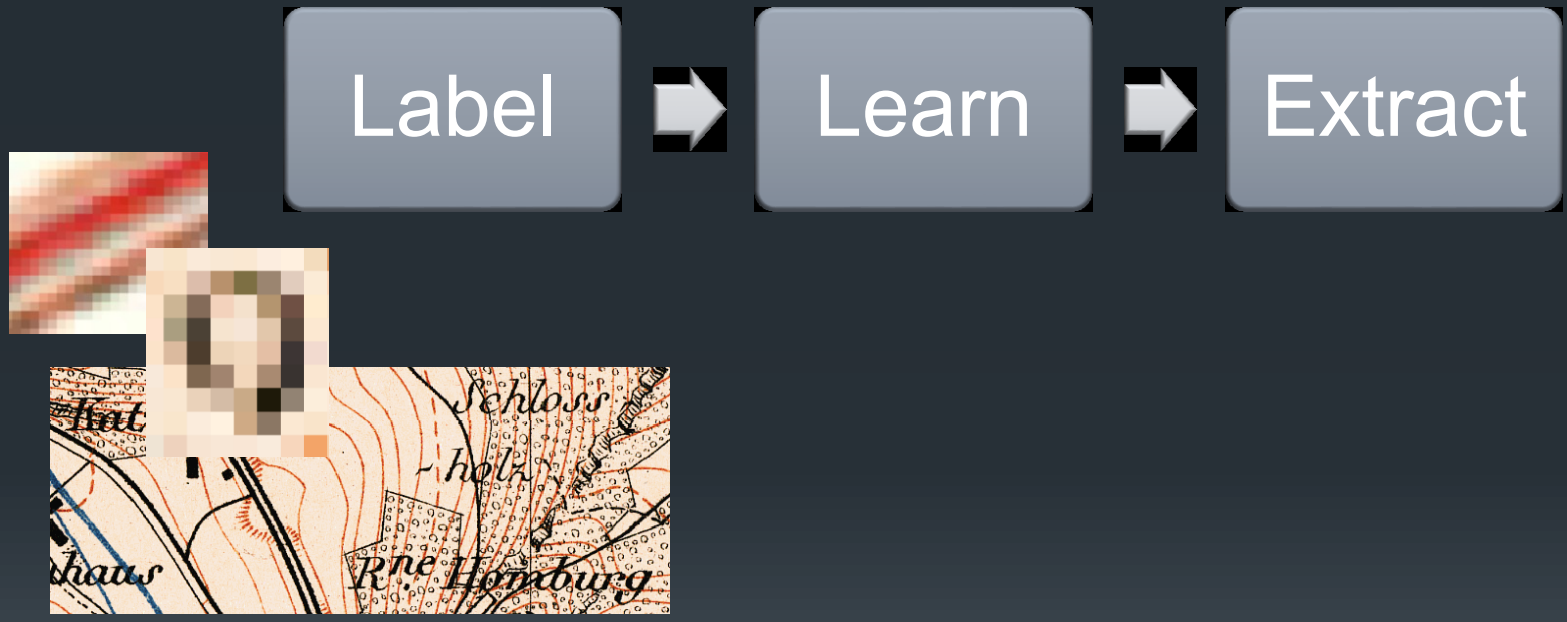

Current Challenges in Map Processing

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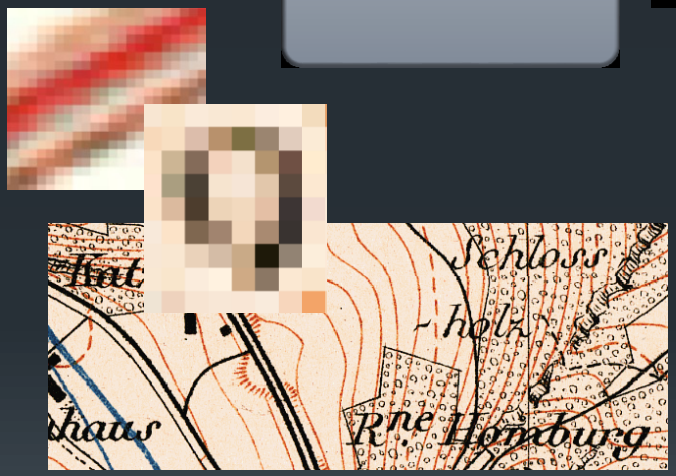
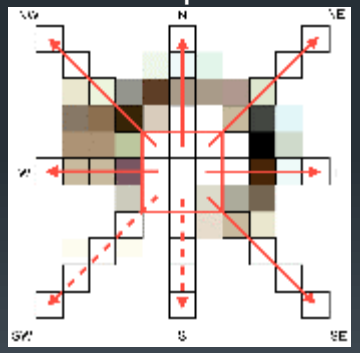
Label → Learn → Extract



shape, color & gradient descriptors



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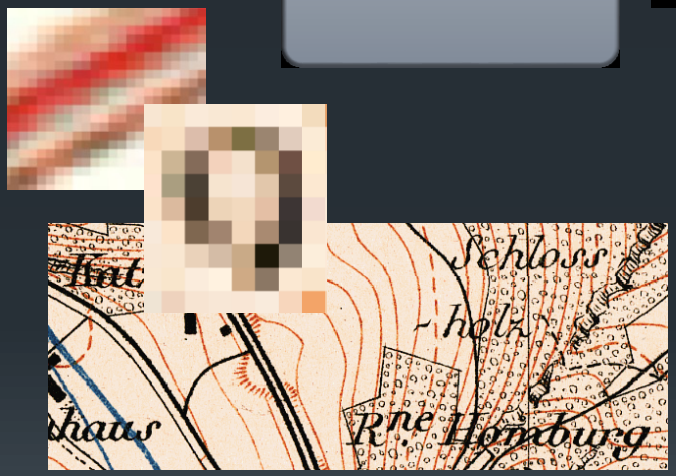

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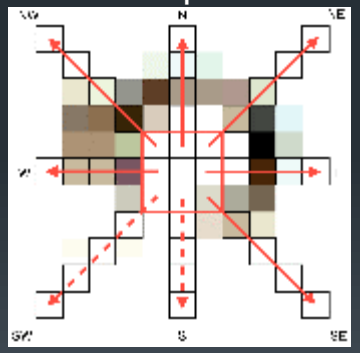

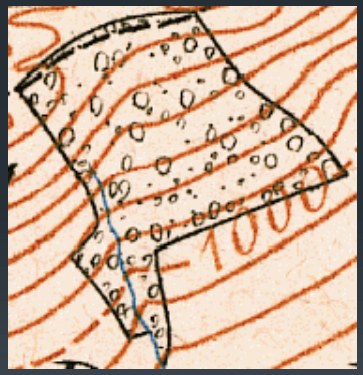

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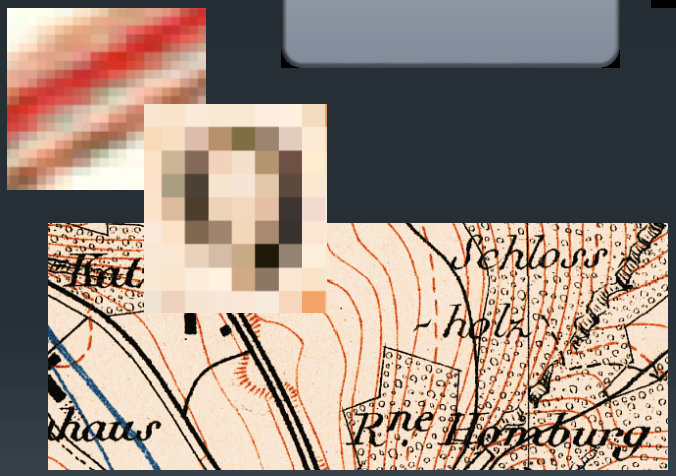

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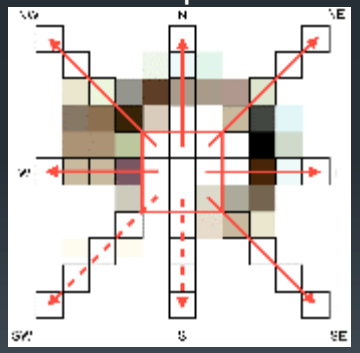

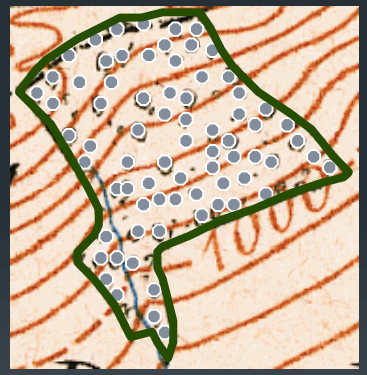

How to **overcome user labeling** to achieve higher levels of automation?

II The Principle of Geographic Context

Effective use of external (geographic) data for improved information extraction from maps

Geographic Context?

- Map series in digital archives
- Large data volume
- Dependent editions with incremental change (updates)
- Overlap in content to guide learning?

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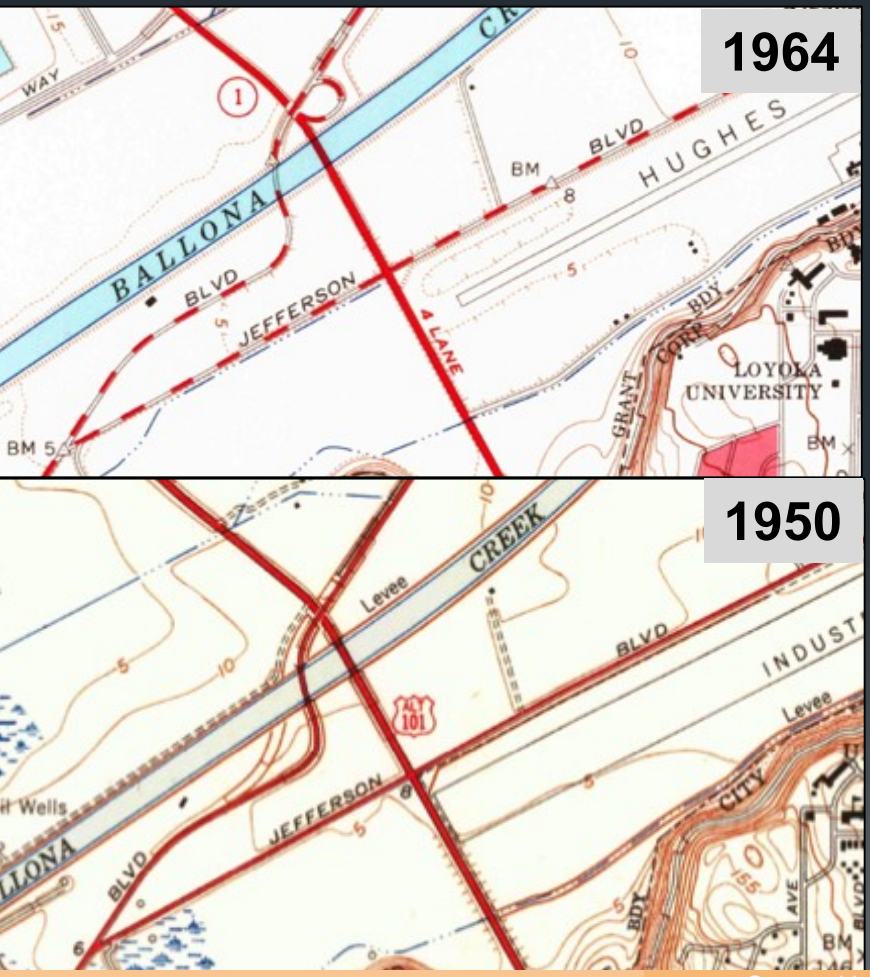

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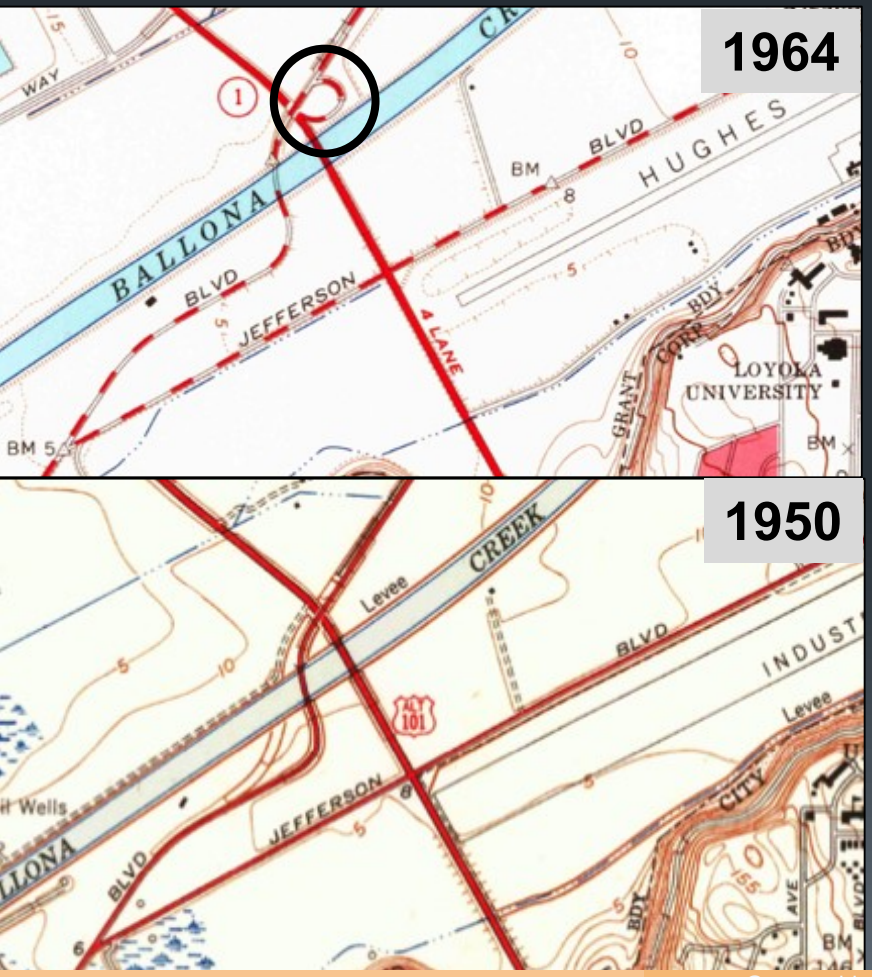

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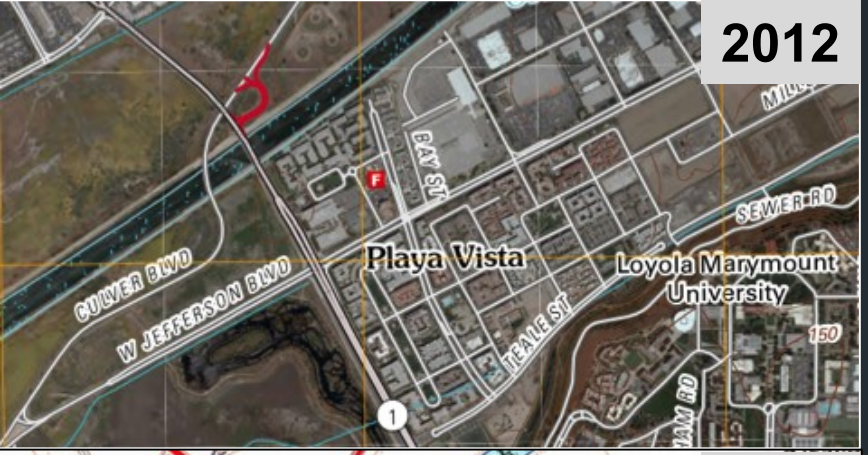

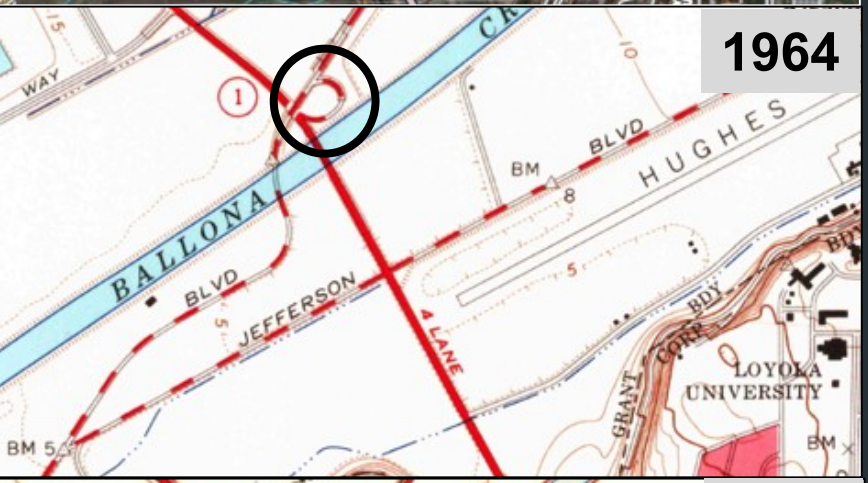

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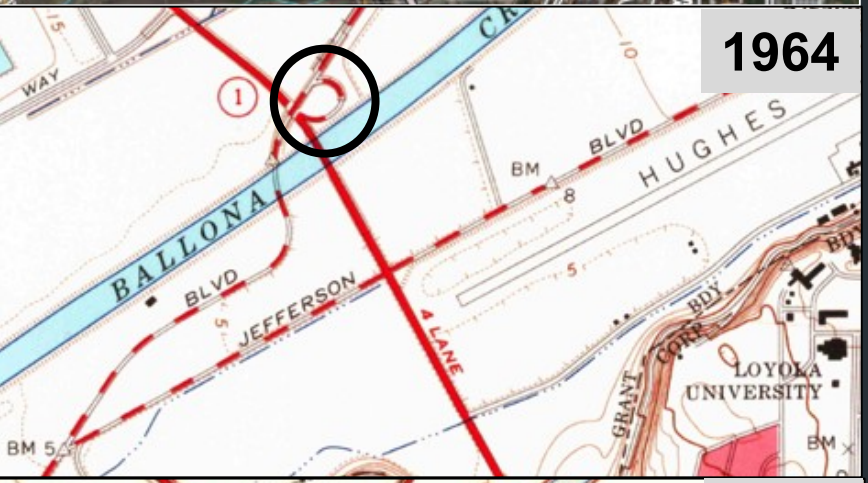

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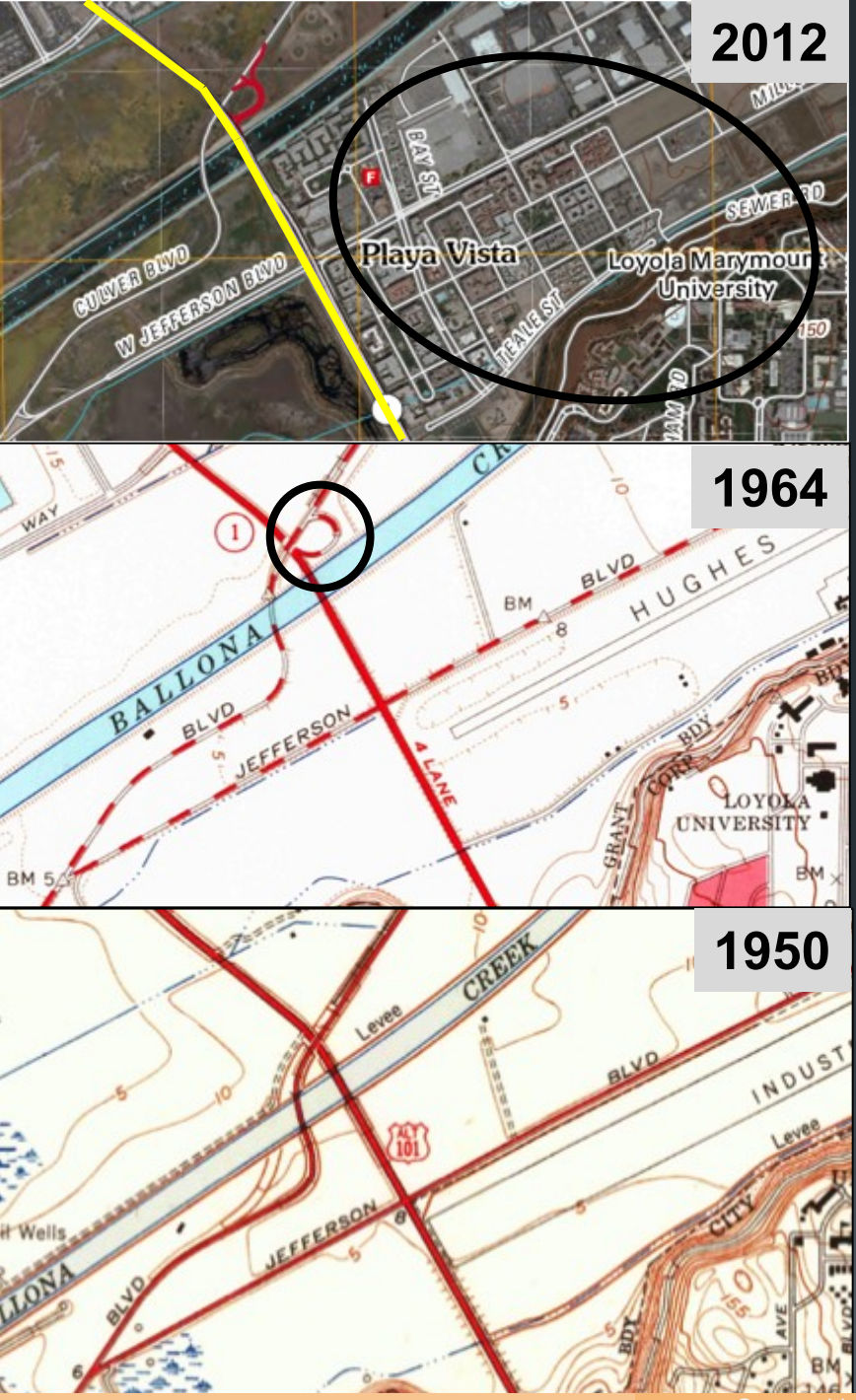

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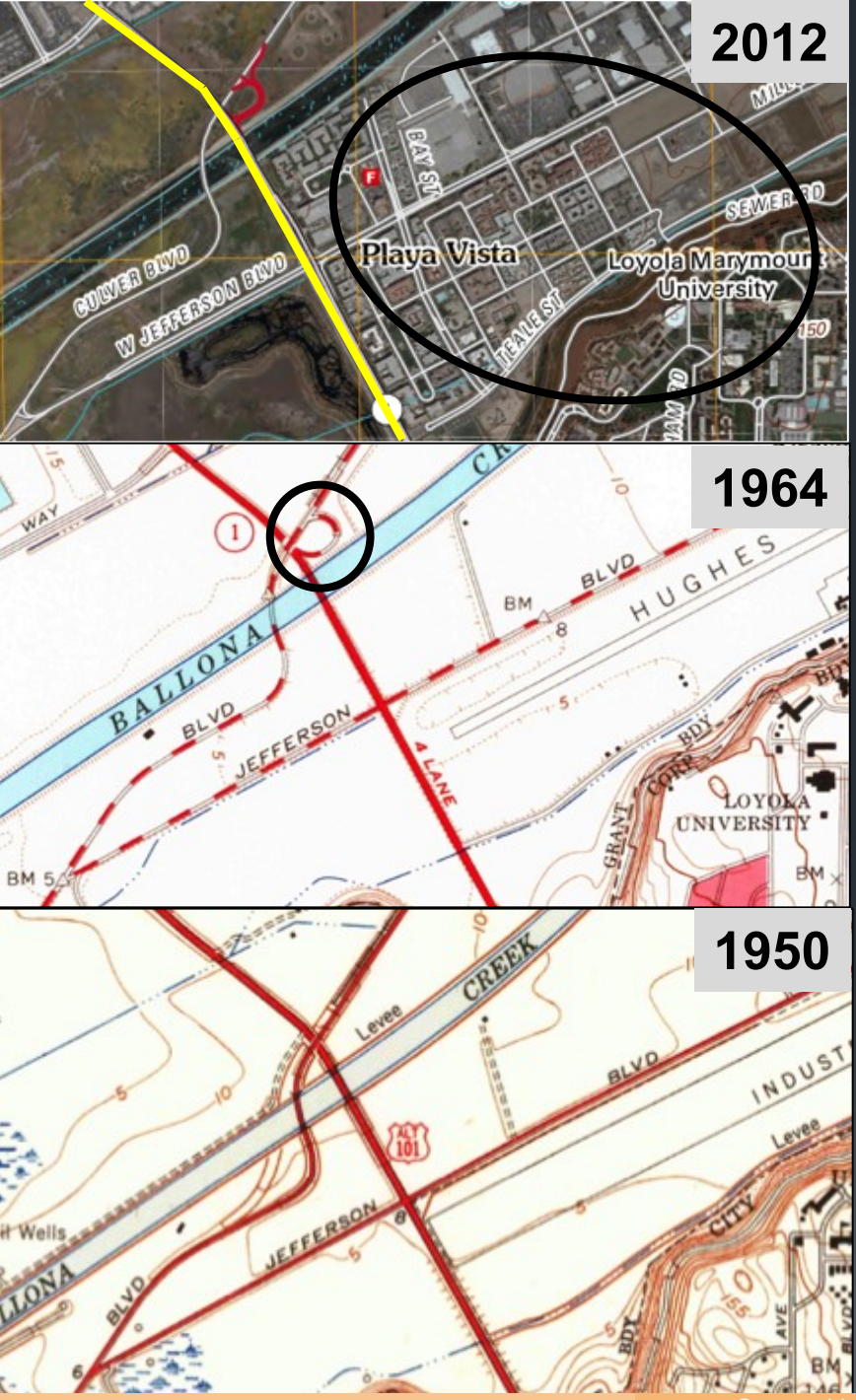

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- Generic (not independent) ancillary data representing feature of interest
- Know “where to expect” the feature of interest

Information Extraction & Geographic Context

(1) Creating contextual information

- Geometry
- Attributes

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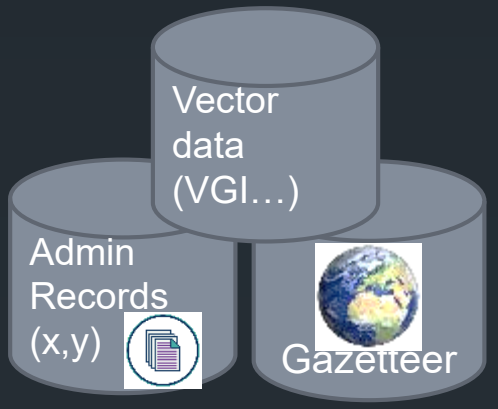

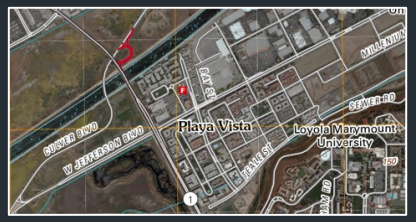

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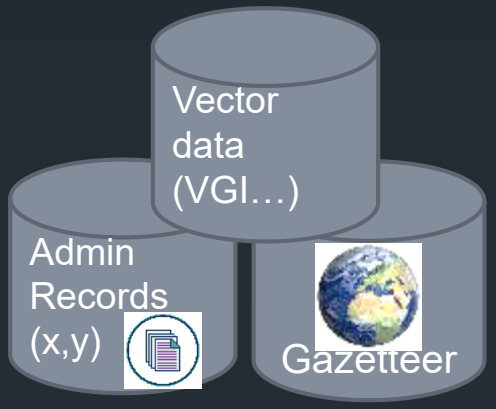

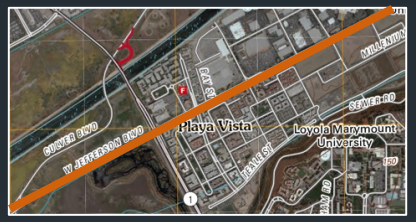

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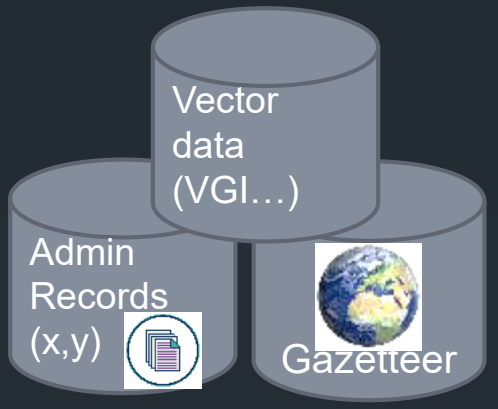

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- Geometry
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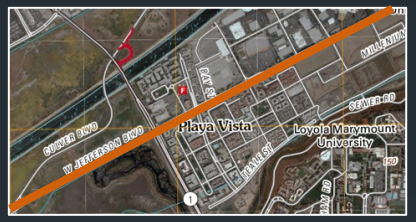
(2) Adaptive graphics sampling

- Collect spatially constrained graphics examples
- Assume overlap: map & context



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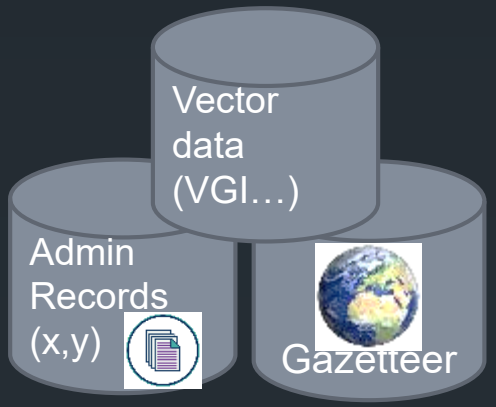

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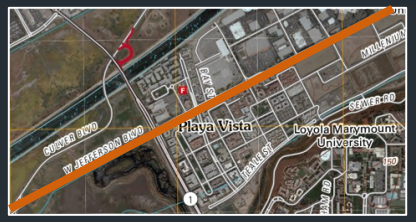

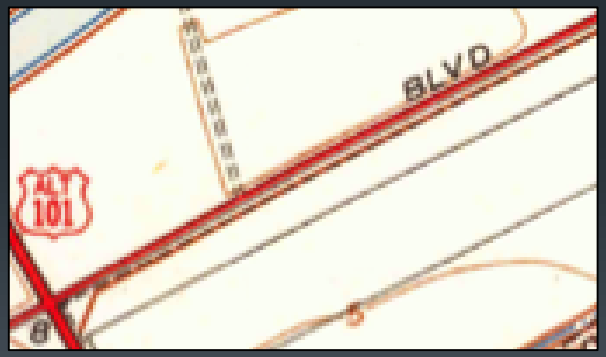

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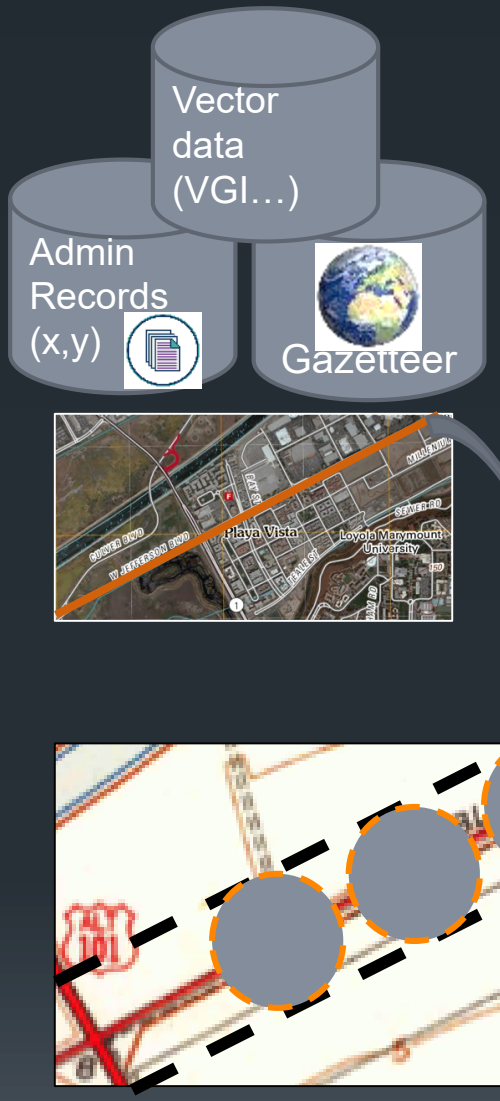

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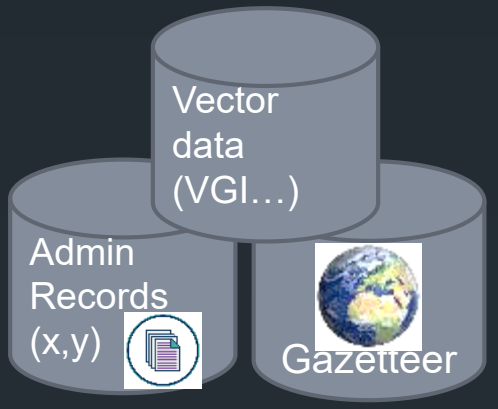
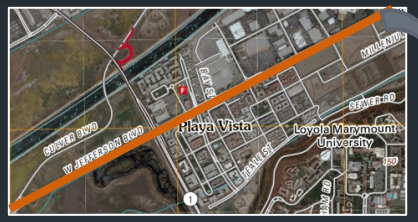
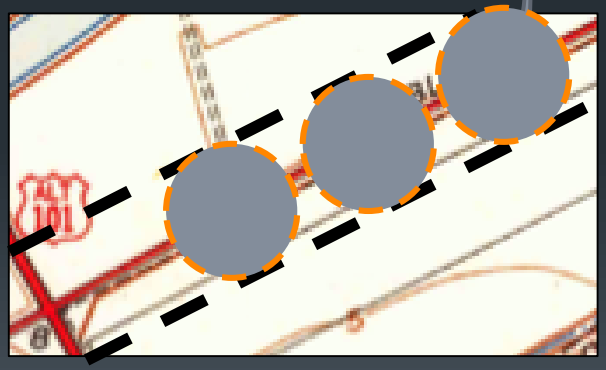
(3) Compute feature descriptors: Create knowledge base
- Shape, color, texture descriptors
- To be used in learning and extraction







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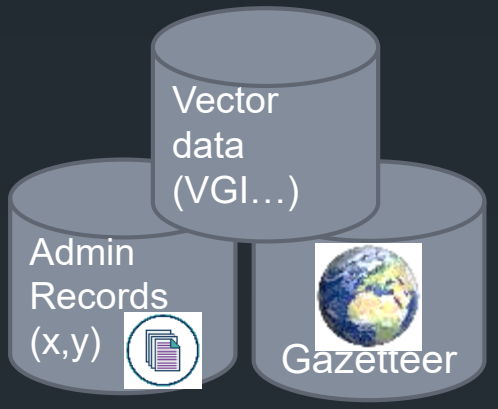

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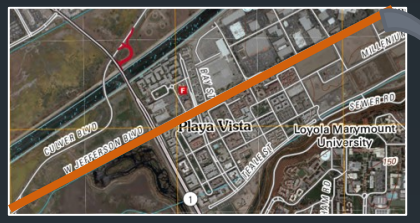
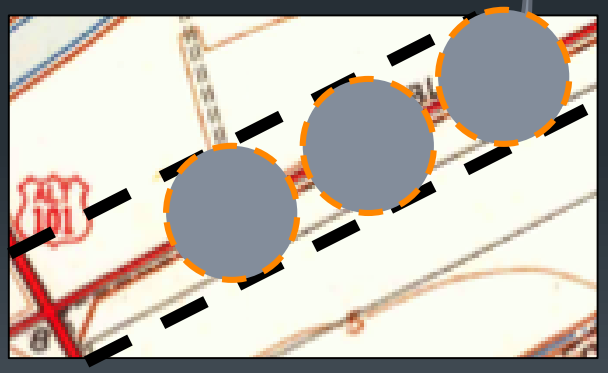


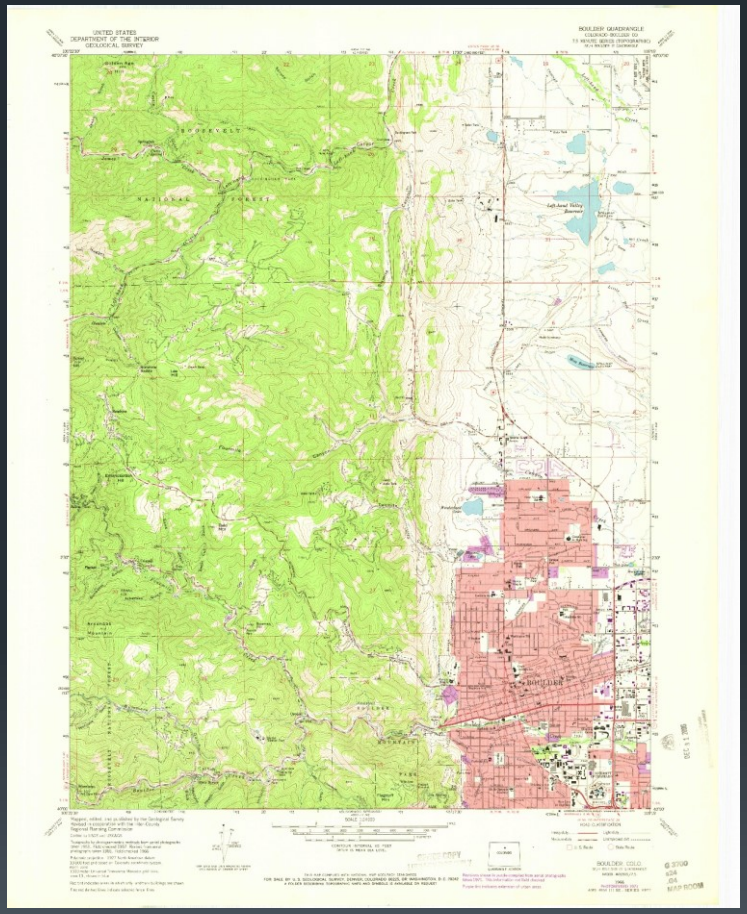


Step (1) and (2): Eliminate user interaction

III Case Study

Geographic context for automated map symbol recognition: Buildings and Urban Areas

The Experiment



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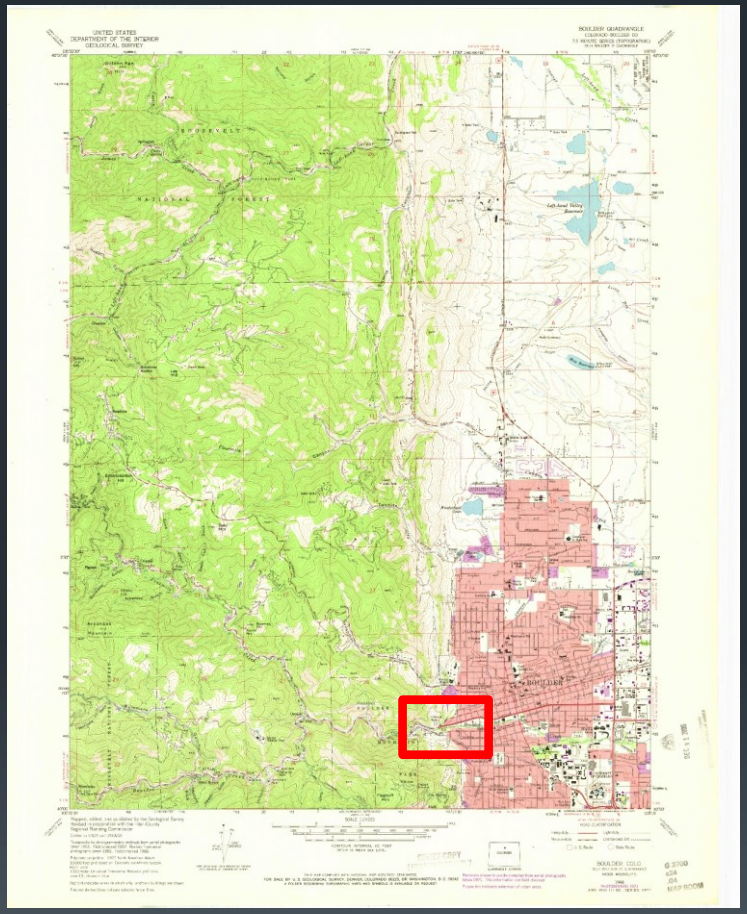

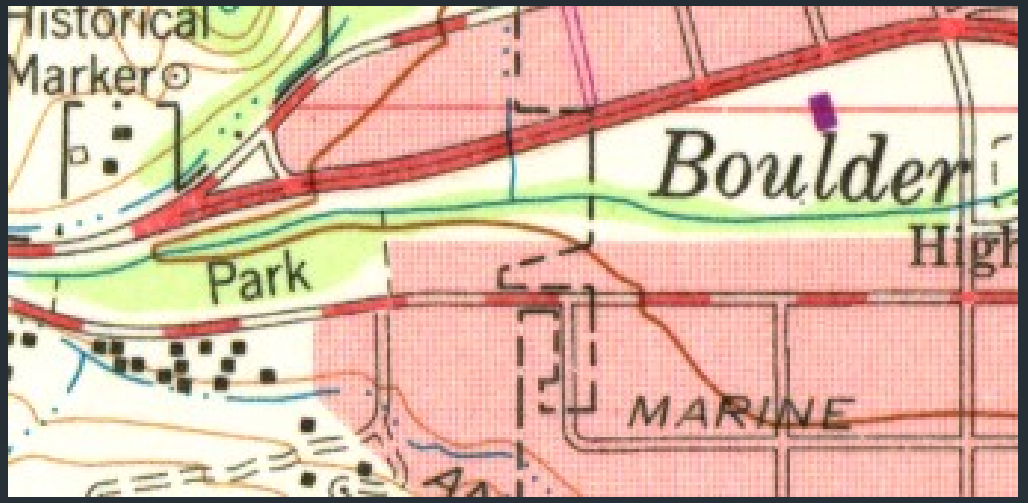

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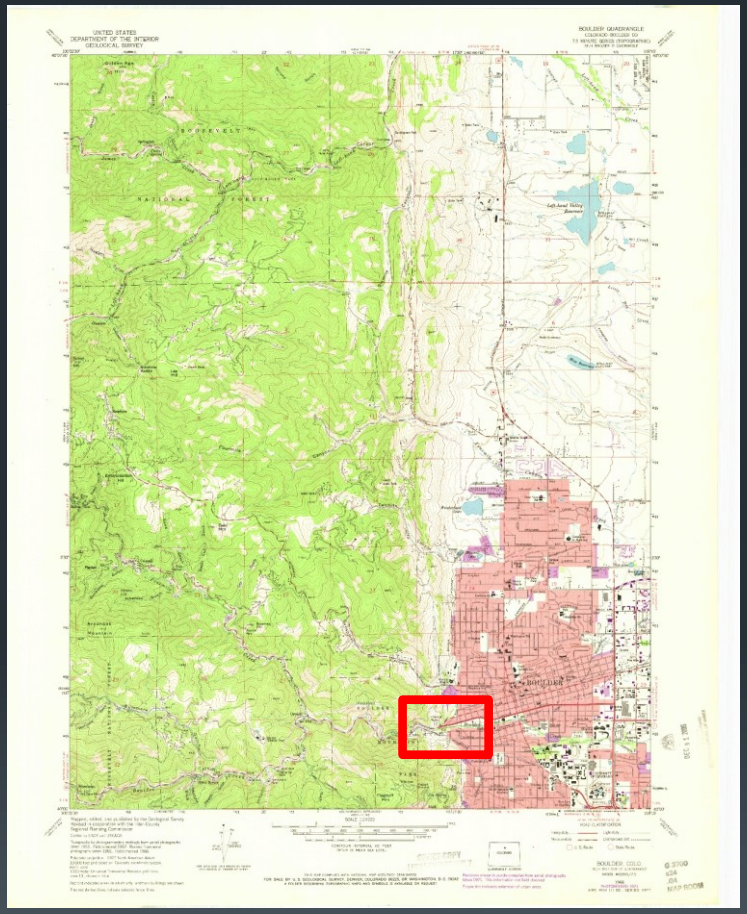

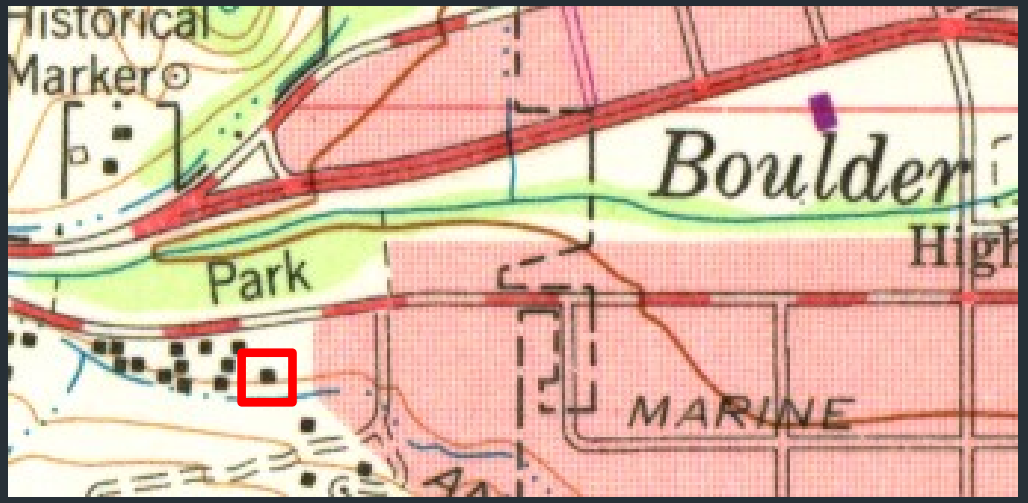

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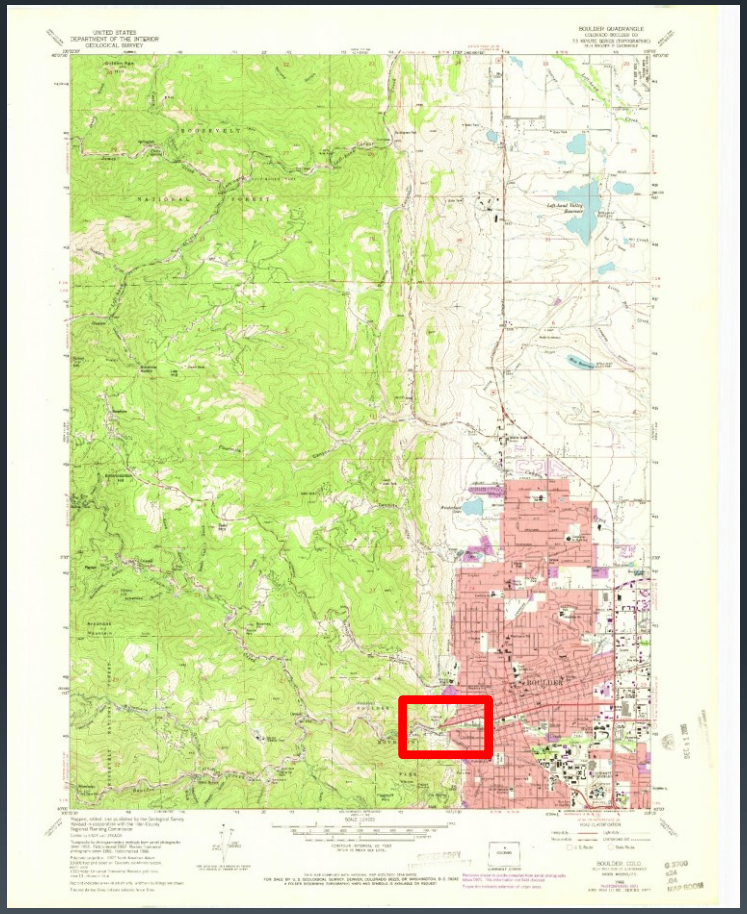

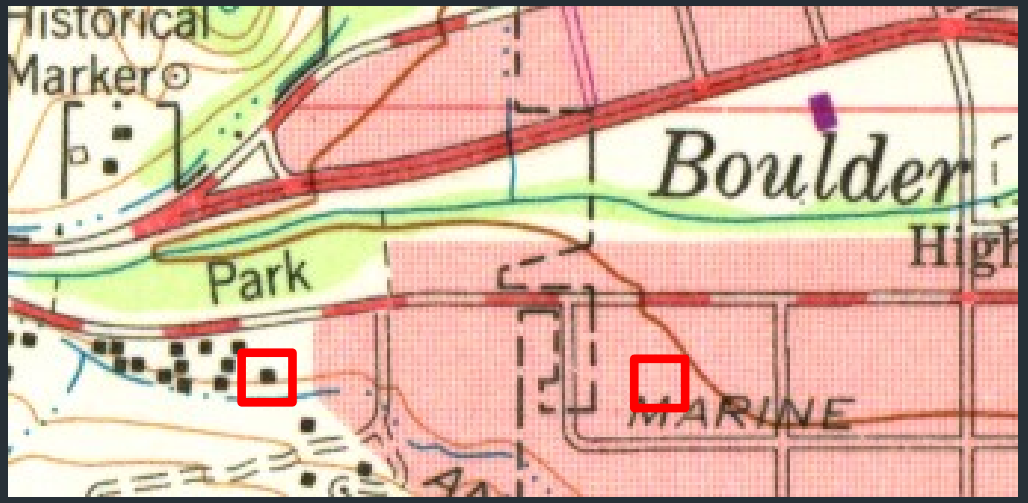

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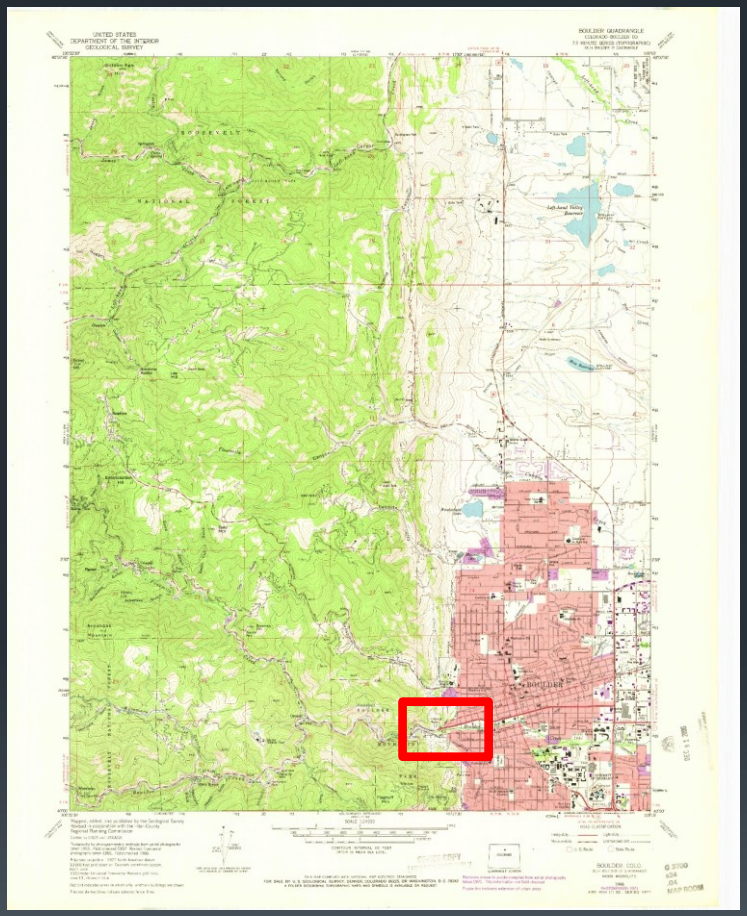

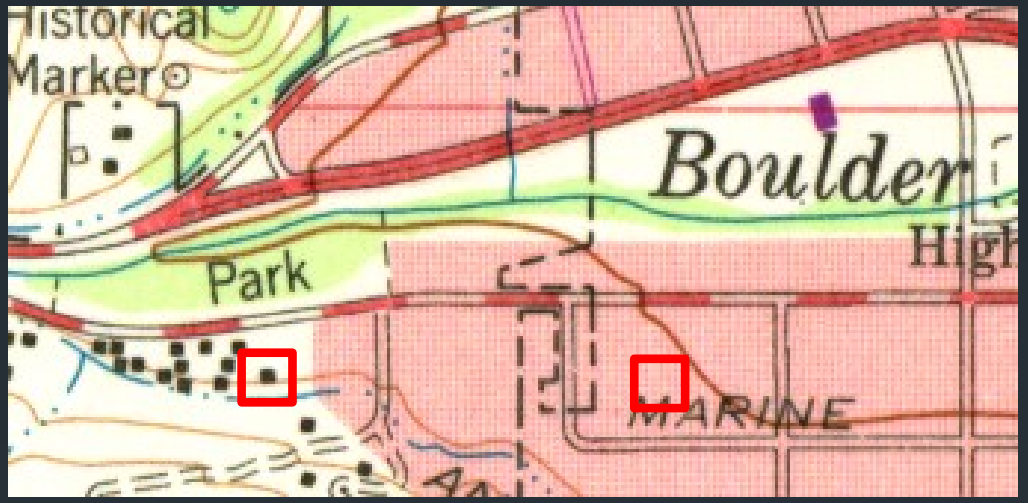

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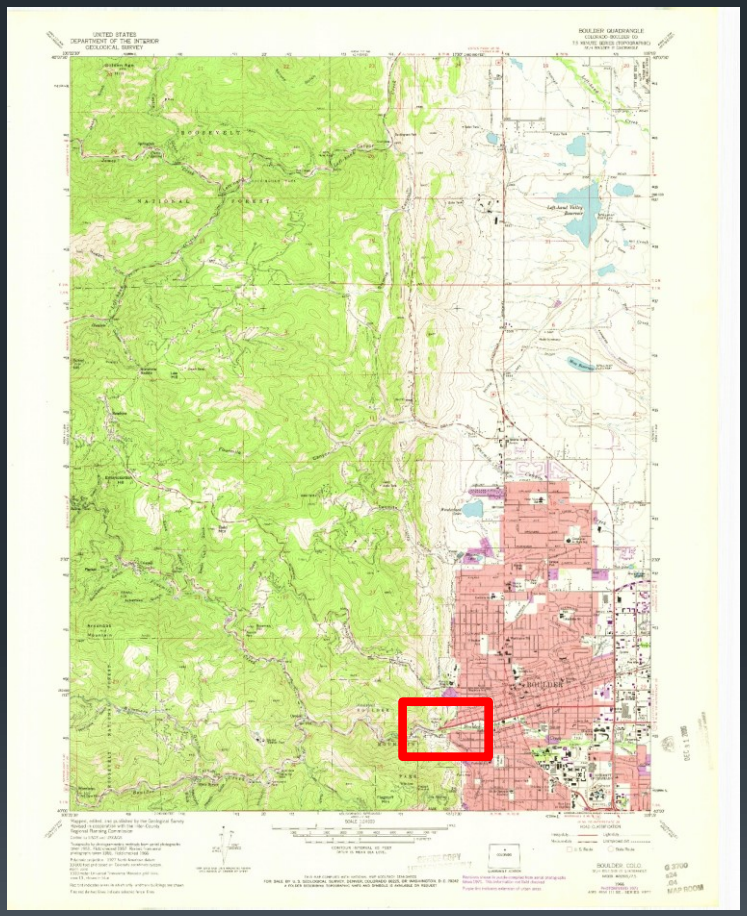

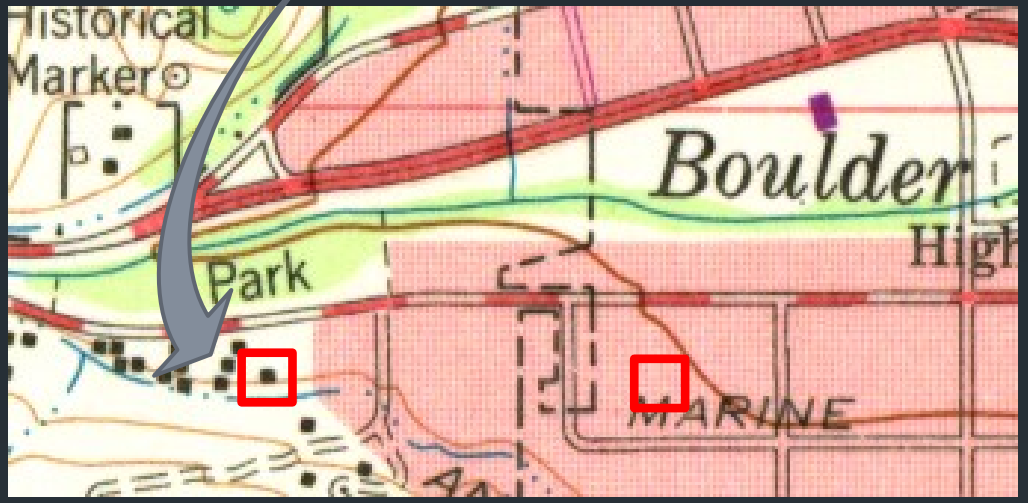

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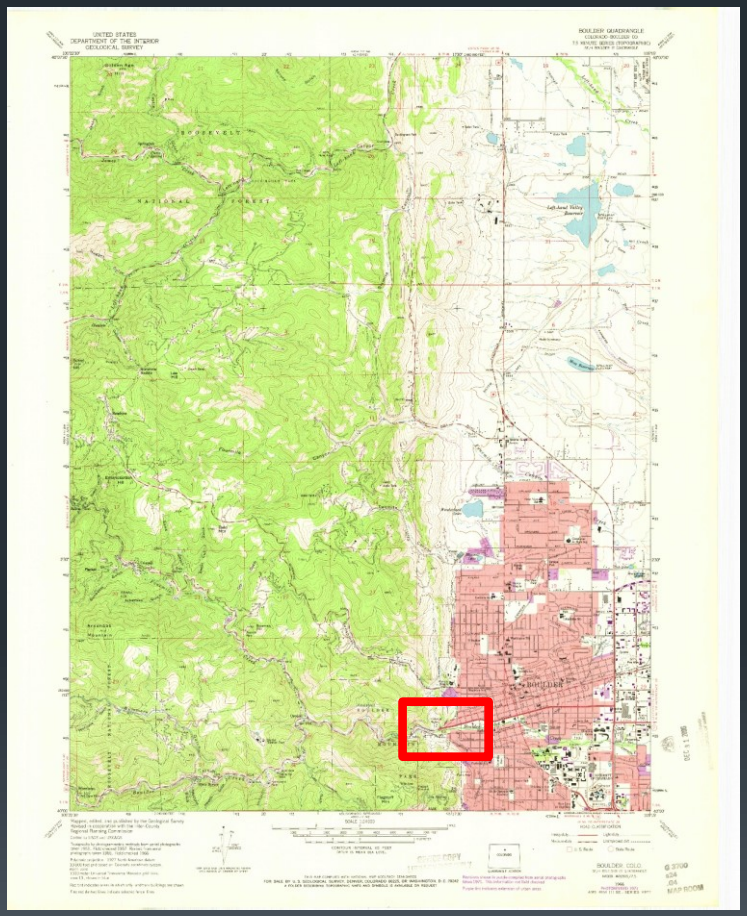

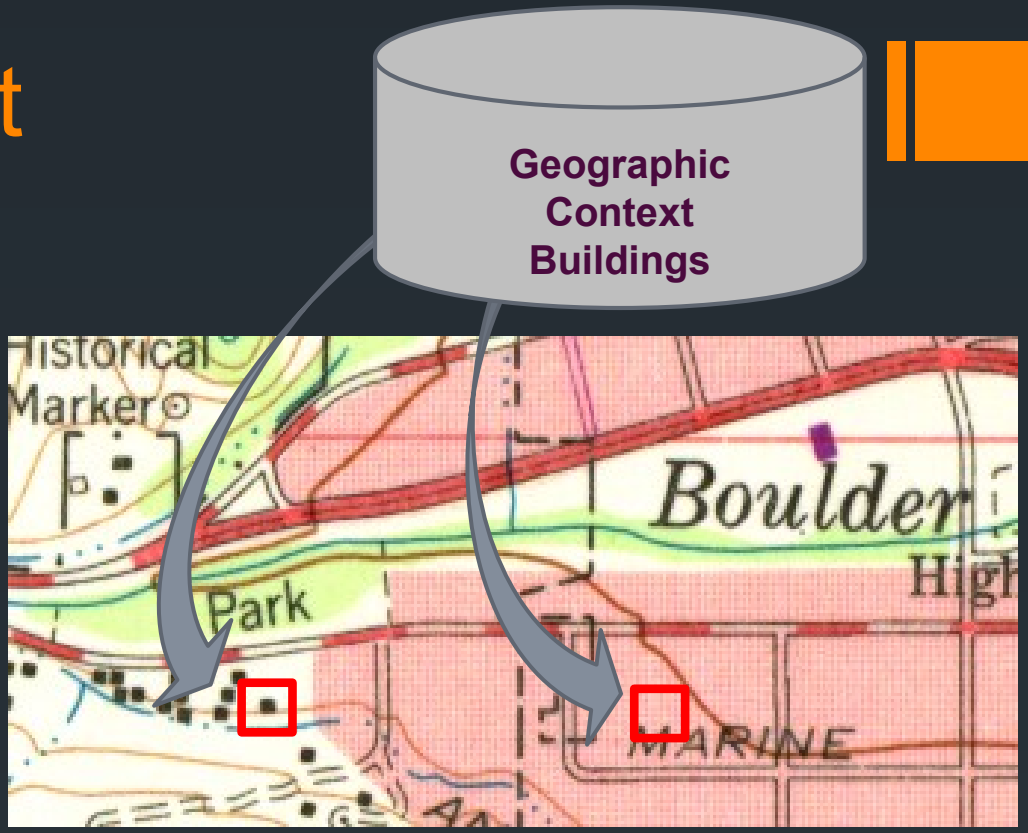

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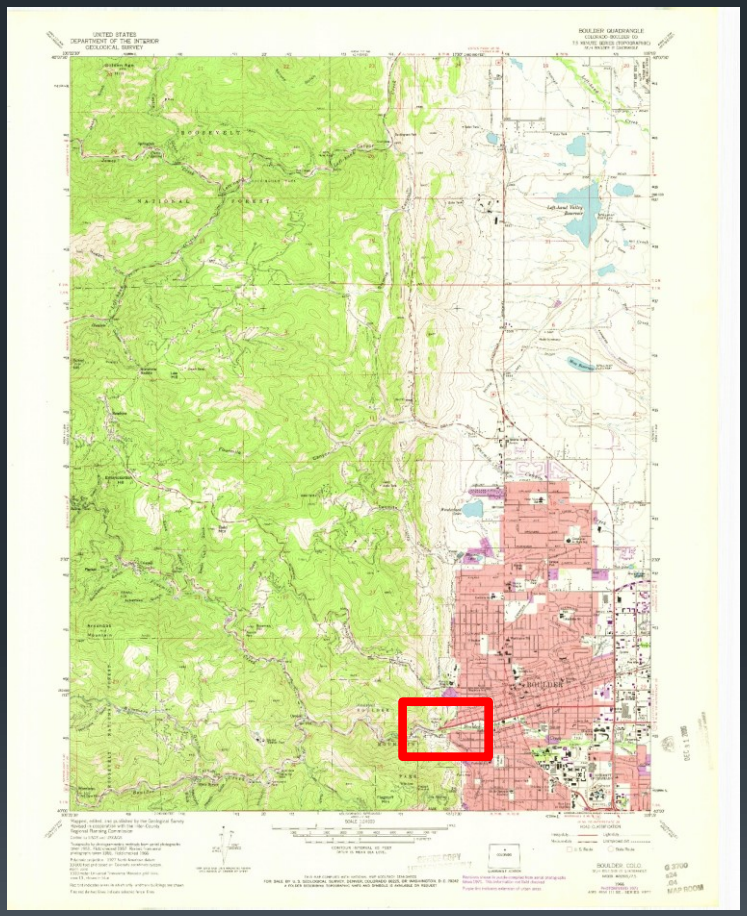
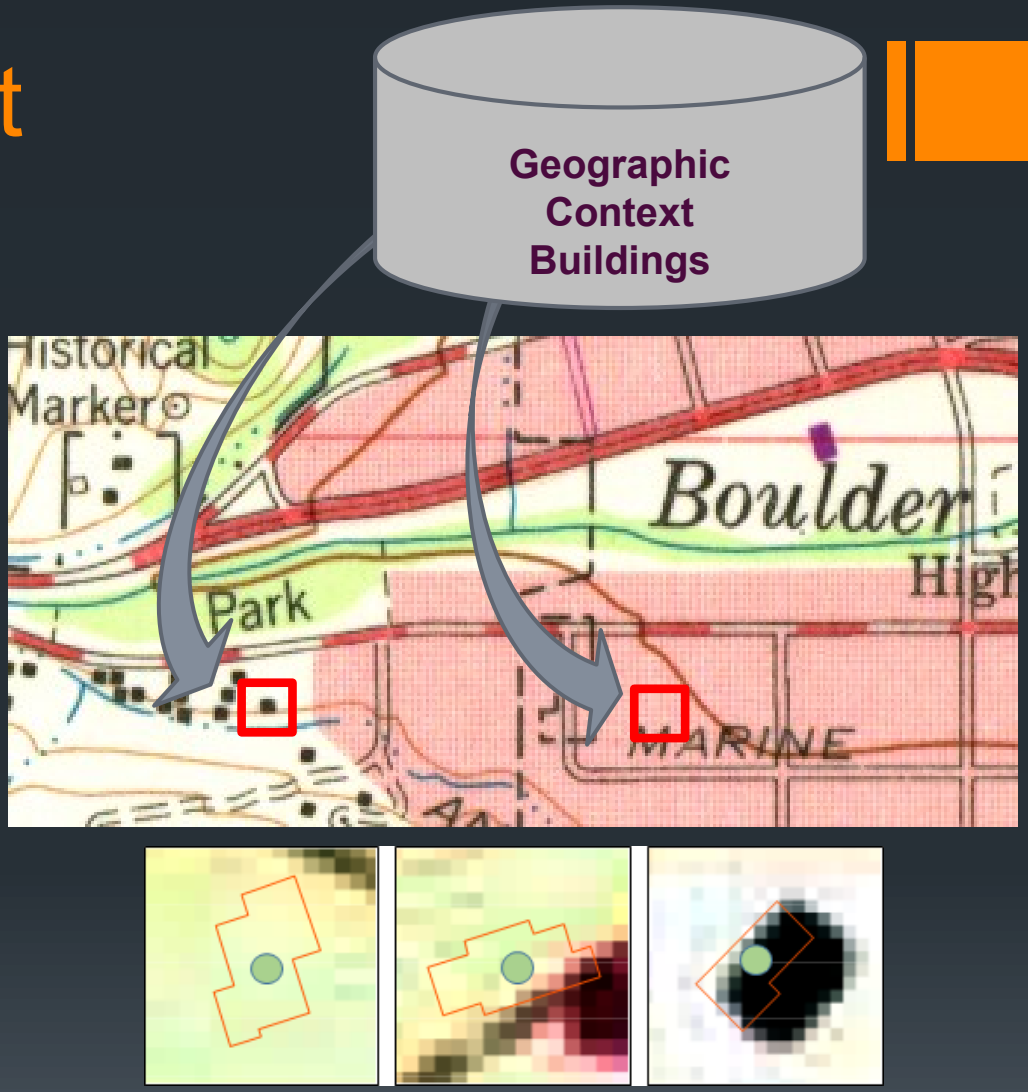
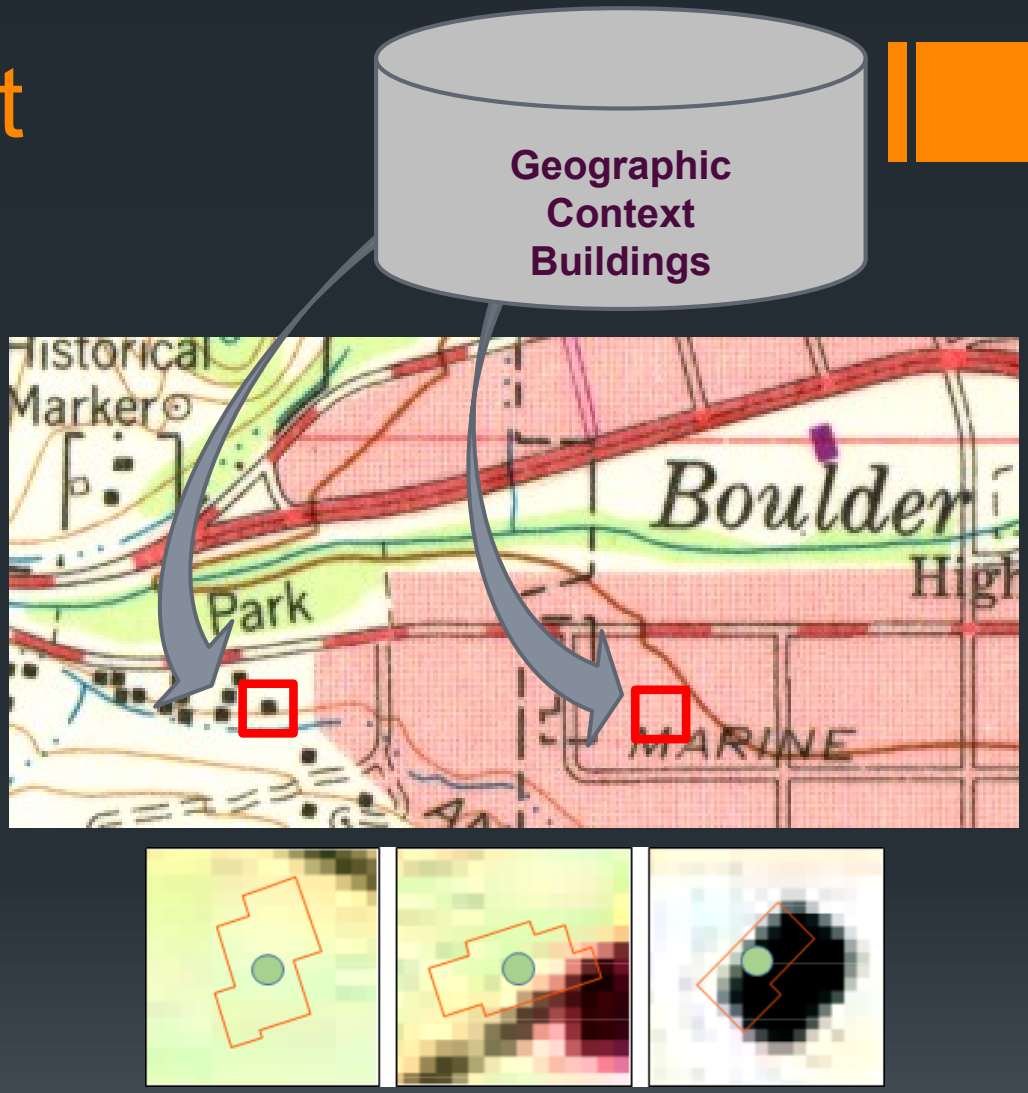




Spatial offsets
Temporal inconsistencies
Generalization effects

The Experiment

- Preprocessing
- Graphics sampling
- Sample cleaning
- Learning
- Recognition
- Extracted buildings & urban areas



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Discrepancies between contextual and map data

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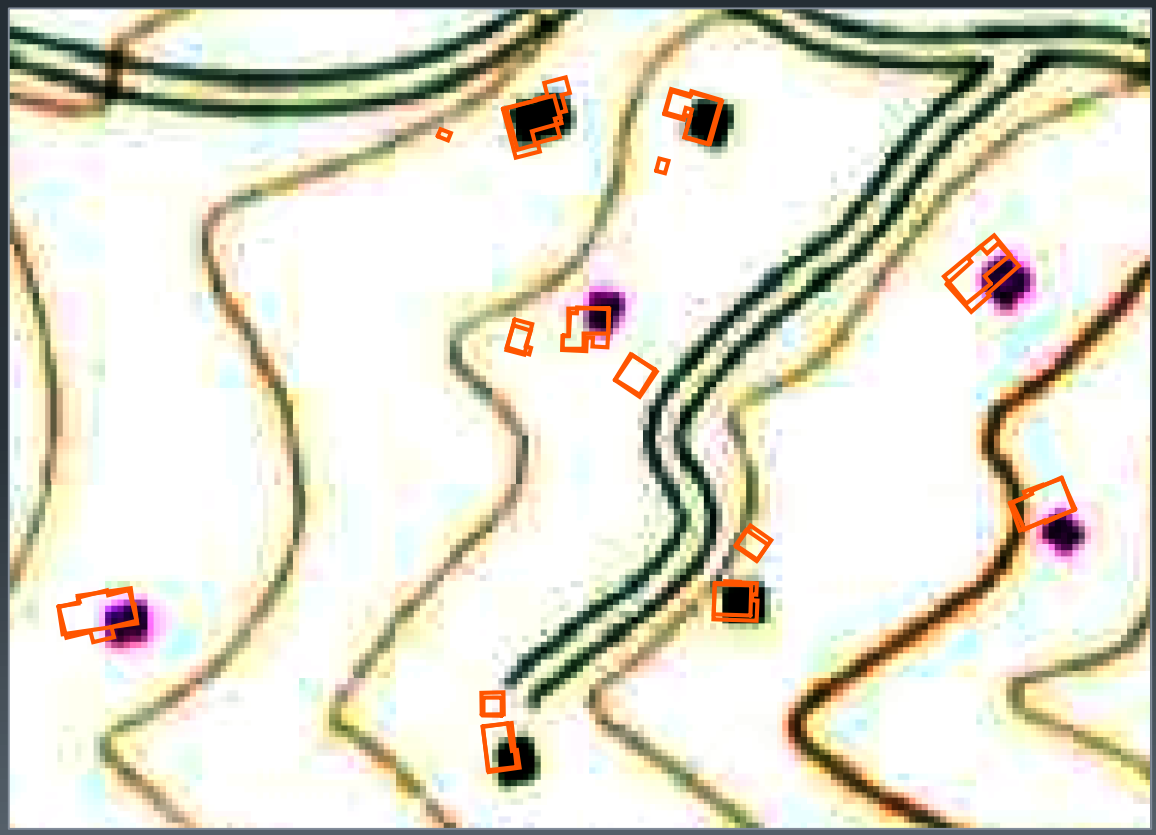
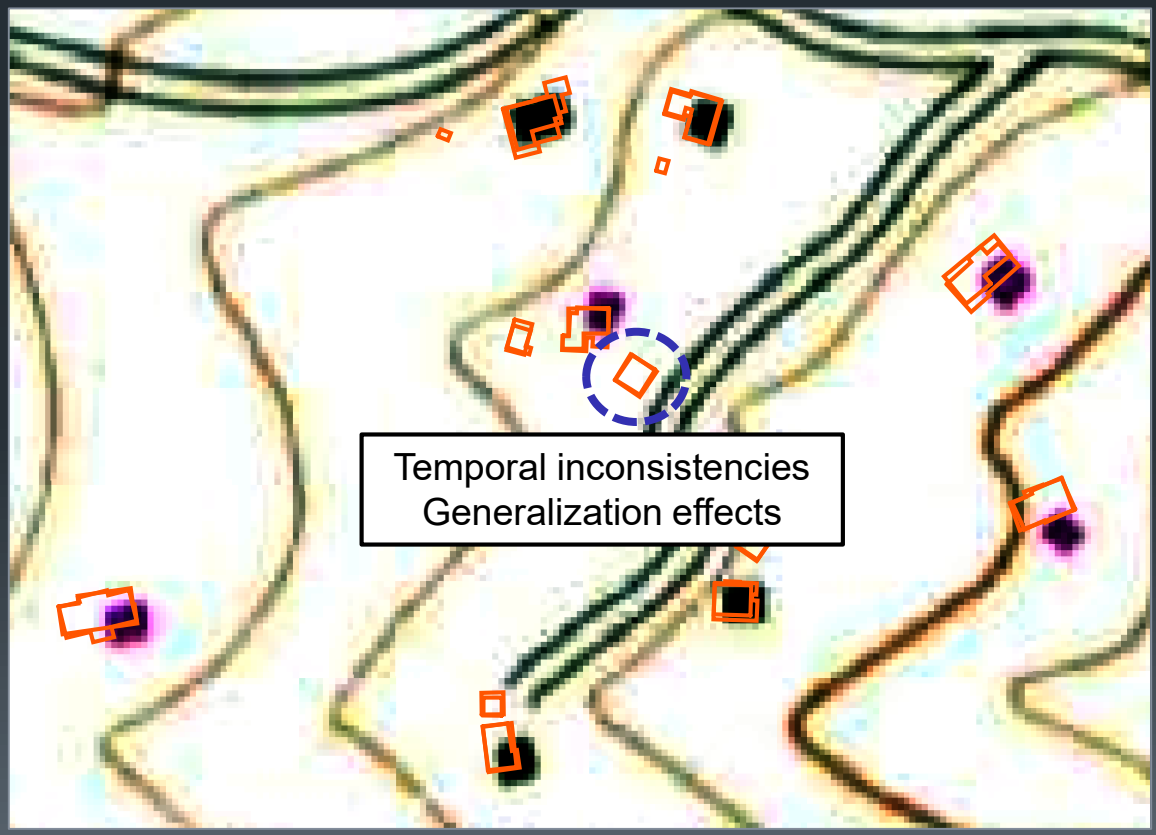
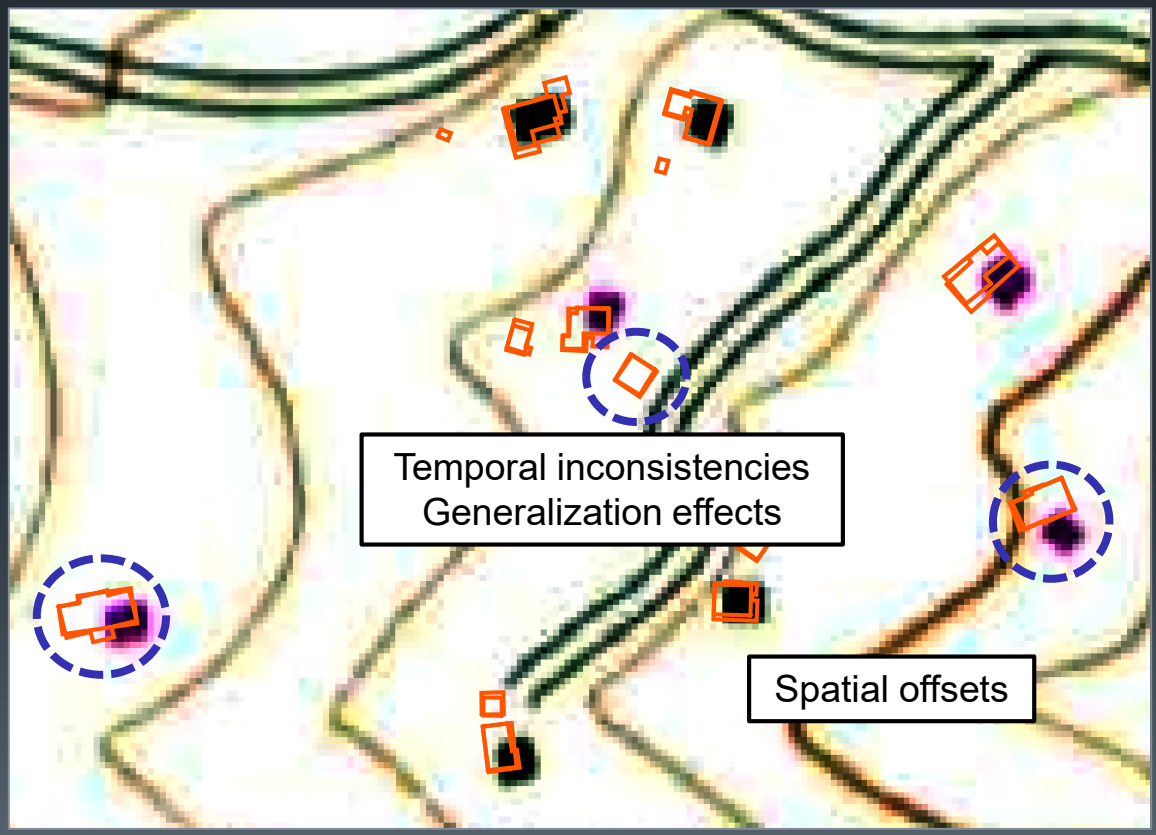


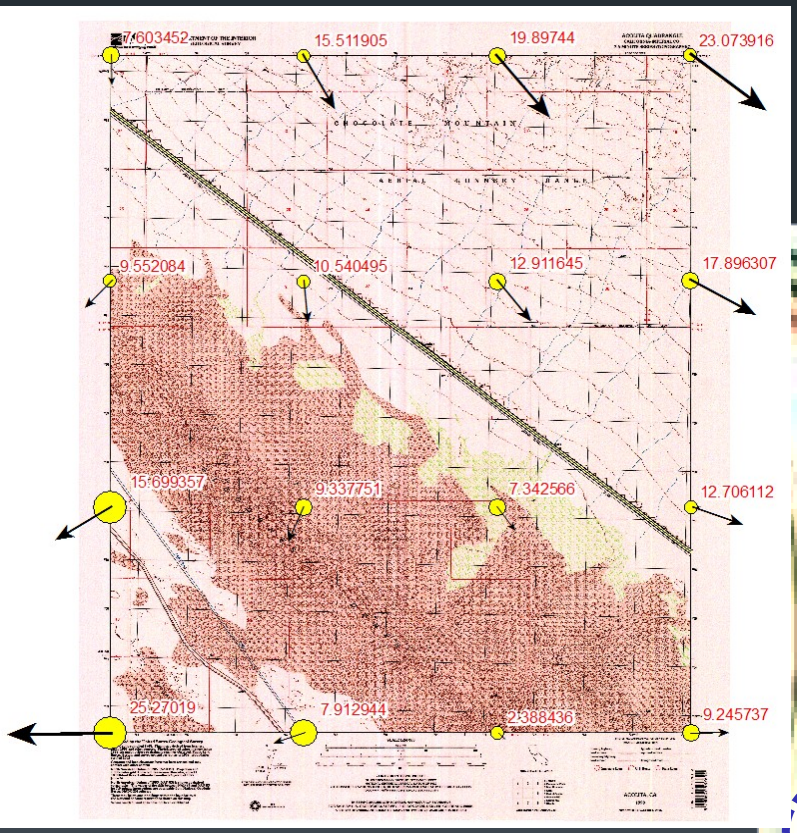
Discrepancies between contextual and map data



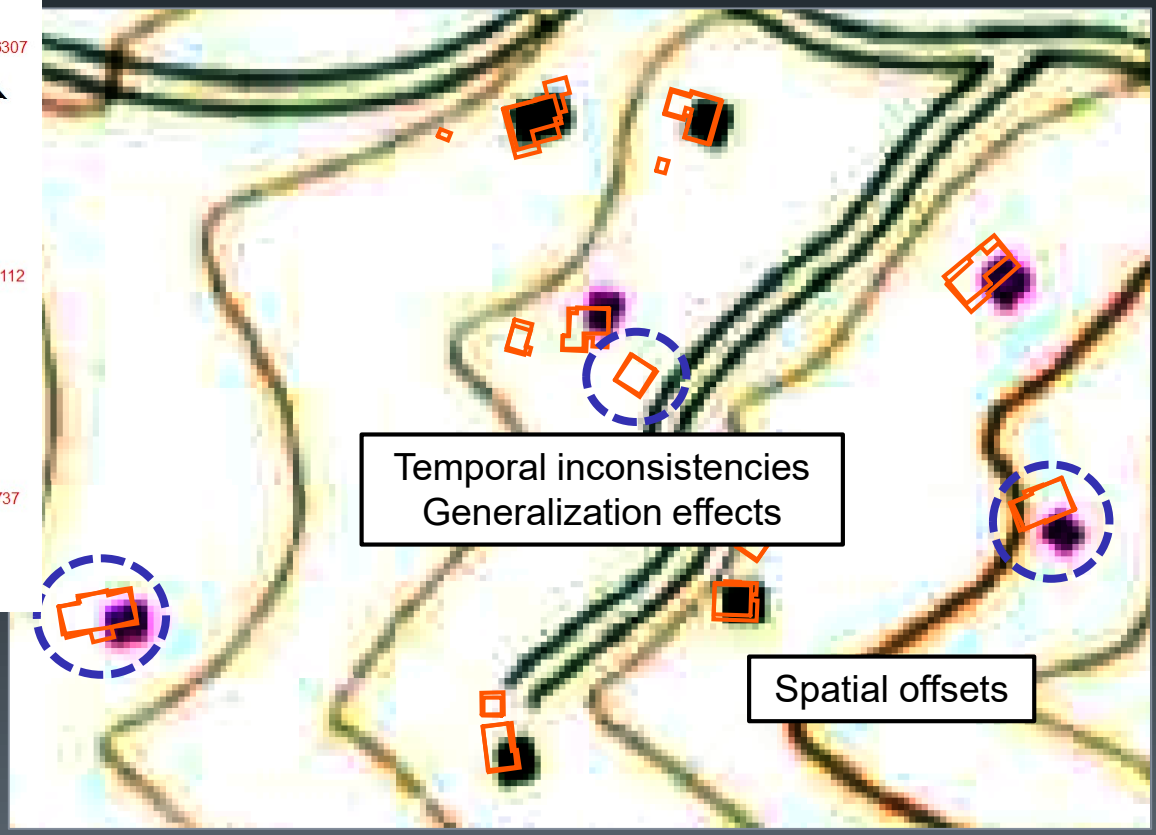
Discrepancies between contextual and map data



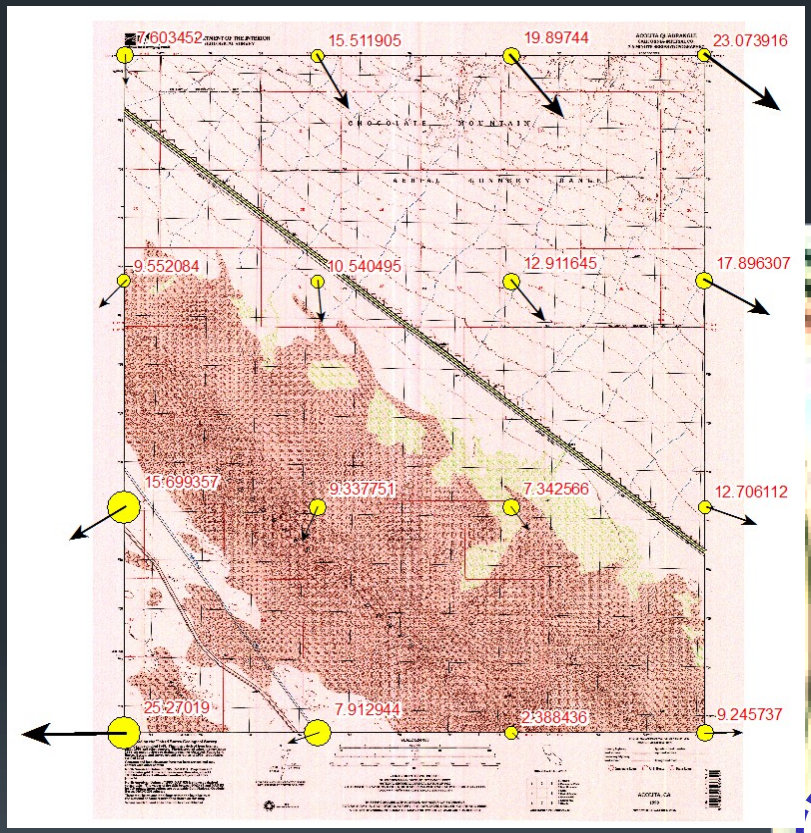
Discrepancies between contextual and map data



Distortions introduced during georeferencing



Discrepancies between contextual and map data



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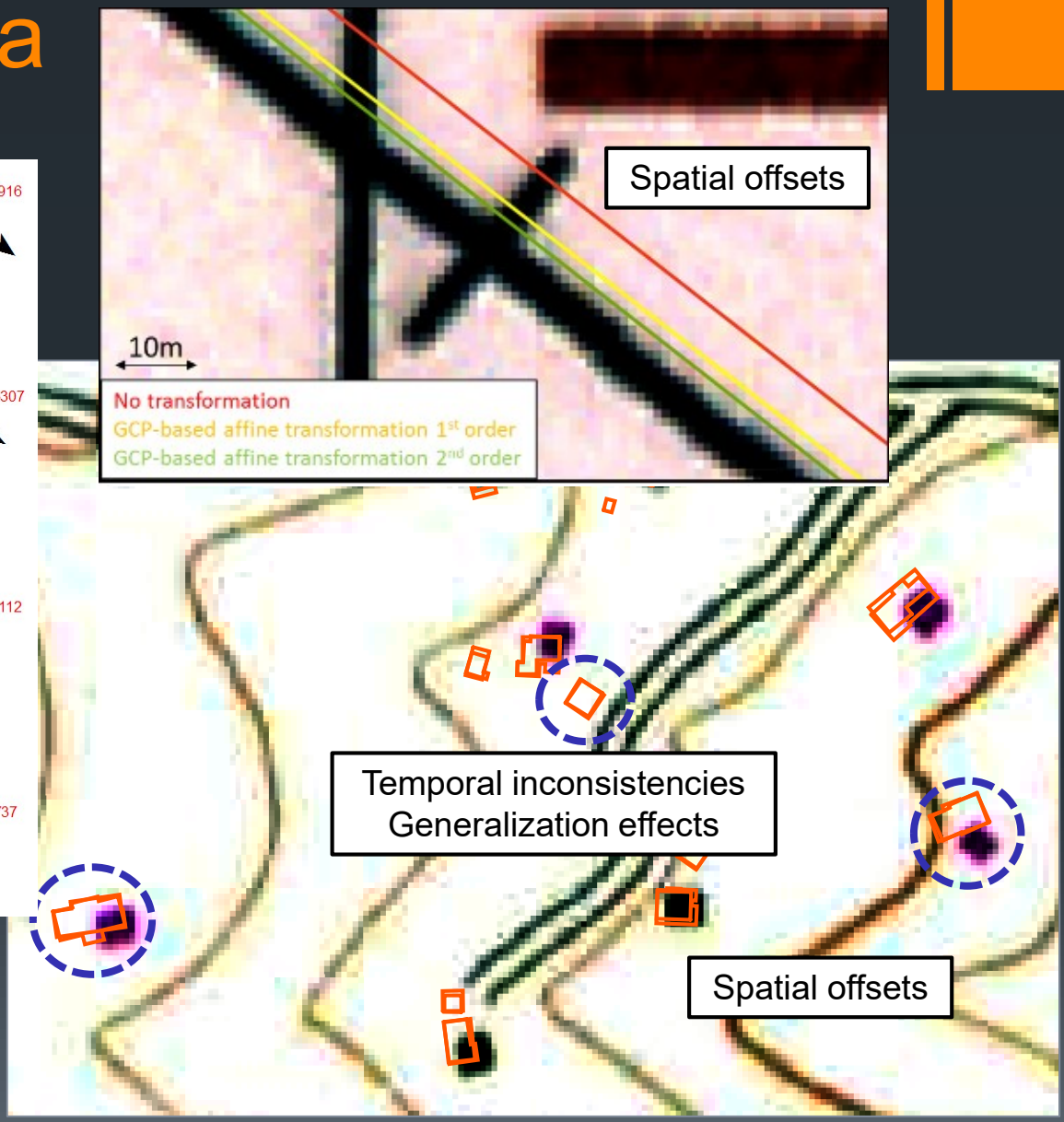
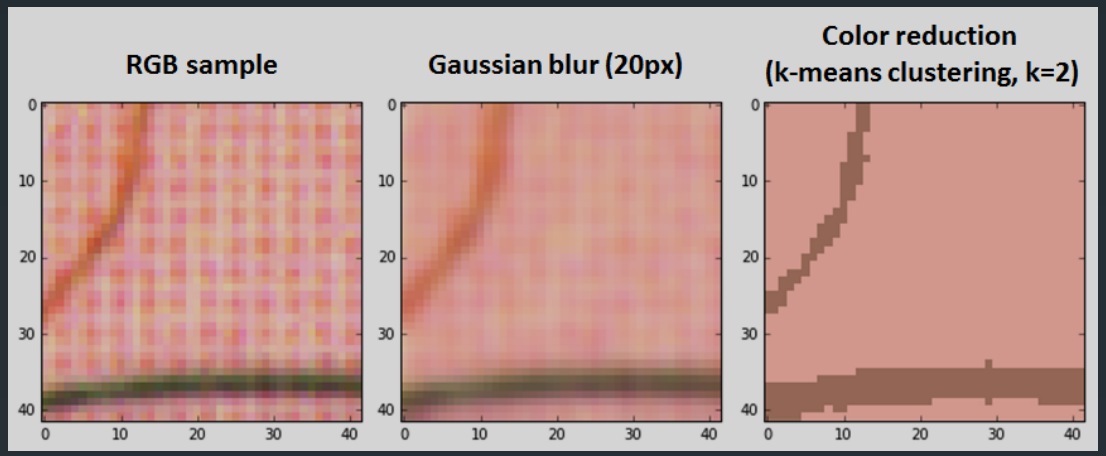
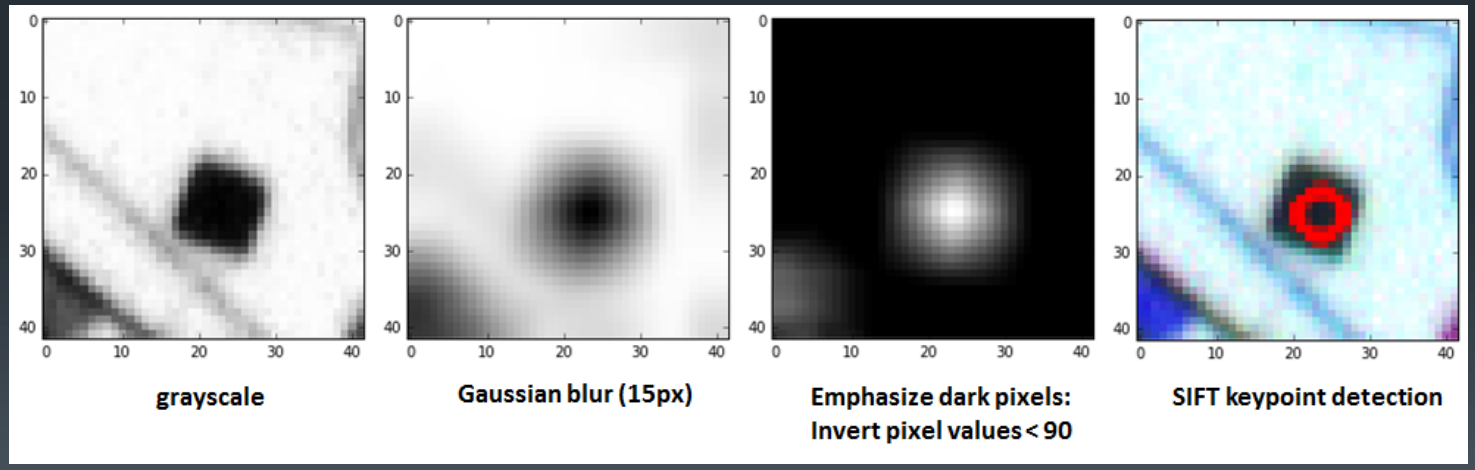


Guided Graphics Sampling

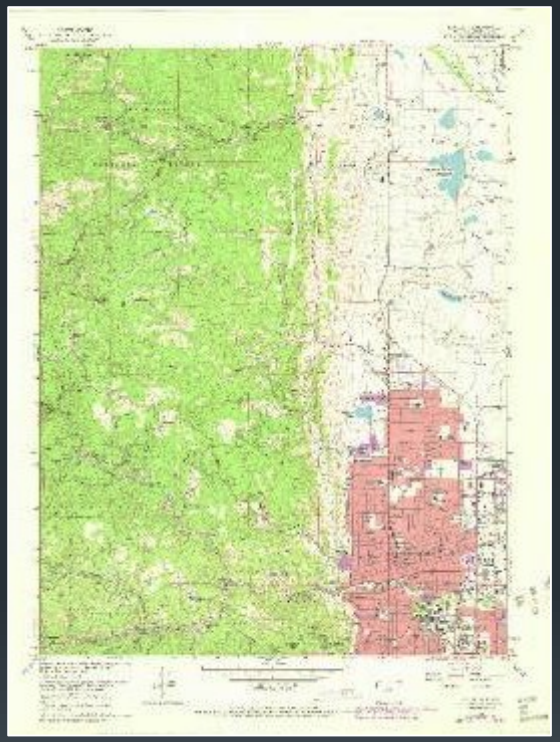


"Cleaning"
the samples…



…using image processing / computer vision techniques

Clean graphic samples for learning process



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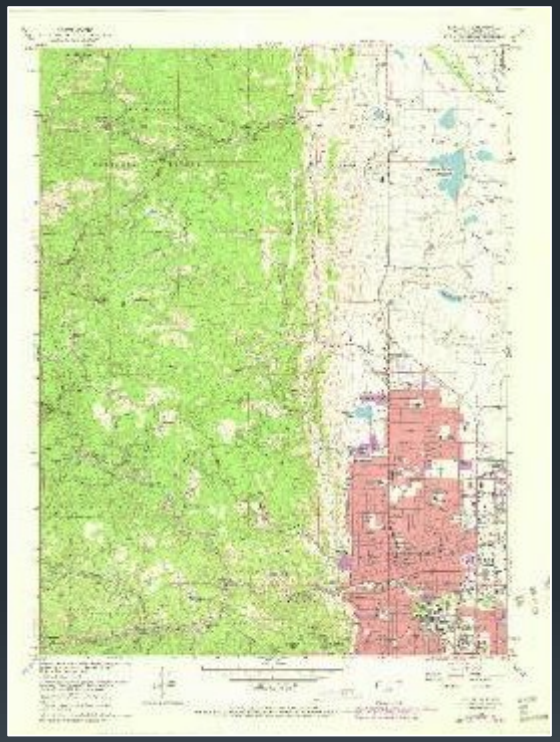
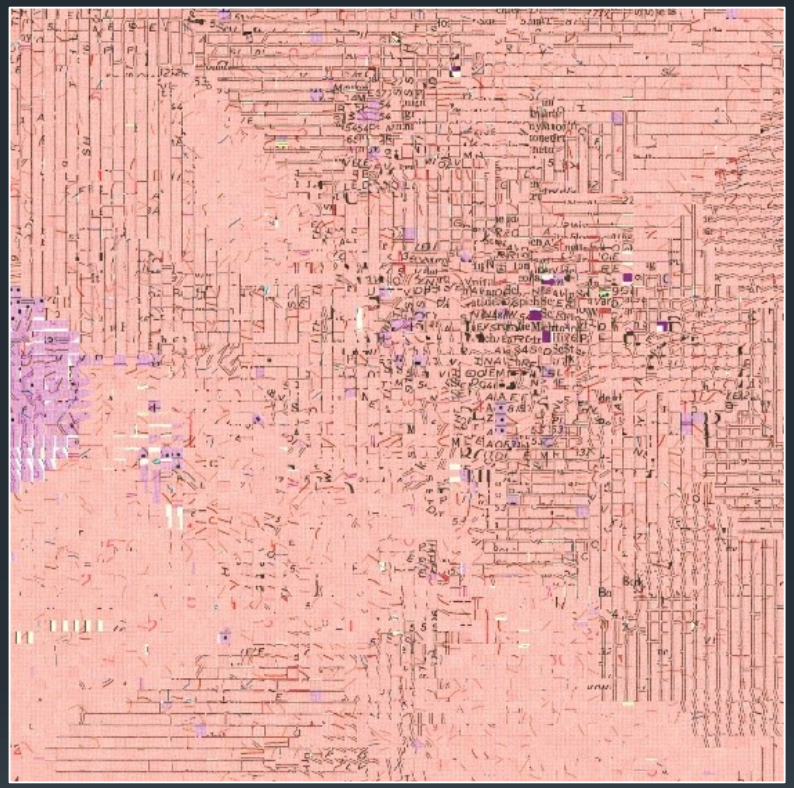
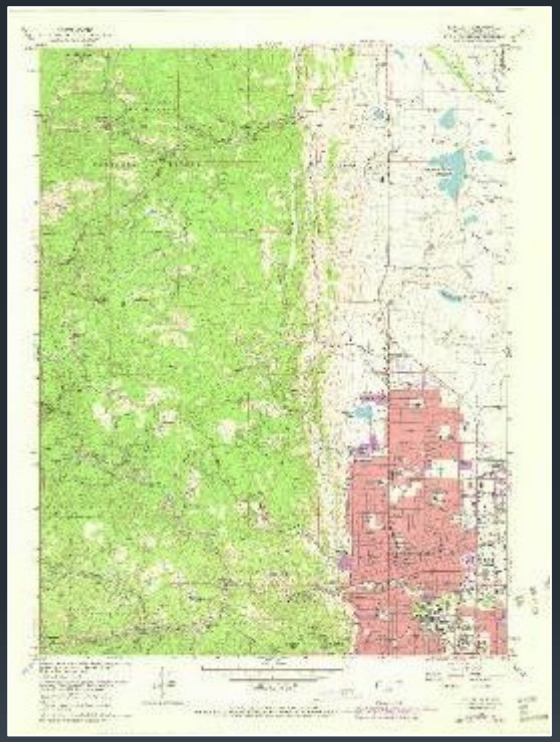




t-distributed stochastic neighbor embedding (t-SNE) plots for visual quality assessment

Clean graphic samples for learning process



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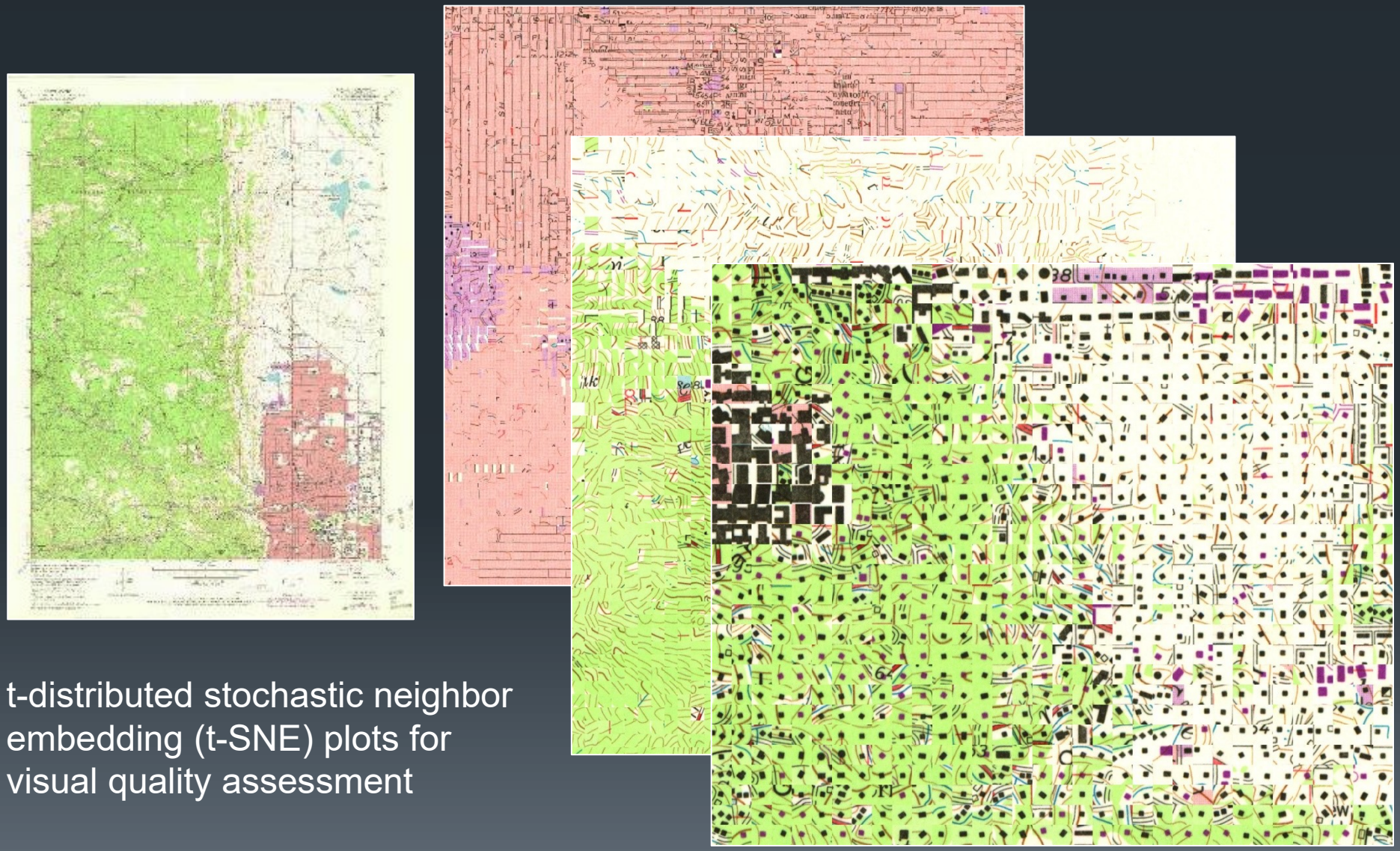


t-distributed stochastic neighbor embedding (t-SNE) plots for visual quality assessment

Feature extraction based on convolutional neural networks

Feature extraction based on convolutional neural networks

Feature extraction based on convolutional neural networks

Input data
42x42x3

Convolution + ReLU
20x5x5

MaxPooling
2x2

Convolution + ReLU
50x15x15

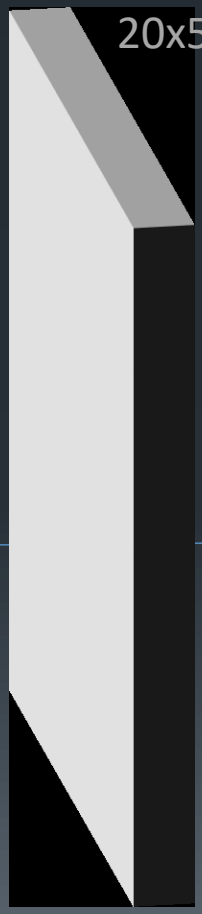
MaxPooling
2x2

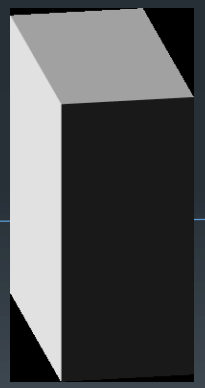
Fully connected
+ ReLU (500)

Fully connected
+ SoftMax (3)

=
Class scores
(urban,
single bldg.,
no building)

Feature extraction based on convolutional neural networks





LeNet architecture

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42x42x3

Convolution + ReLU
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MaxPooling
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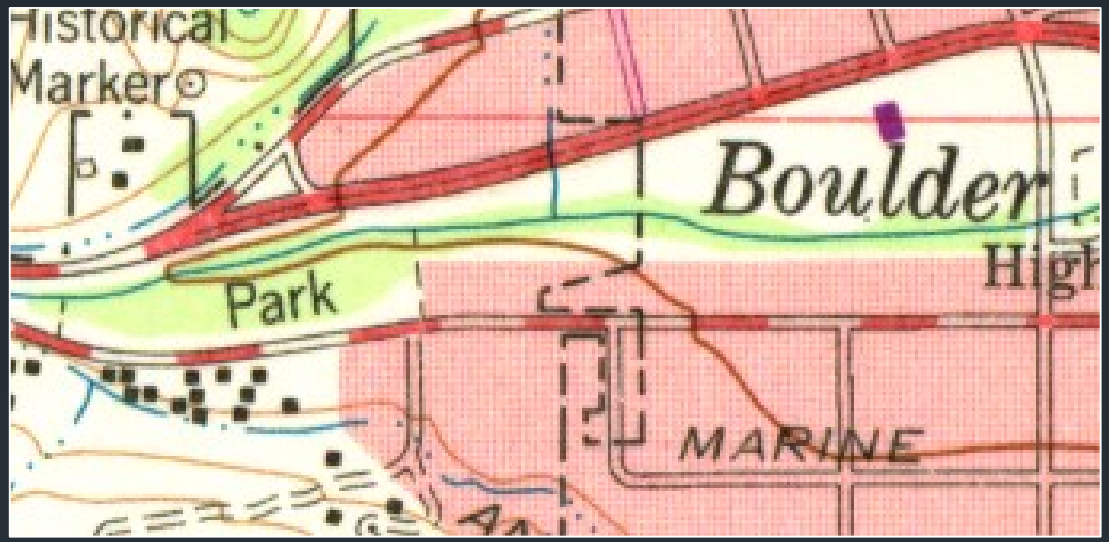
Preliminary Experimental Results



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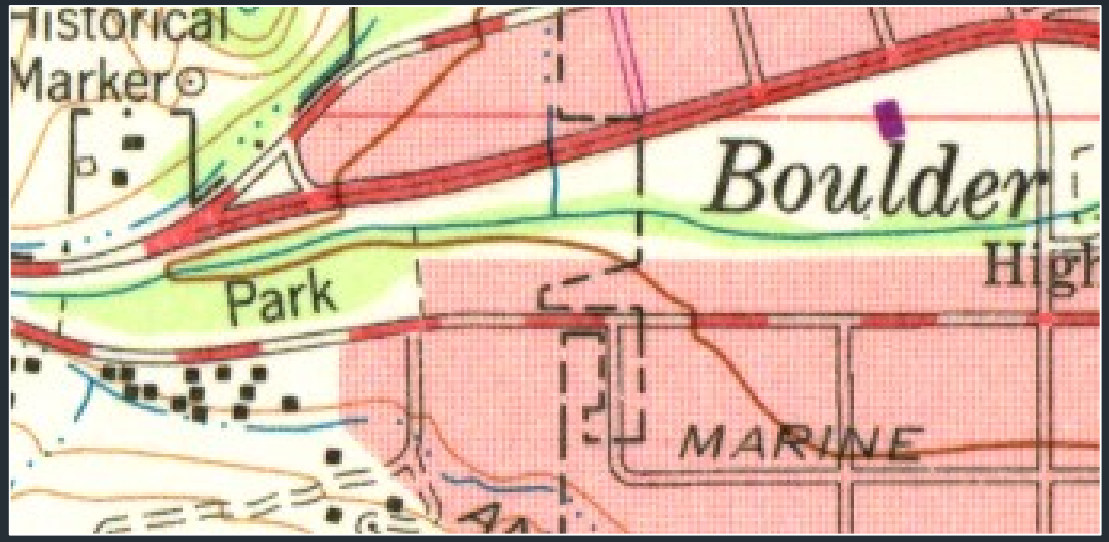

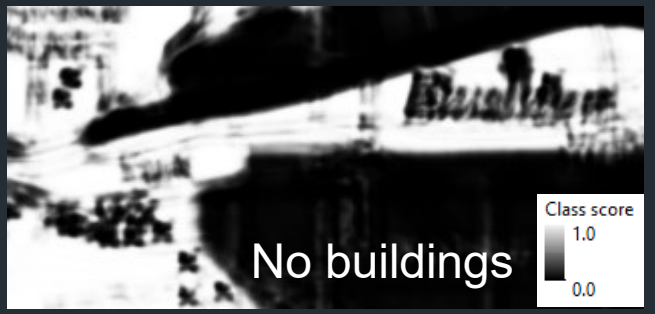

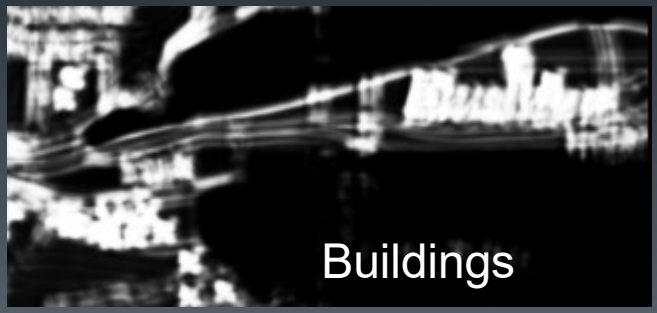

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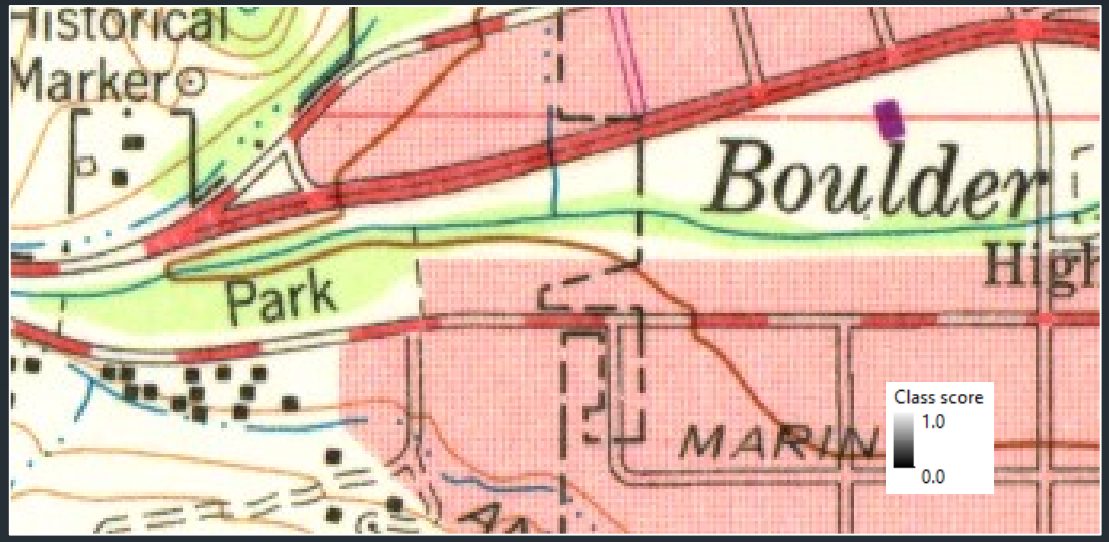

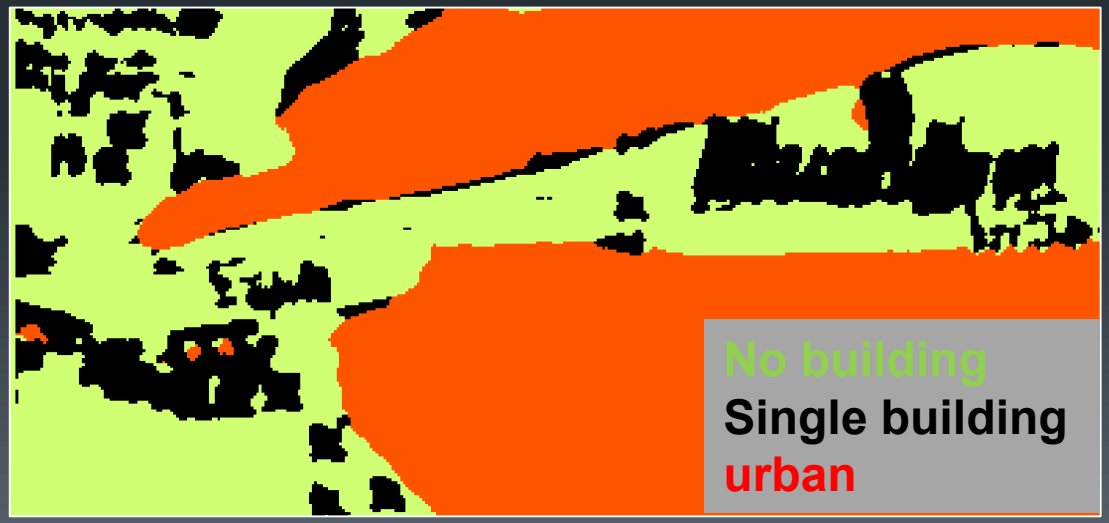

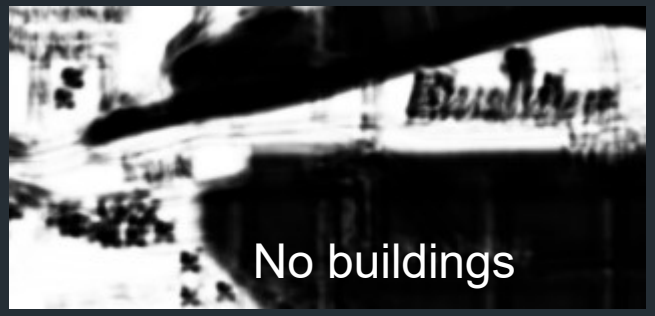

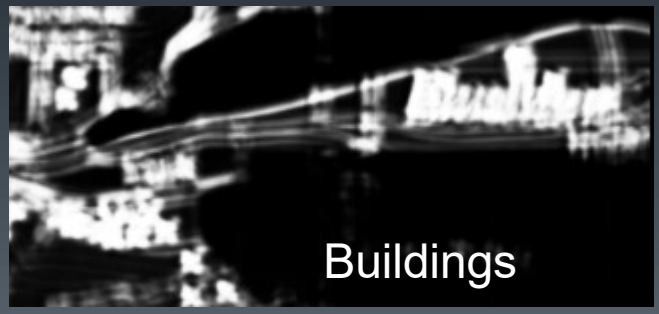

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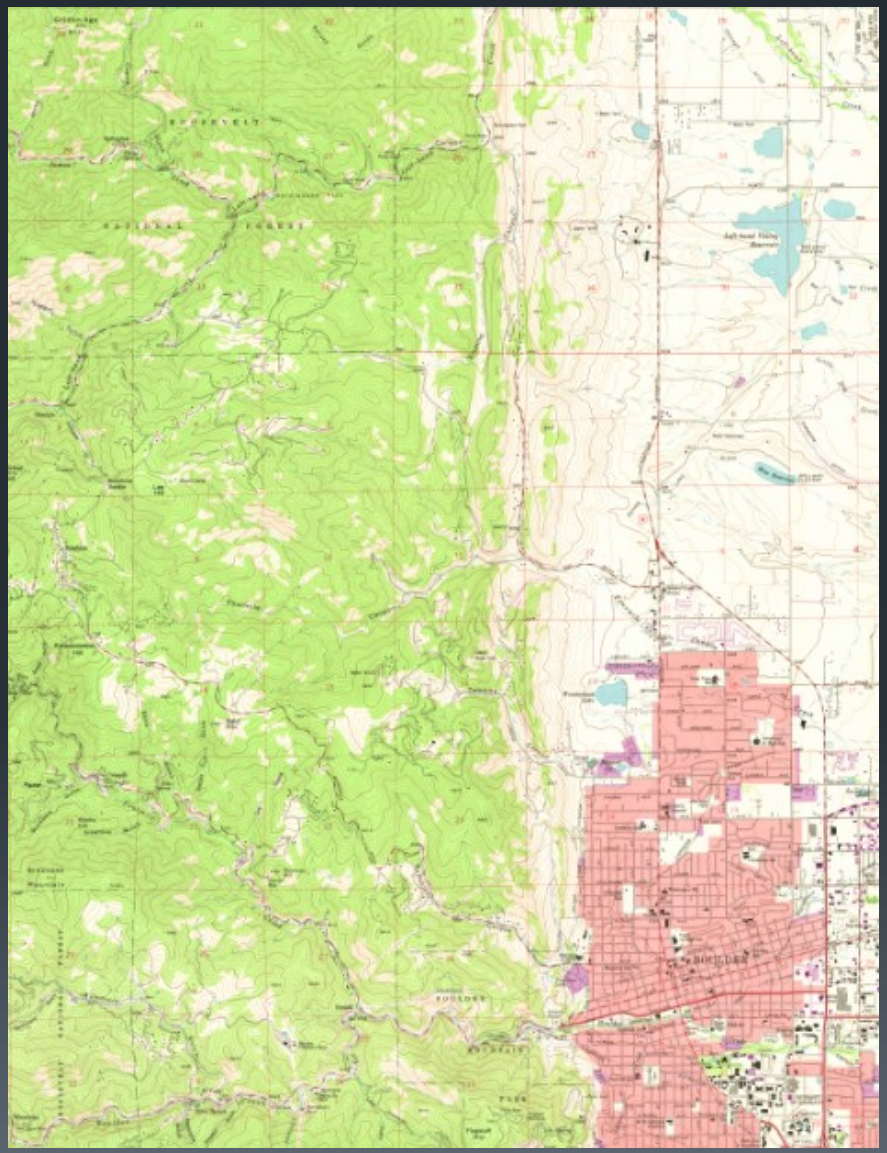

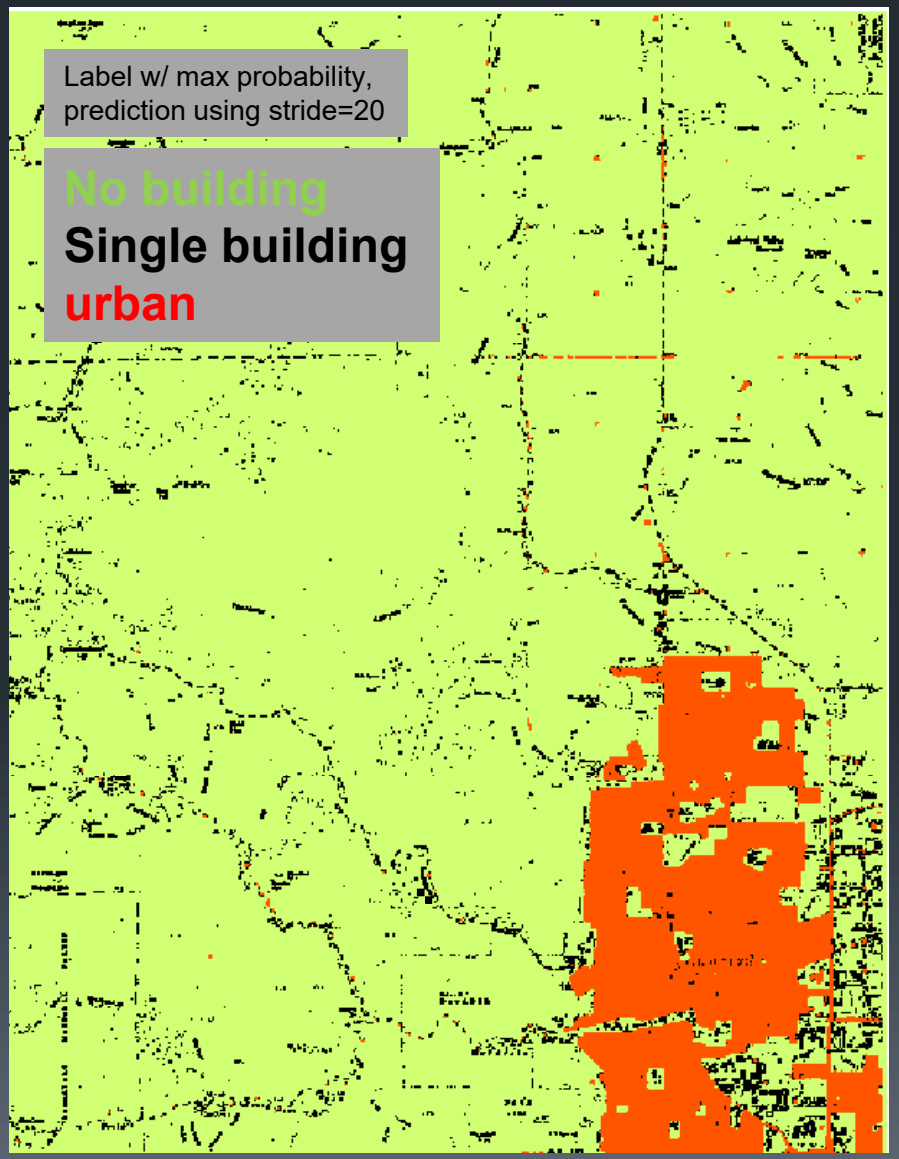

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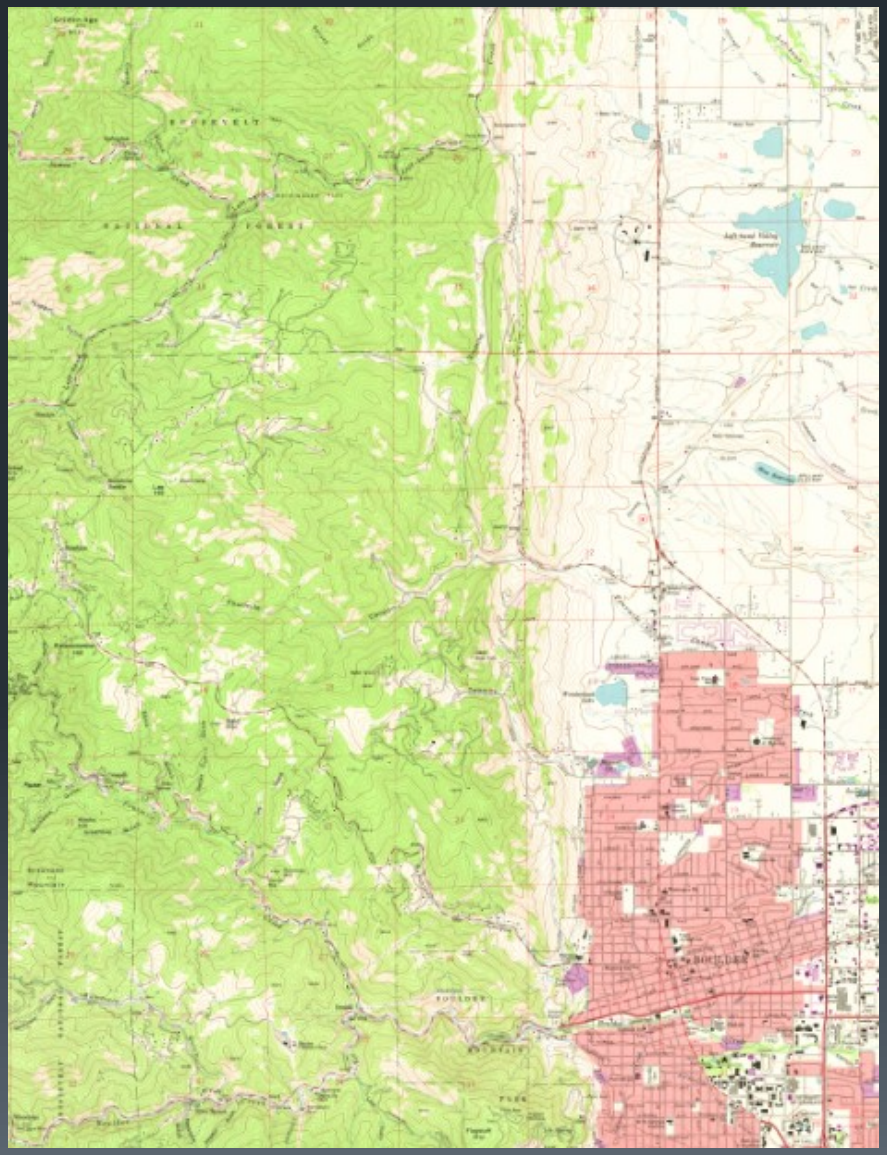
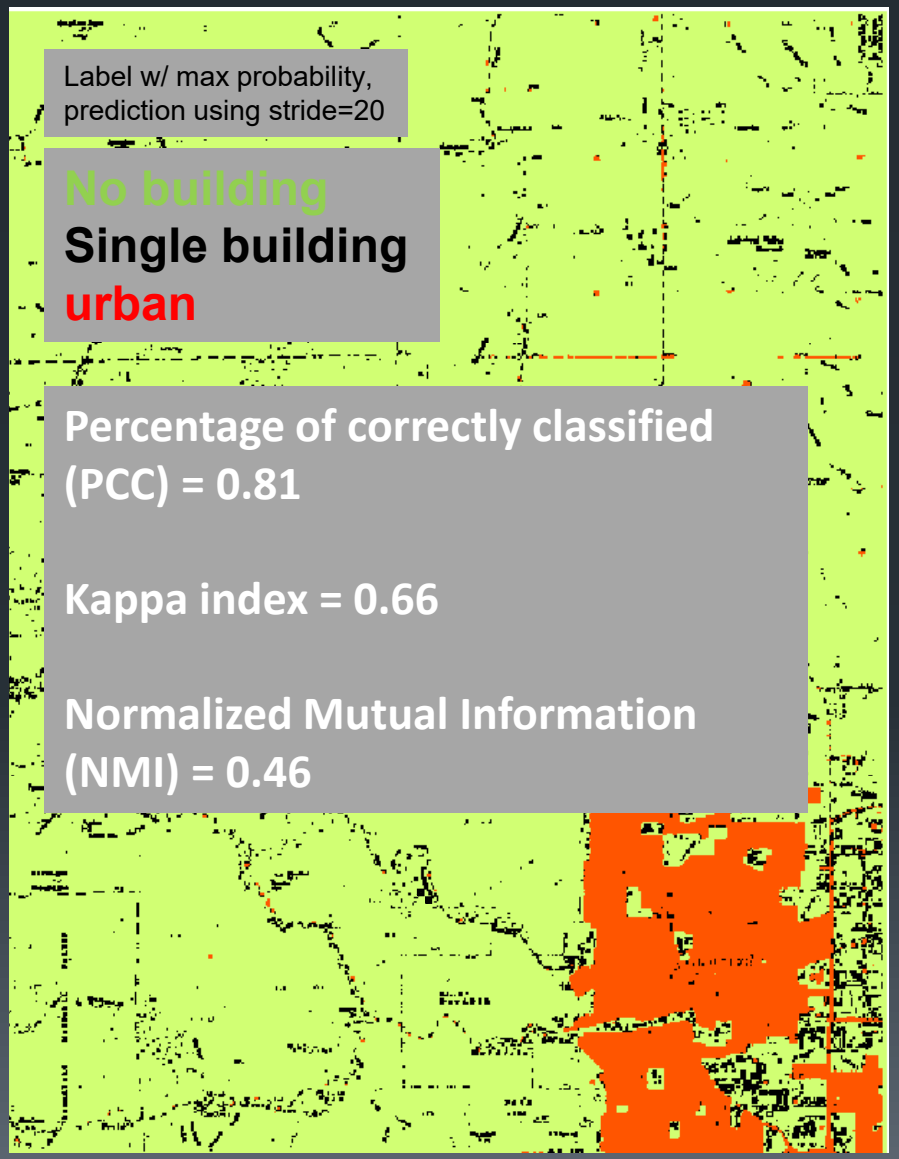
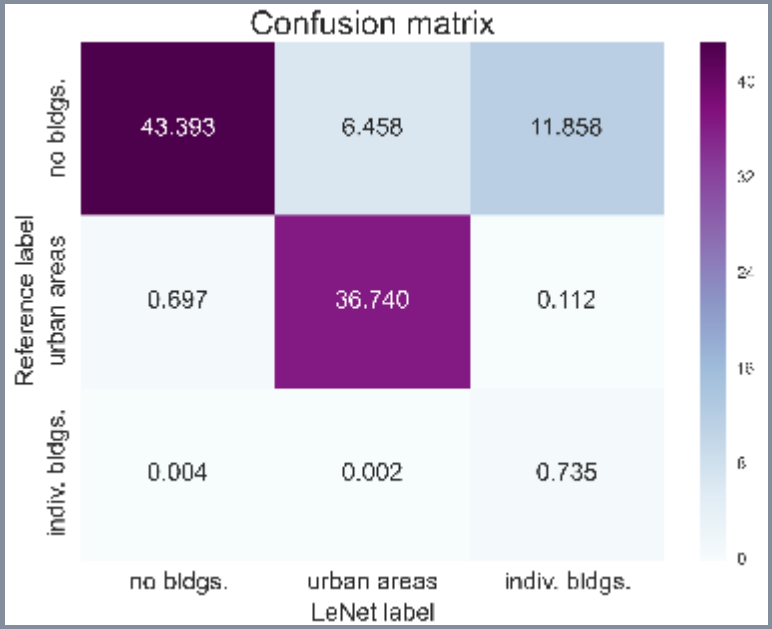
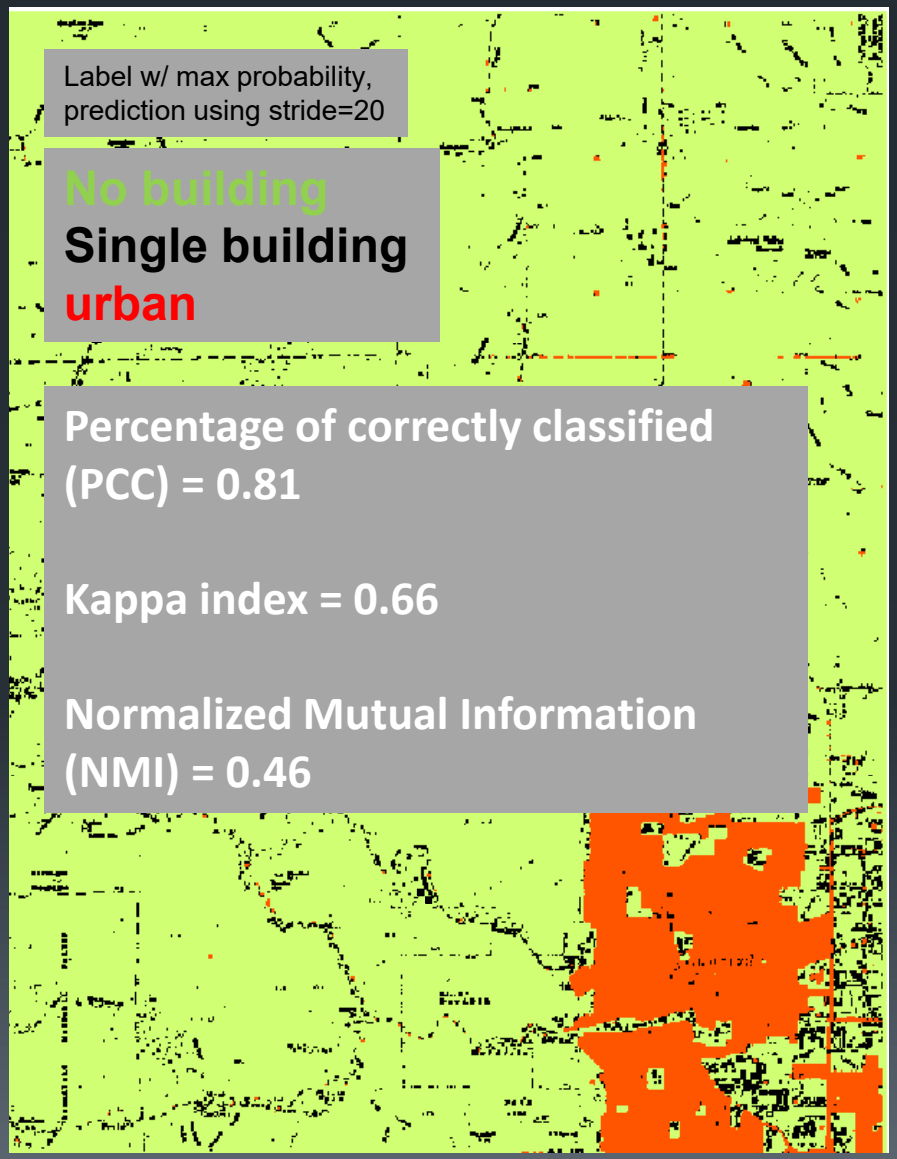




Preliminary Experimental Results

Class	Precision	Recall
No buildings	0.98	0.70
Urban area	0.85	0.98
Individual buildings	0.06	0.99





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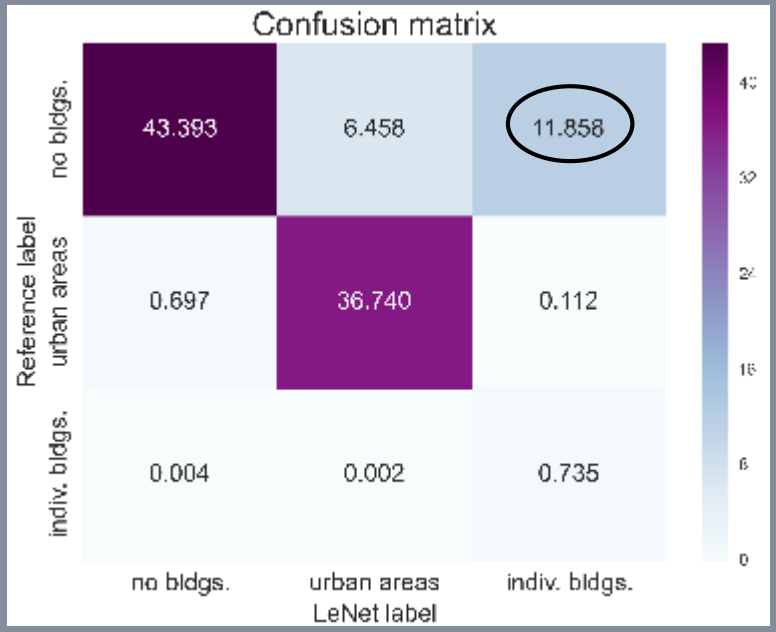
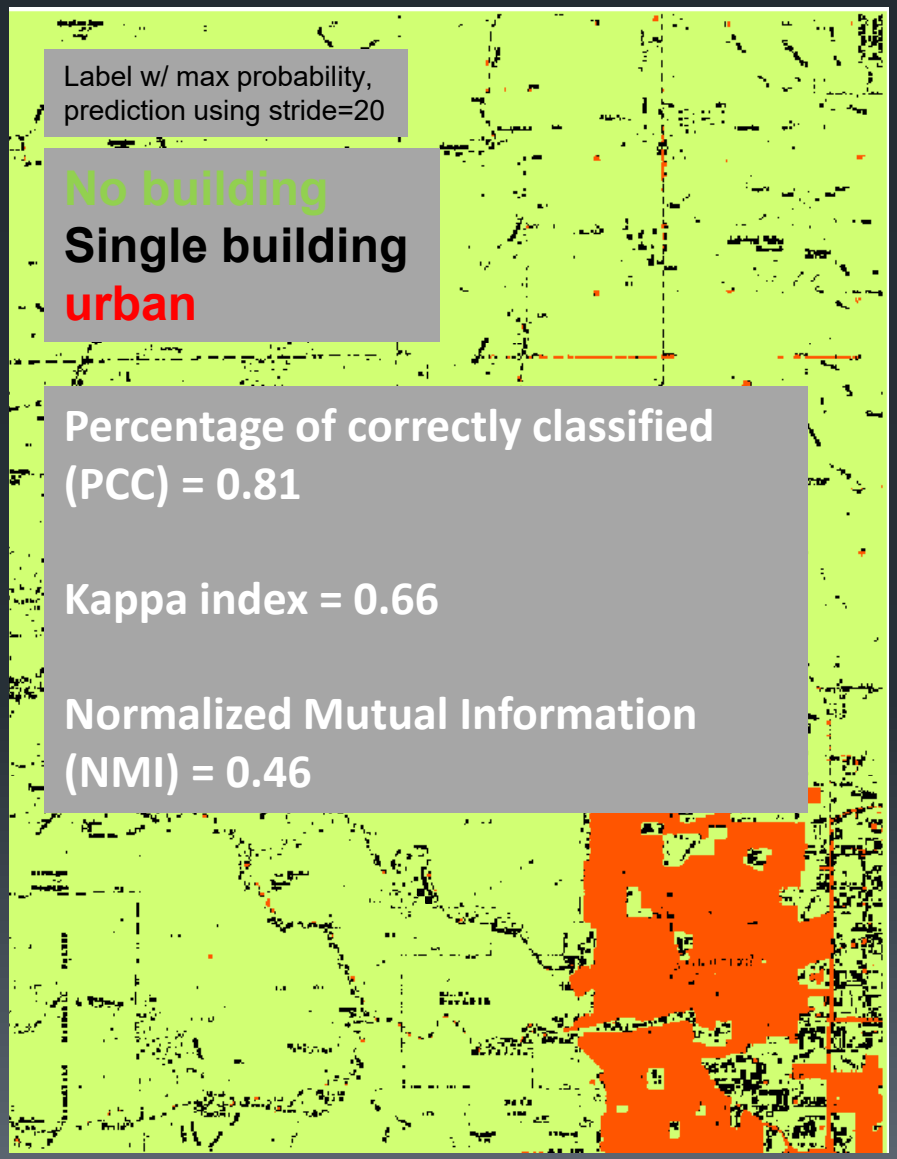




Discussion

- Availability of contextual geographic data + machine learning:
  - Great potential for **fully automatic** map recognition
- External (but not independent) contextual information:
  - Efficiently guides graphics sampling
- Elimination of user intervention:
  - Necessary to exploit large volumes of digital historical map archives

Acknowledgements

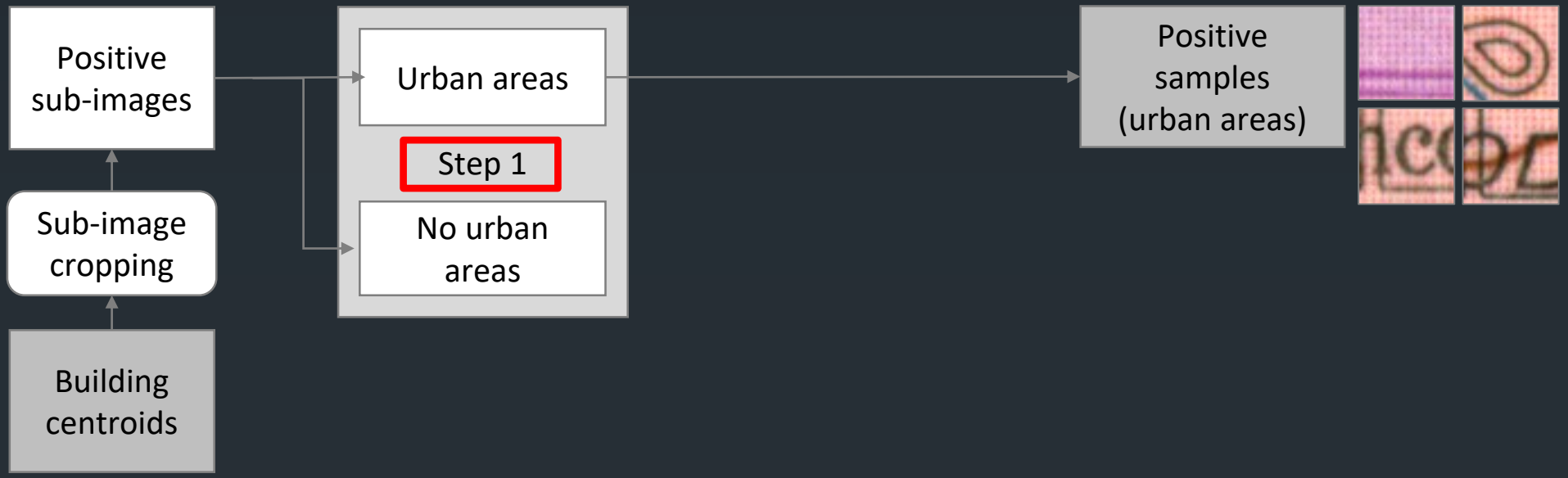
US National Science Foundation award IIS 1563933 to the University of Colorado at Boulder and IIS 1564164 to the University of Southern California

"*Exploiting Context in Cartographic Evolutionary Documents to Extract and Build Linked Spatial-temporal Datasets*"

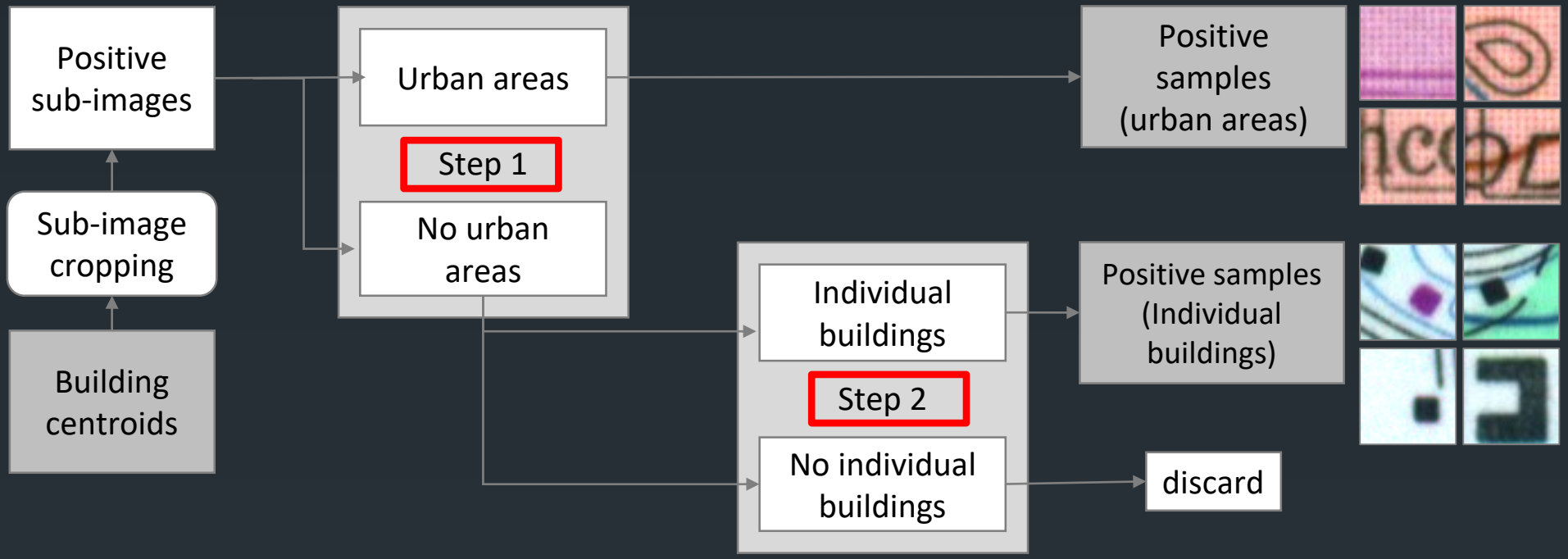
Additional material

Guided Graphics Sampling

Guided Graphics Sampling



Guided Graphics Sampling



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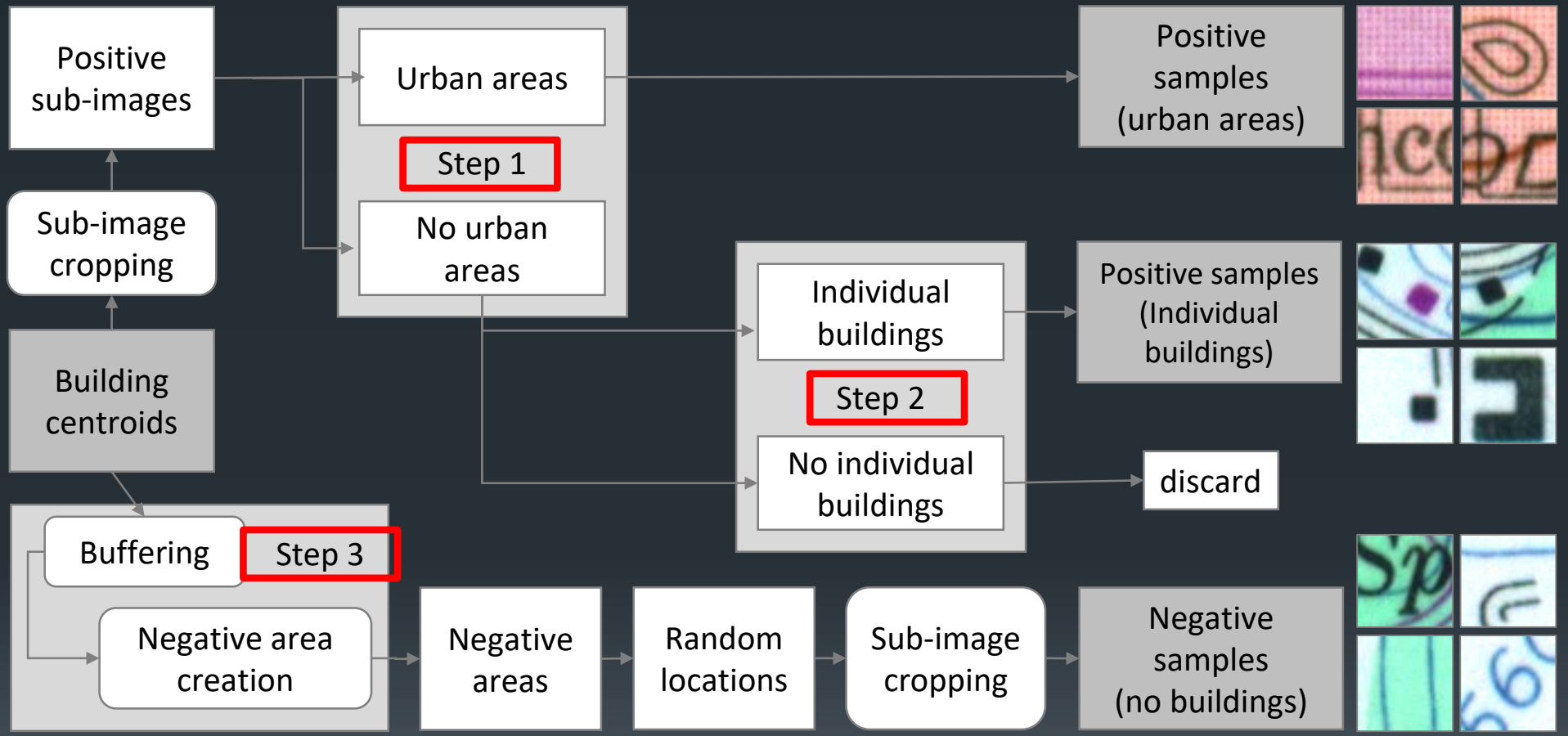

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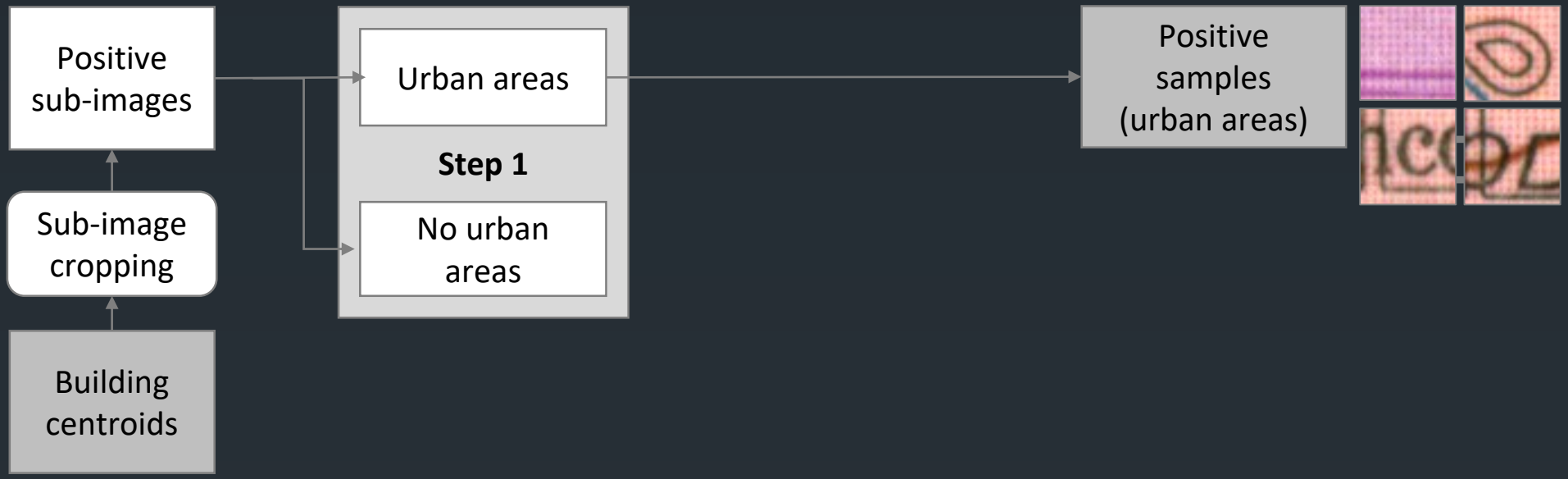

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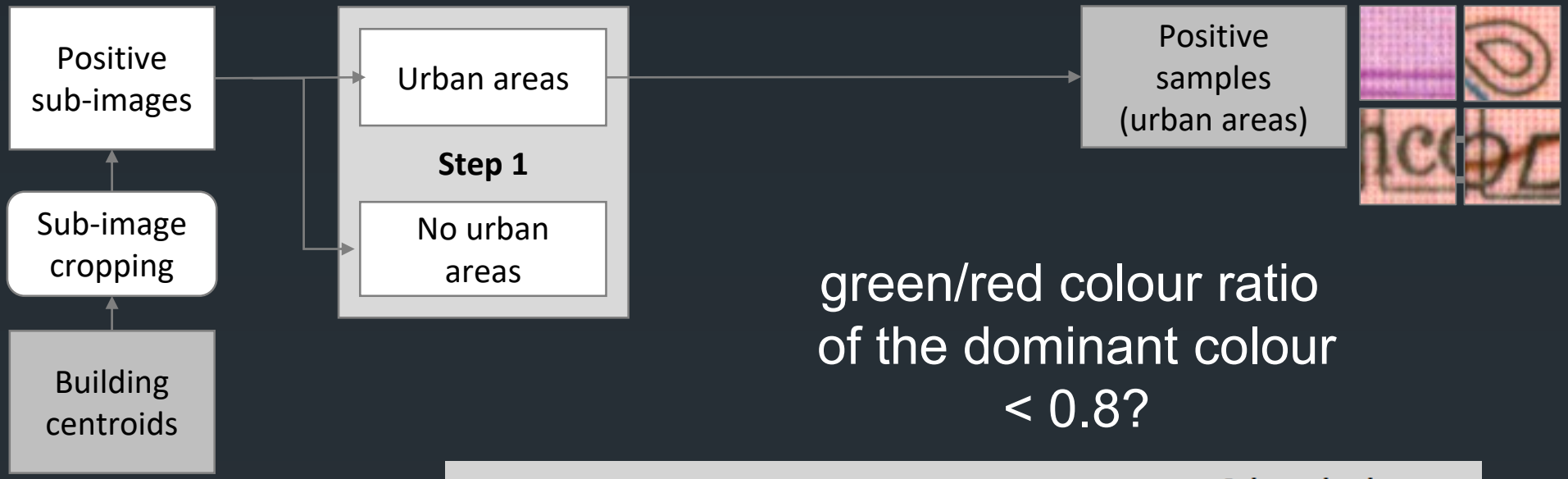
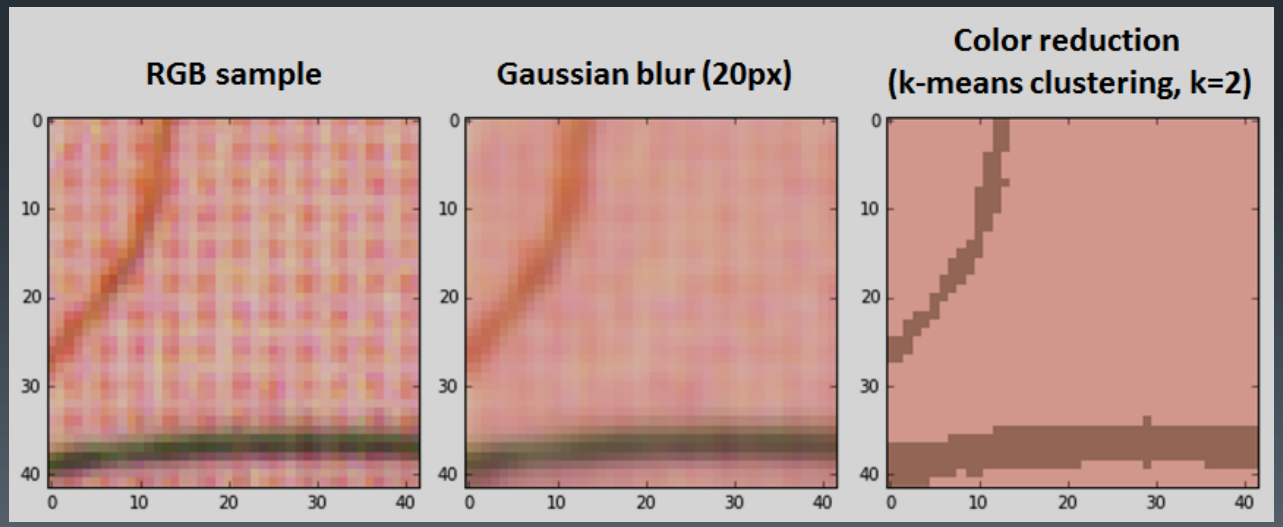


green/red colour ratio of the dominant colour < 0.8?



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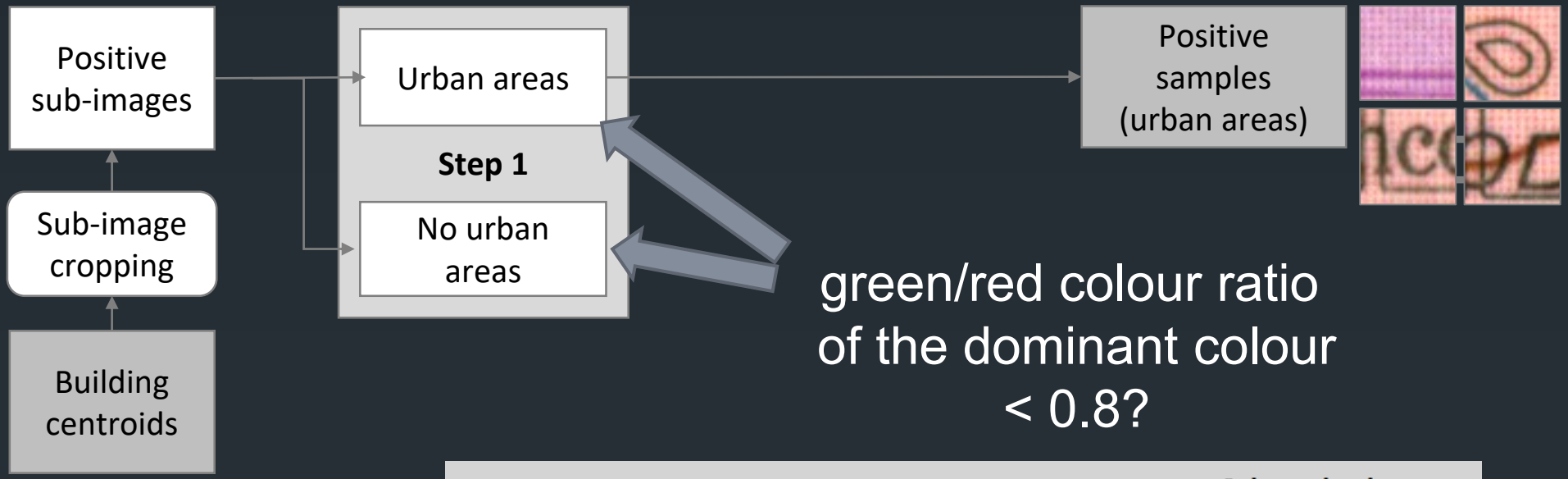

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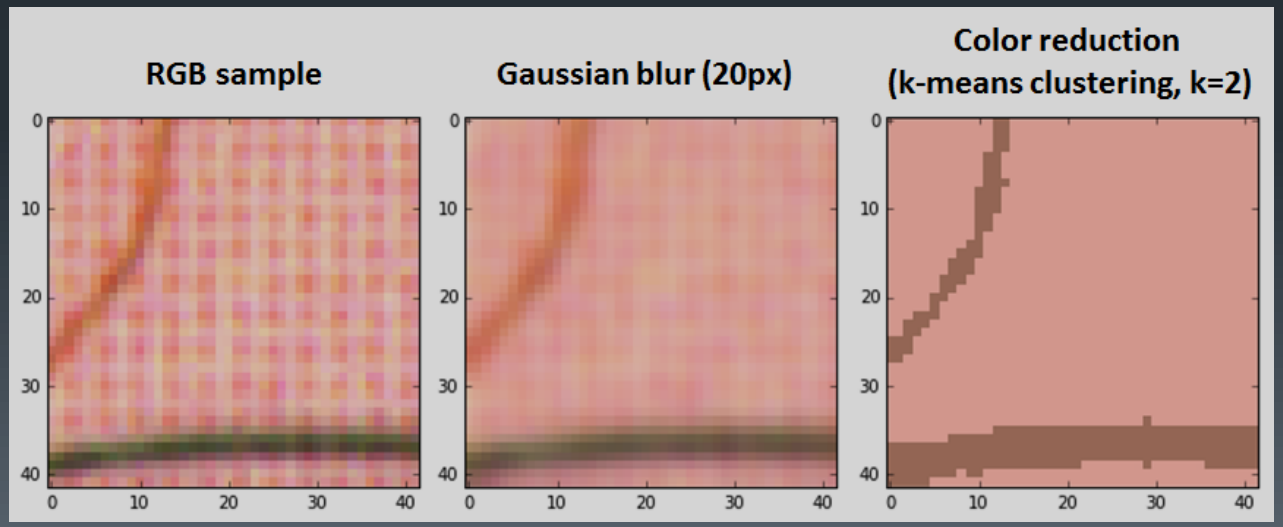

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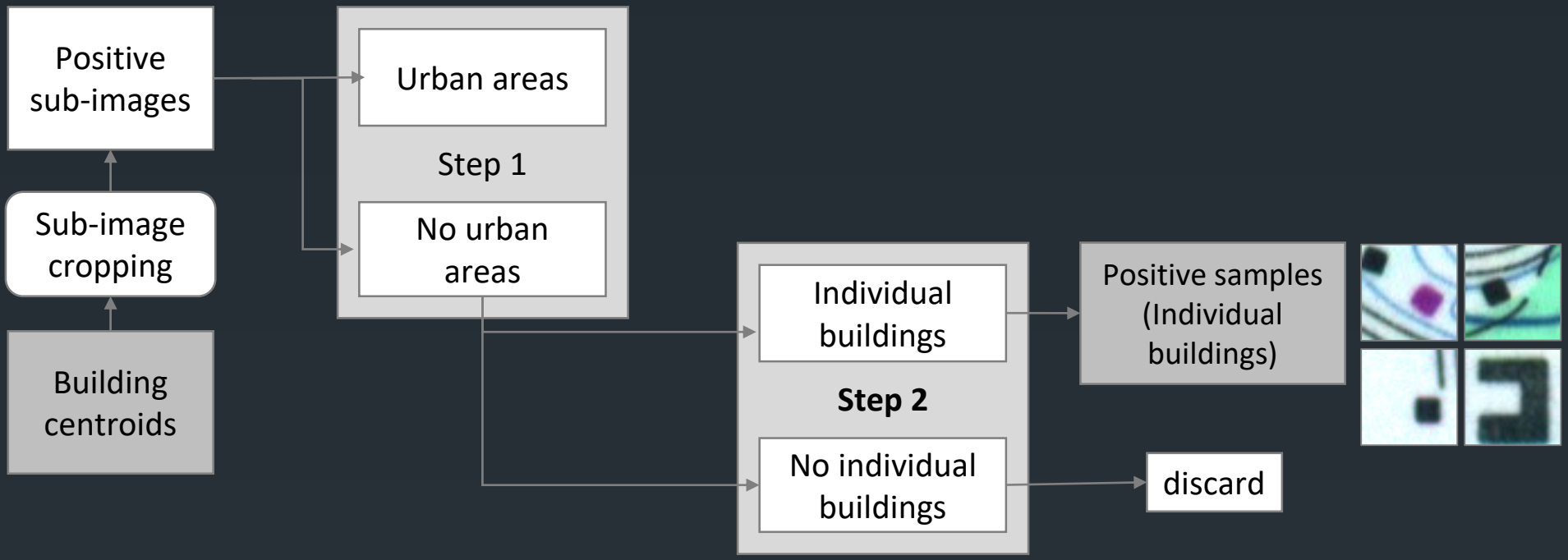

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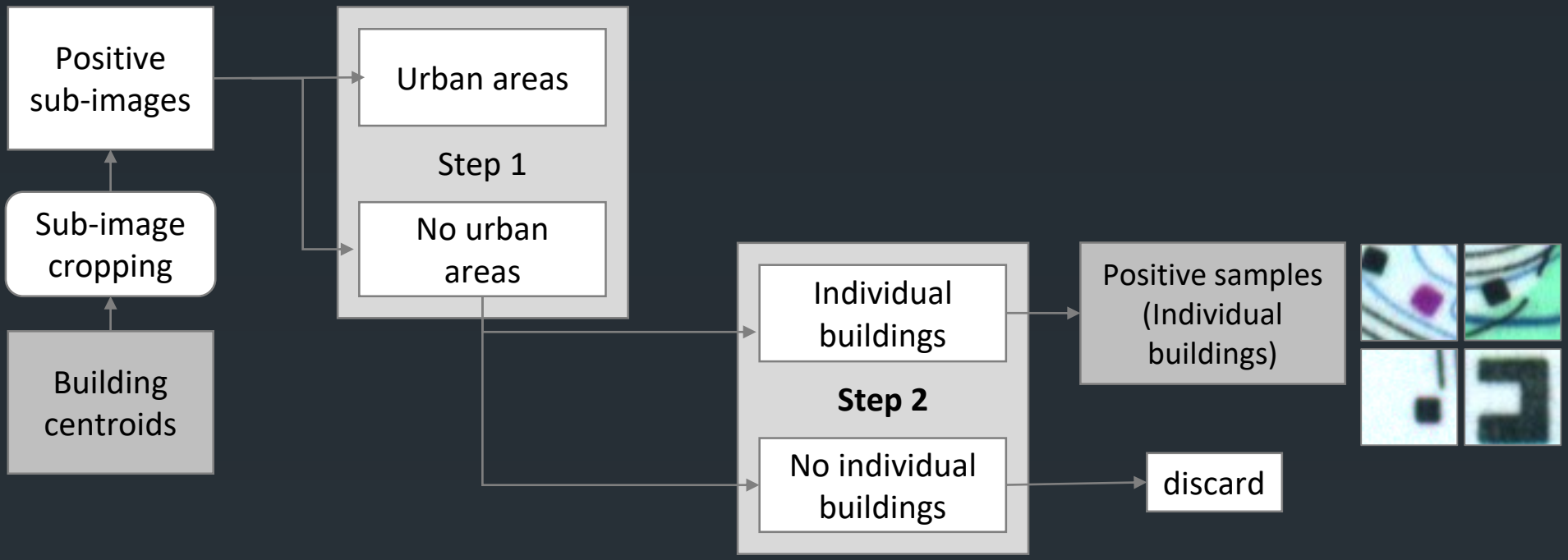

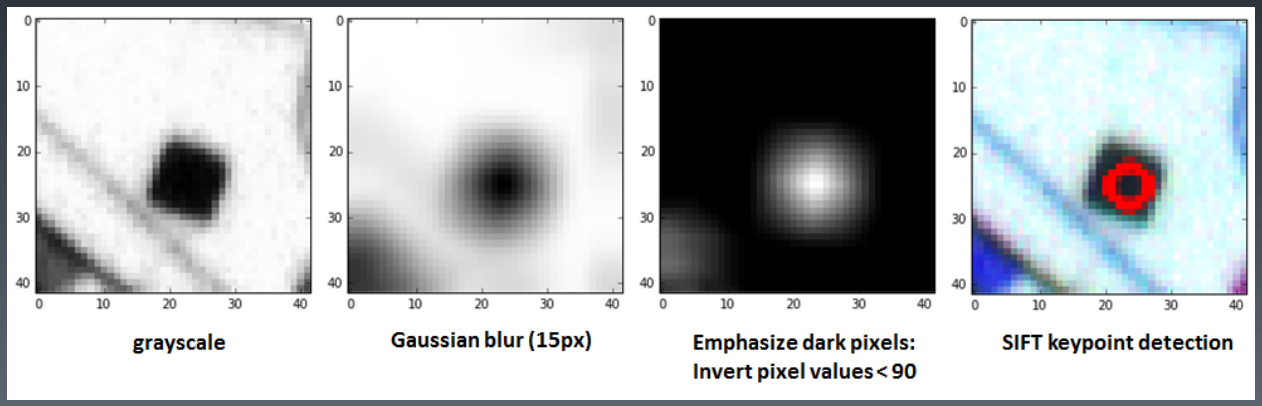

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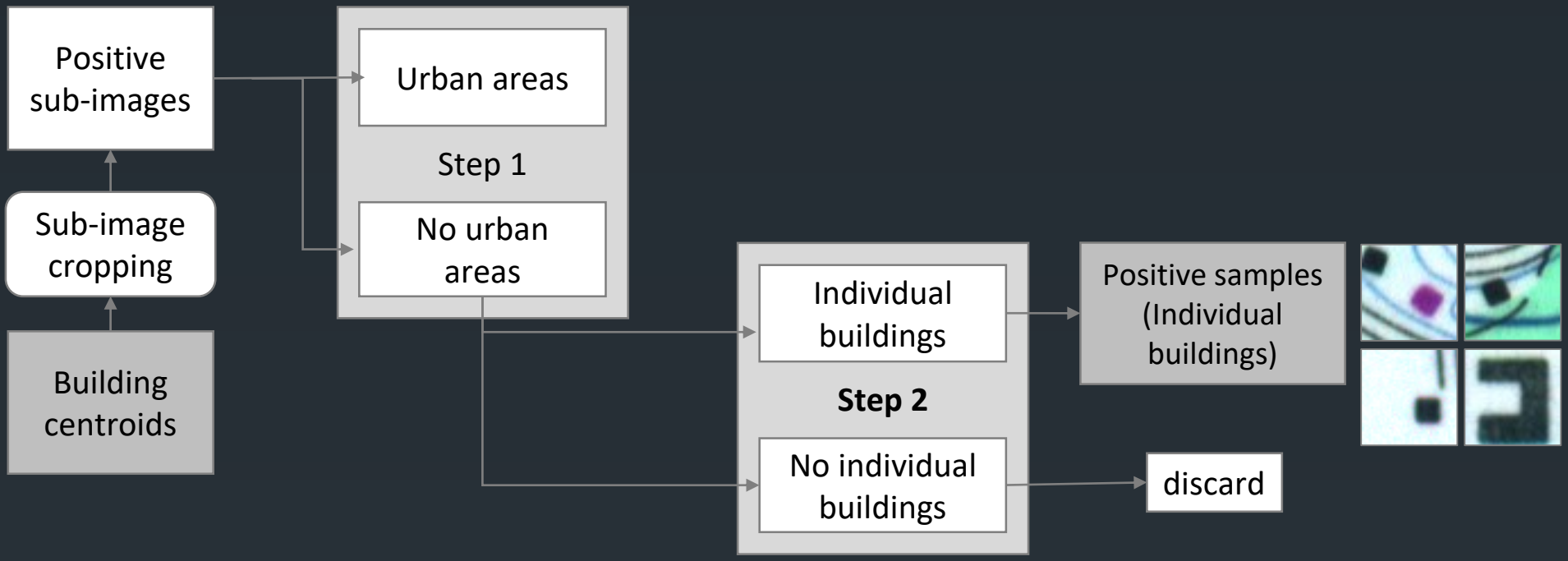
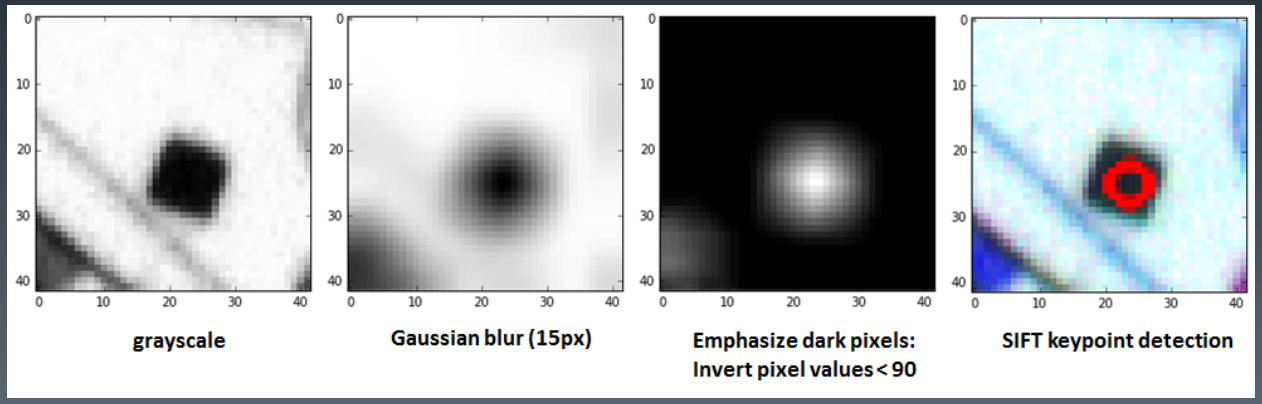


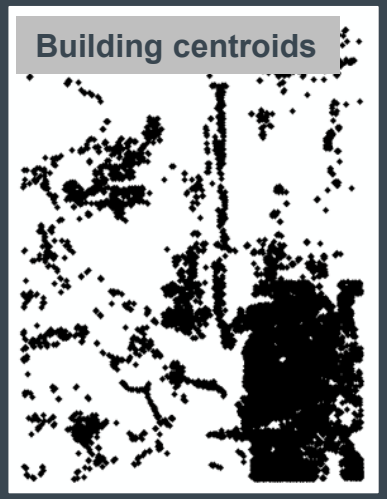


→ Maxima in the difference of Gaussian (DoG) scale space

→ DoG max at the center of a building

Guided Graphics Sampling

Guided Graphics Sampling



Building centroids

Buffering

Step 3

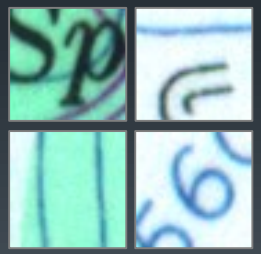
Negative area creation

Negative areas

Random locations

Sub-image cropping

Negative samples (no buildings)



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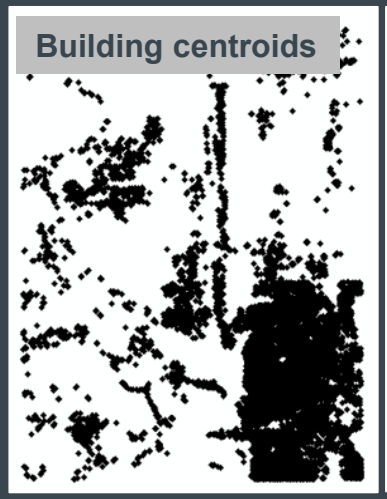

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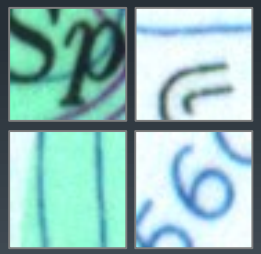

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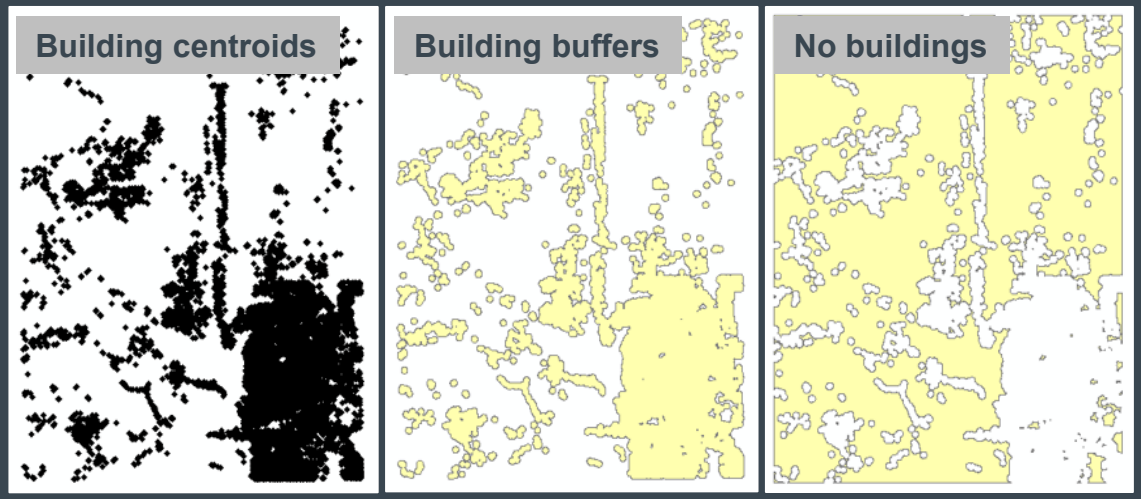

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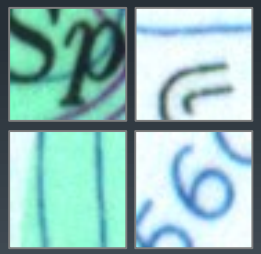

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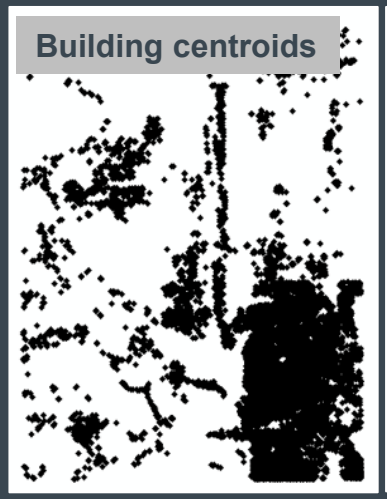

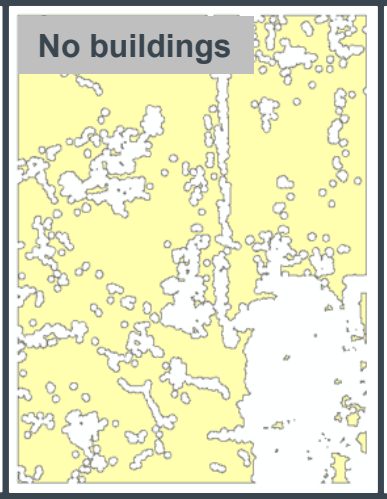

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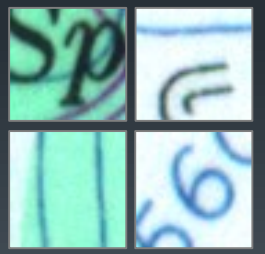
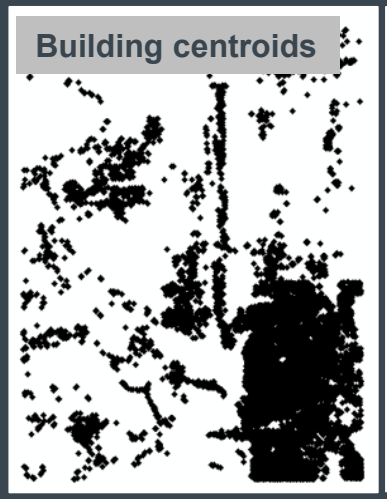
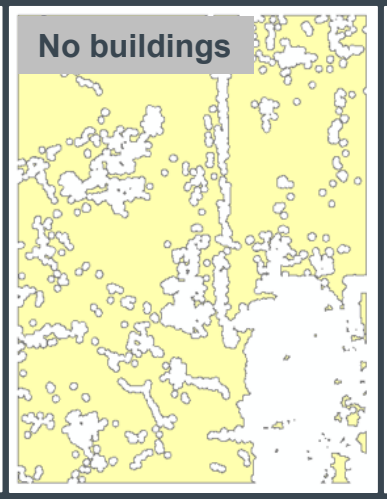
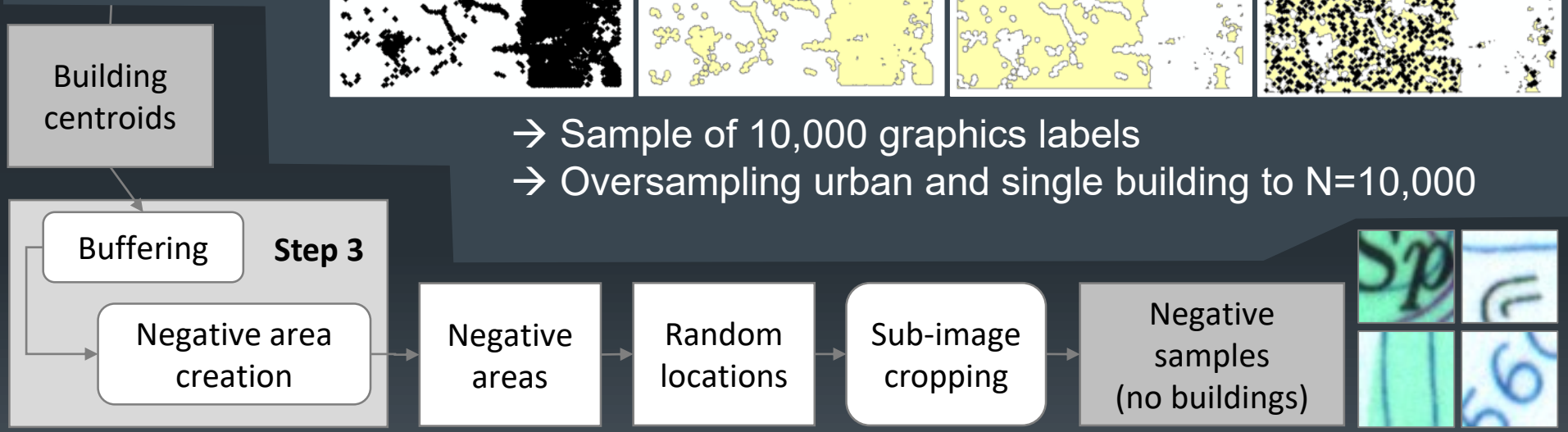


Guided Graphics Sampling

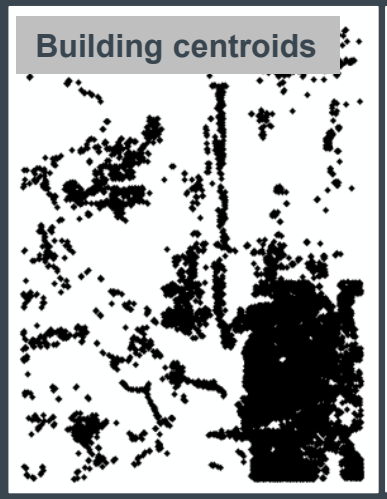


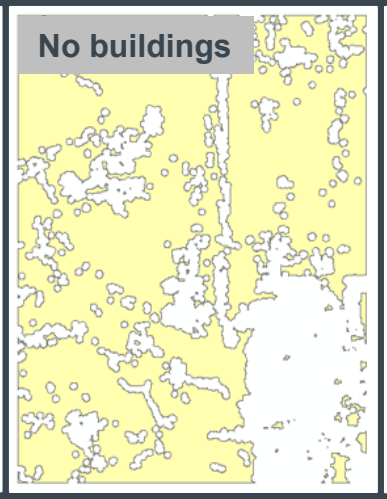


→ Sample of 10,000 graphics labels
→ Oversampling urban and single building to N=10,000



Guided Graphics Sampling





Building centroids

→ Sample of 10,000 graphics labels

→ Oversampling urban and single building to N=10,000

Step 3

Buffering

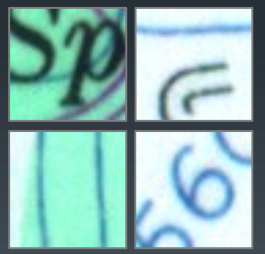
Negative area creation

Negative areas

Random locations

Sub-image cropping

Negative samples (no buildings)



→ Graphics samples as input data for **convolutional neural network**