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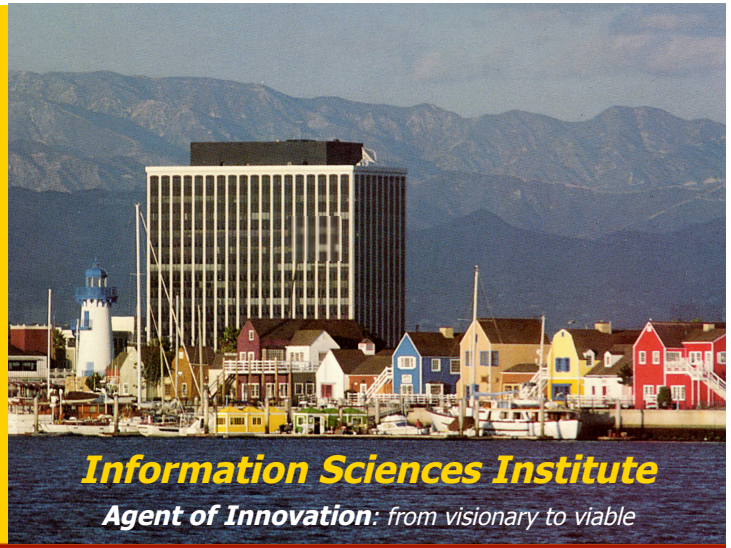

A General Approach to Discovering, Registering, and Extracting Features from Raster Maps

Craig Knoblock
University of Southern California
&
Geosemble Technologies

Joint work with Ching-Chien Chen, Yao-Yi Chiang, Aman Goel, Matthew Michelson, and Cyrus Shahabi

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Introduction

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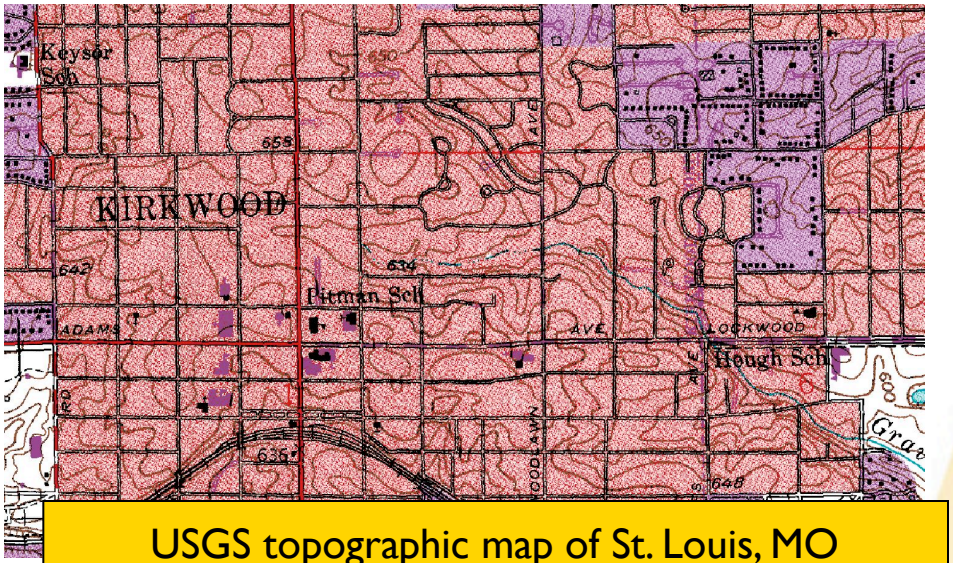
- **Raster maps are a rich source of geospatial data:**
  - Easily accessible
  - Many different types of information
  - Often contains information that cannot be found elsewhere

Travel map of Tehran, Iran



USGS topographic map of St. Louis, MO

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Challenges

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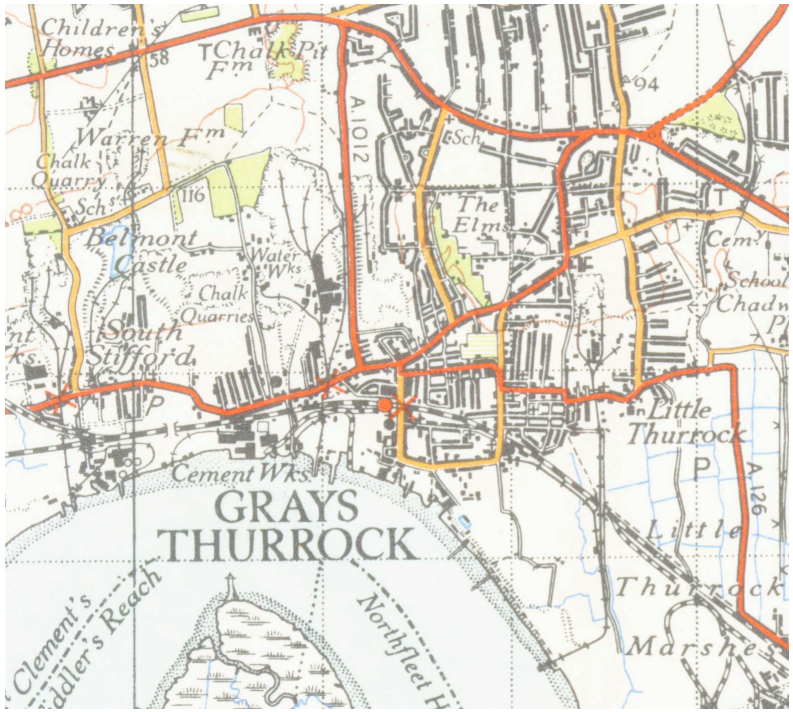
- **Maps have lots of useful information, but…**
  - They have overlapping features
  - There is limited access to the meta-data
  - Often only available in raster format
- **How do we find, register, and extract and recognize the features in a raster map**



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Outline

ISI Information Sciences Institute

- Map Discovery
- Automatic Extraction of Features
- Feature Extraction from Noisy Maps
- Automatic Registration of Maps
- Next Steps
- Related Work and Discussion

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ISI Information Sciences Institute

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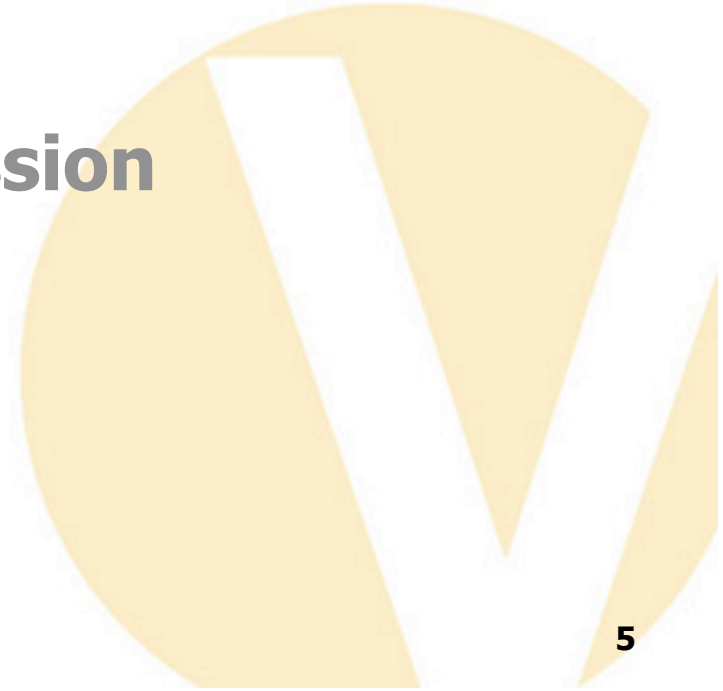

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Map Discovery

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- **Collect candidate maps from the Web**
  - —Standalone maps
    - *Found using an image search engine*
  - —Maps embedded in PDF documents
    - *Found using a general search engine and then extracting the images*
- **Classify the images**
  - —Extract features from the images
  - —Identify similar images using Content Based Image Retrieval (CBIR)
  - —Classify the image using k-Nearest Neighbor

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Identifying Maps

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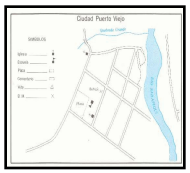
Image Server

Map Image Repository

Non-Map Image Repository

Our approach :

- Extract features
- Find similar images
- Classify image

Map Server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Extract Features

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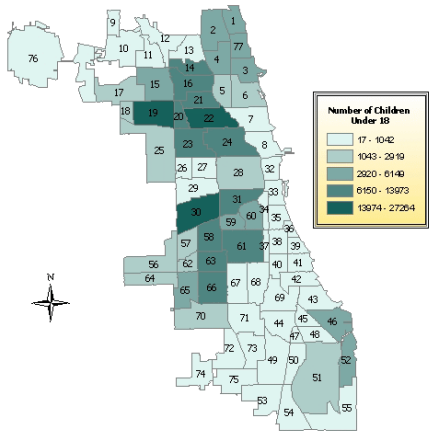
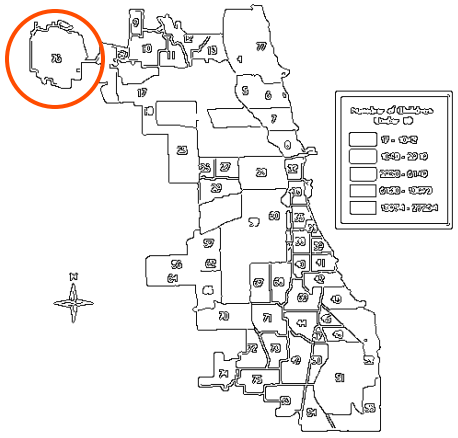
- **Water-filling features**
  - Zhou, X.S. et al. - Water-filling: A novel way for image structure feature extraction, 1999, Intl. conference on Image Processing
  - Works well on images with strong edges





    - Works on standard Canny edge maps of original images
      - Color invariant

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Water-Filling Features

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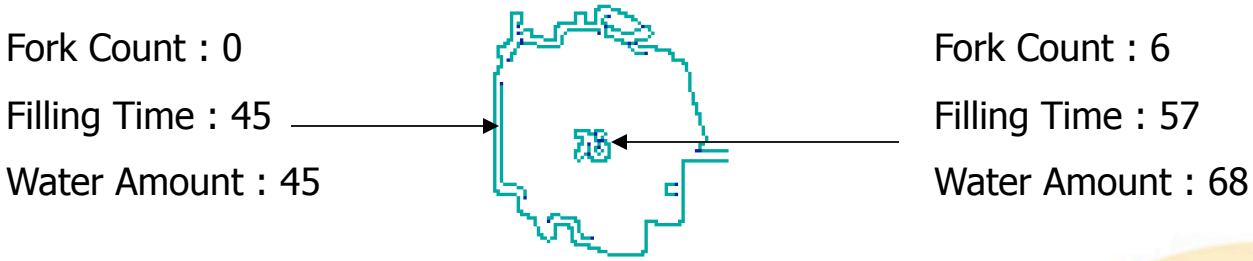
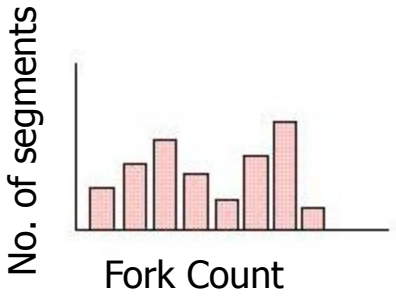
- Features computed for each segment



- Normalized histogram - size invariant



- 3 features x 8 buckets = 24 element feature vector

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Content-Based Image Retrieval (CBIR)

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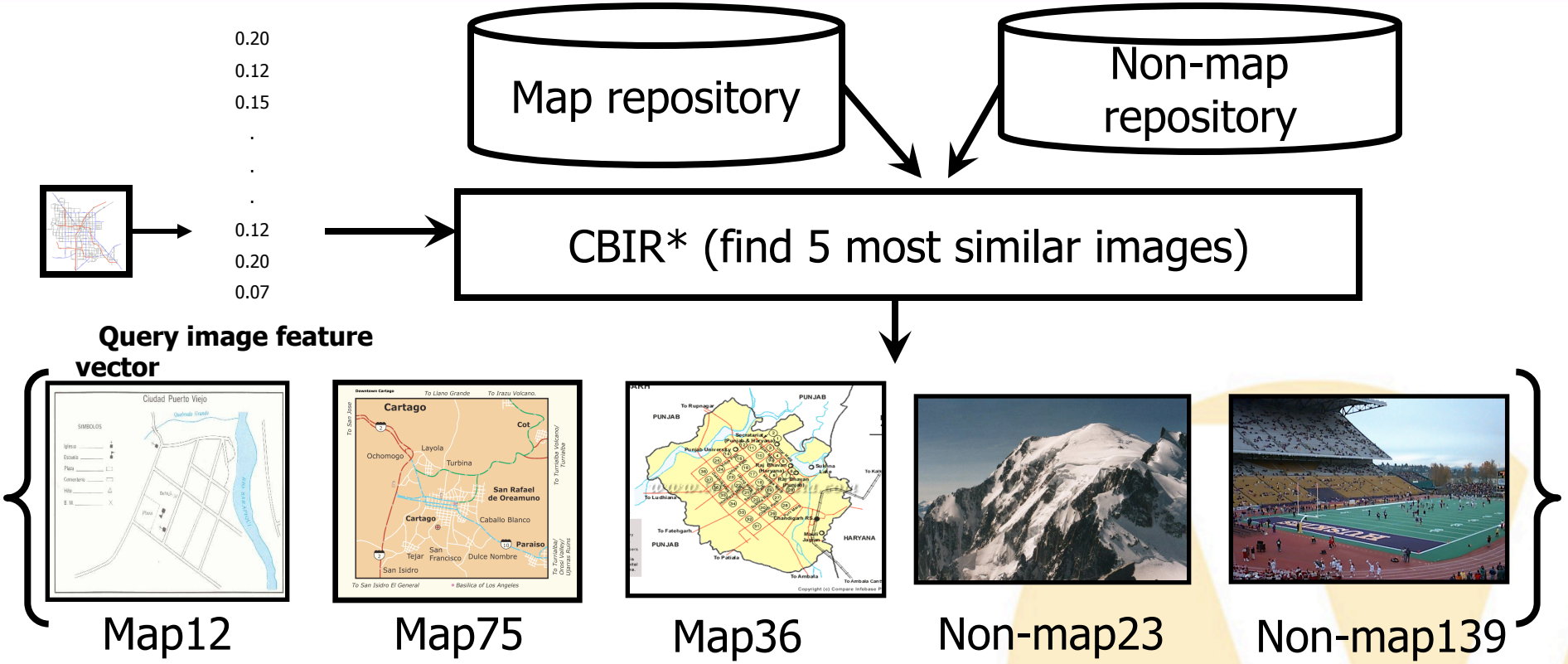

- Built on top of Lire system

* In our experiment we used 9 similar images

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k - Nearest neighbor classification

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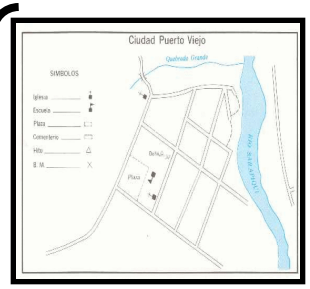
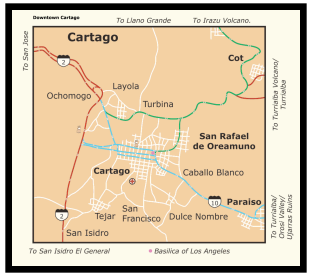


Map12

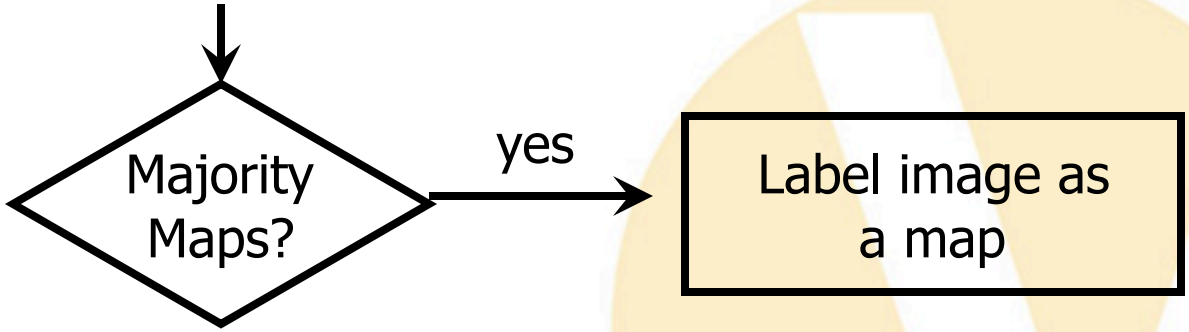


Map75

Map36

Non-map23

Non-map139



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Results

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Precision	Recall	F1-measure
77.39%	71.20%	74.17%

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Results are average over 10 runs

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Background Removal

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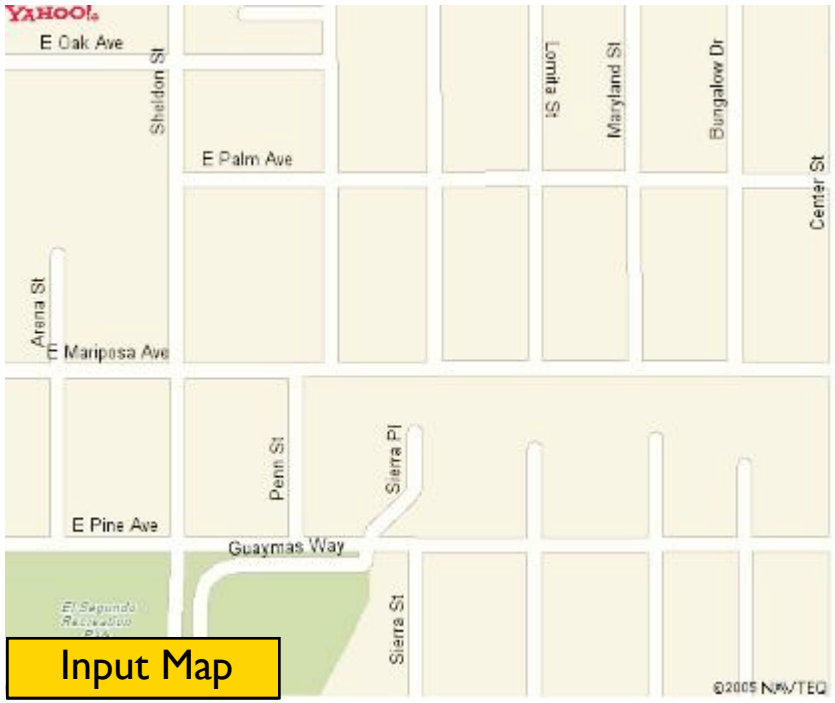
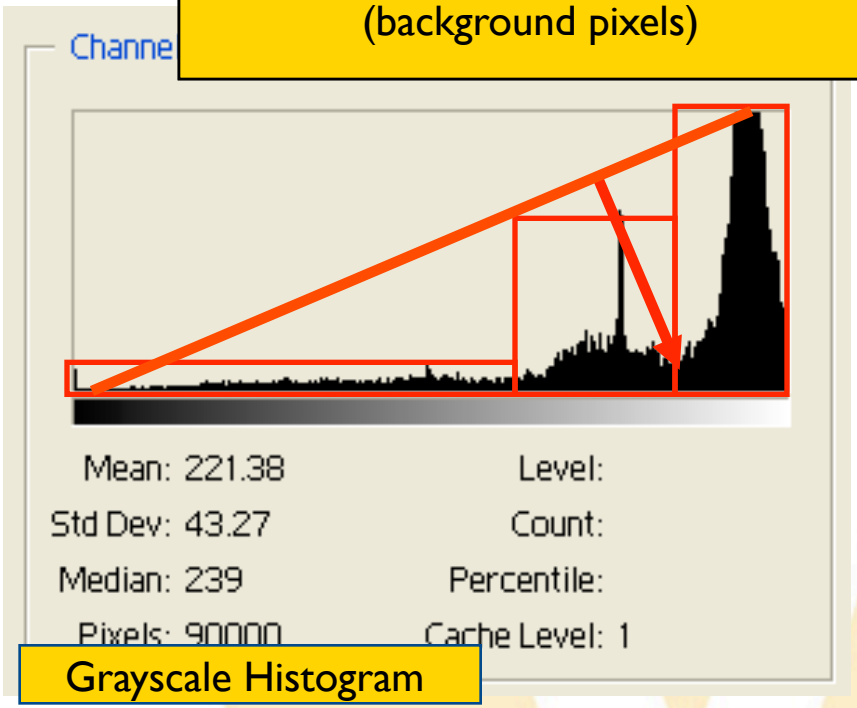
- **Use the Triangle method (Zack, 1977) to locate clusters in the grayscale histogram**
- **Remove the background clusters**



Input Map

Remove the dominate cluster (background pixels)



Grayscale Histogram

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Text/Graphics Separation

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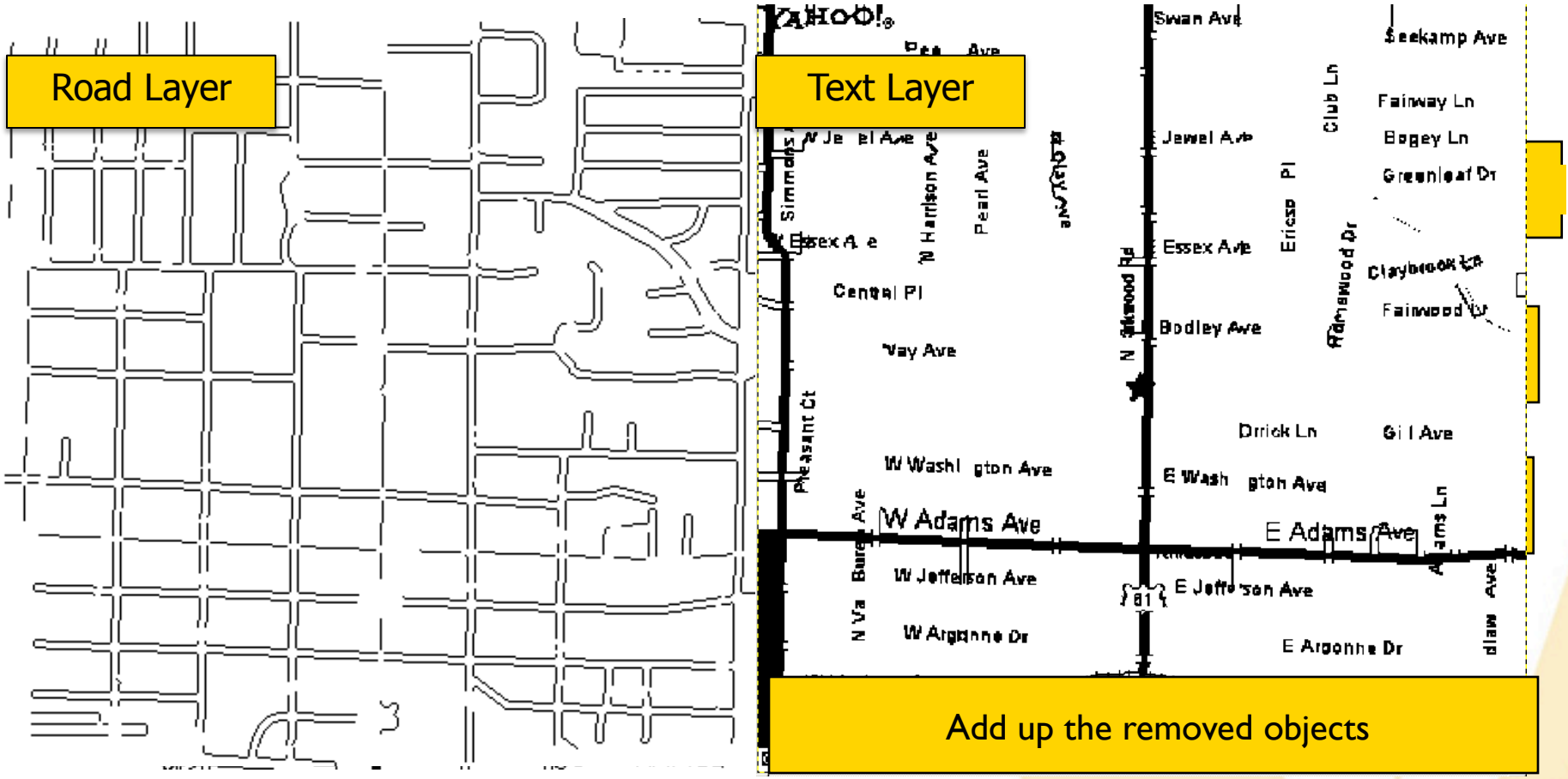
- **Separate linear structures from text (Cao and Tan, 02)**



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Road Format and Road Width Detection

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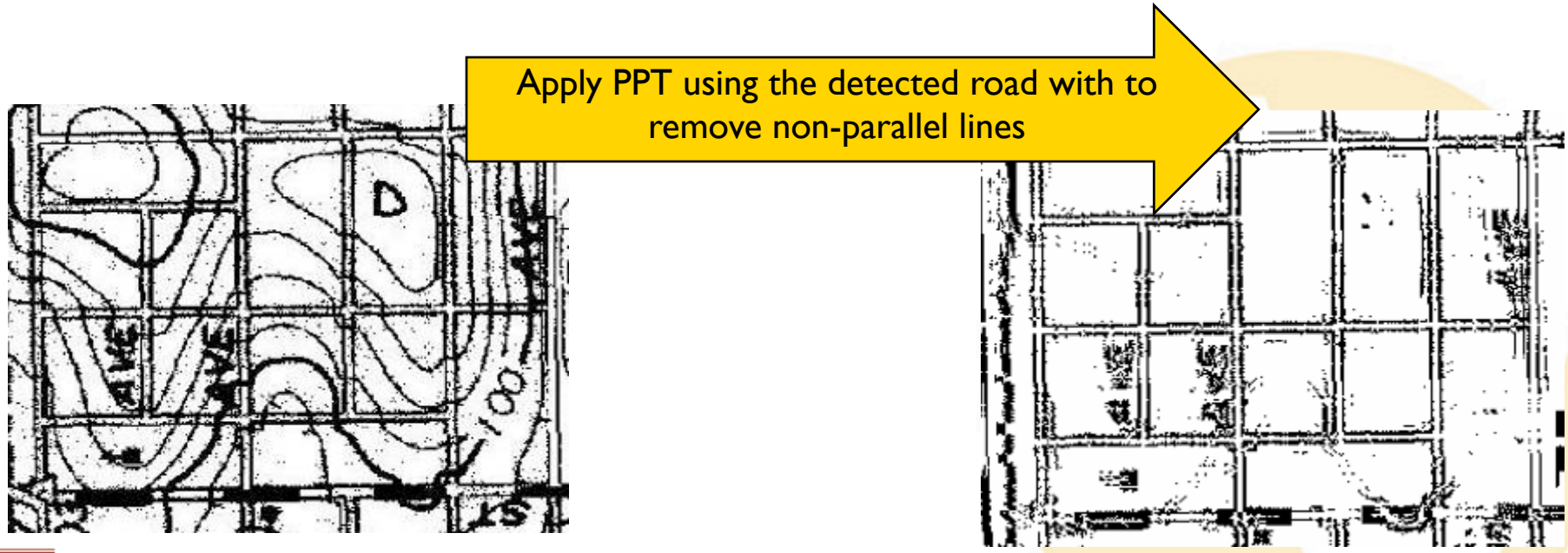
- **Apply parallel-pattern tracing (PPT) iteratively on different sizes of road width**
- **If it is a double-line road layer, the actual road width**
  - Has the maximum percentage of parallel pattern pixels
  - The percentage is larger than a threshold



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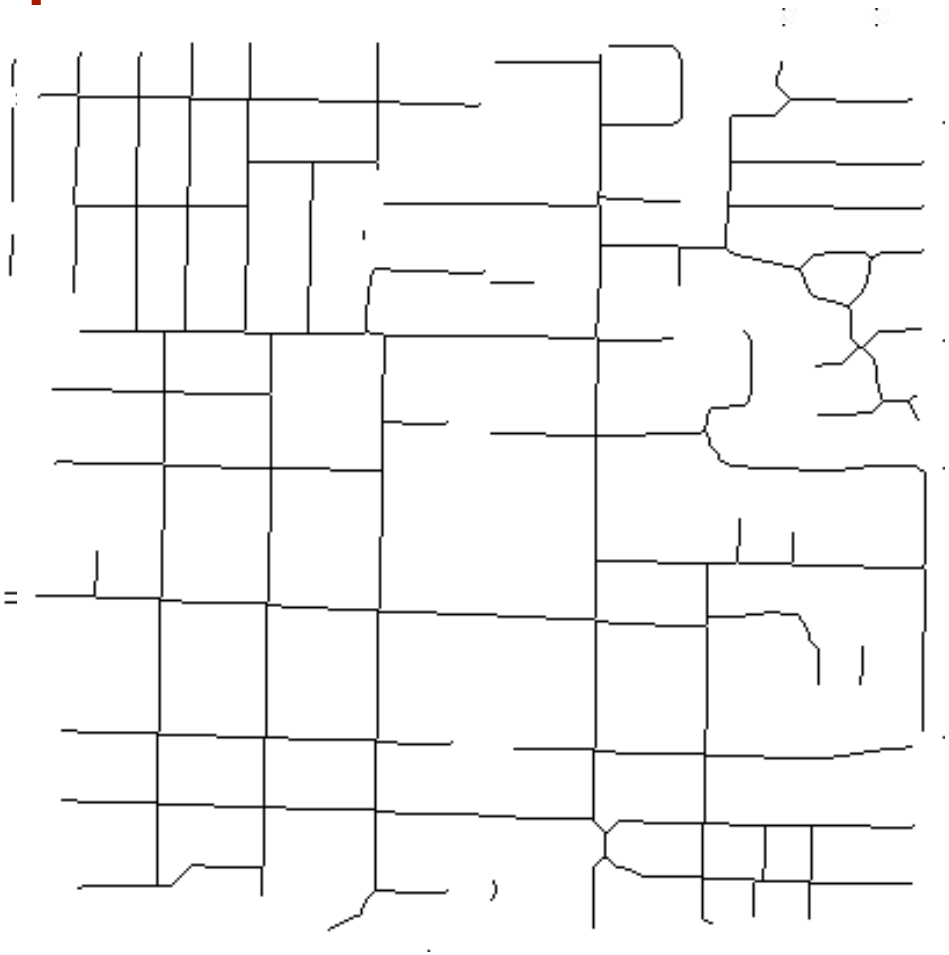
Road Topology Extraction

- **Use morphological operations to reconnect broken lines and generate one-pixel width roads**



Morphological Operations: Use the detected road format and road width to determine the number of iterations

Dilation

Erosion

Thinning

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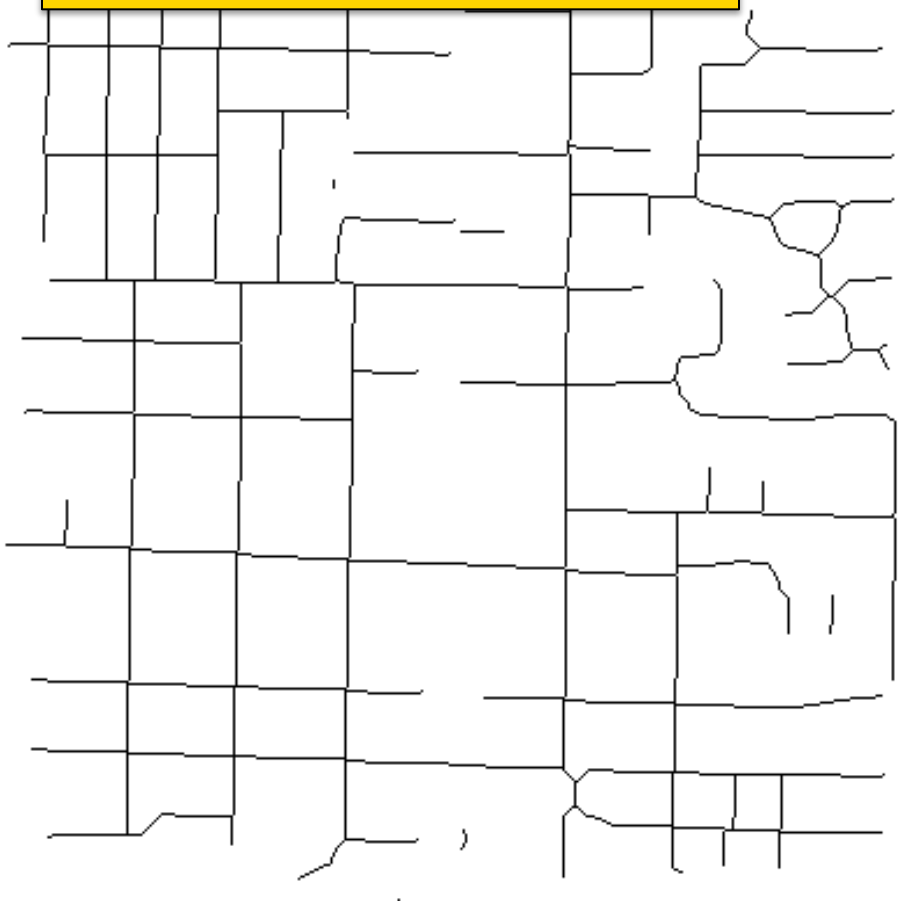
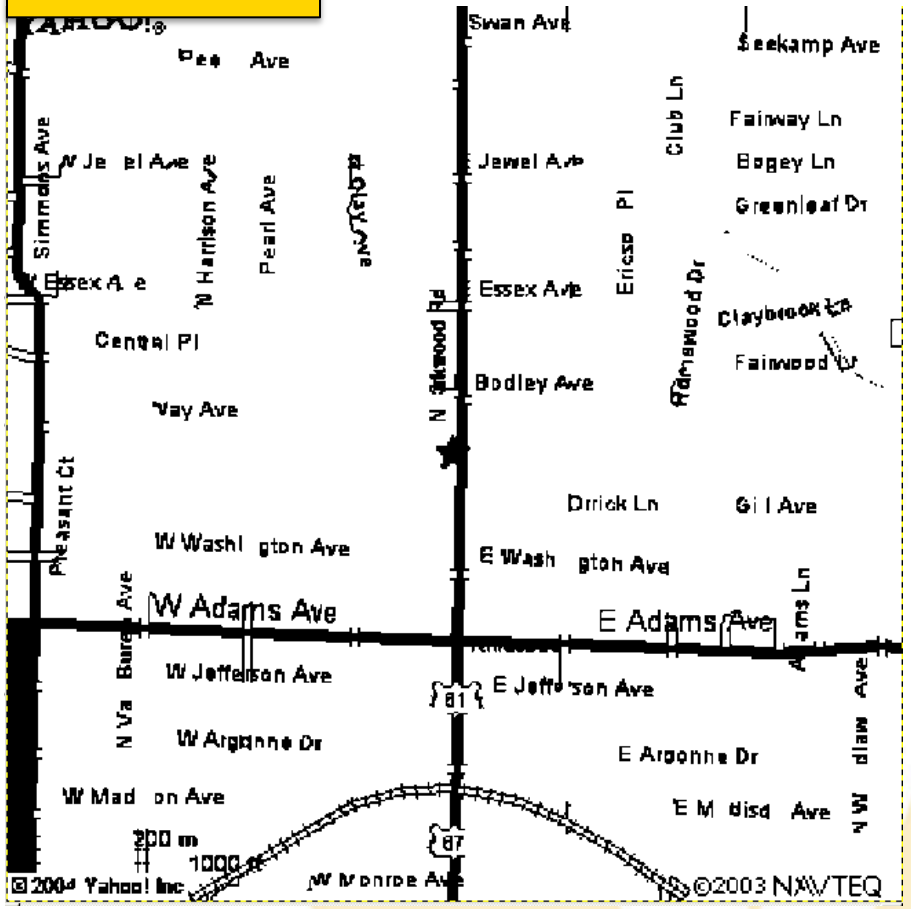
Extracted Road and Text Layers

Road Layer (road topology)



Text Layer



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Supervised Map Decomposition

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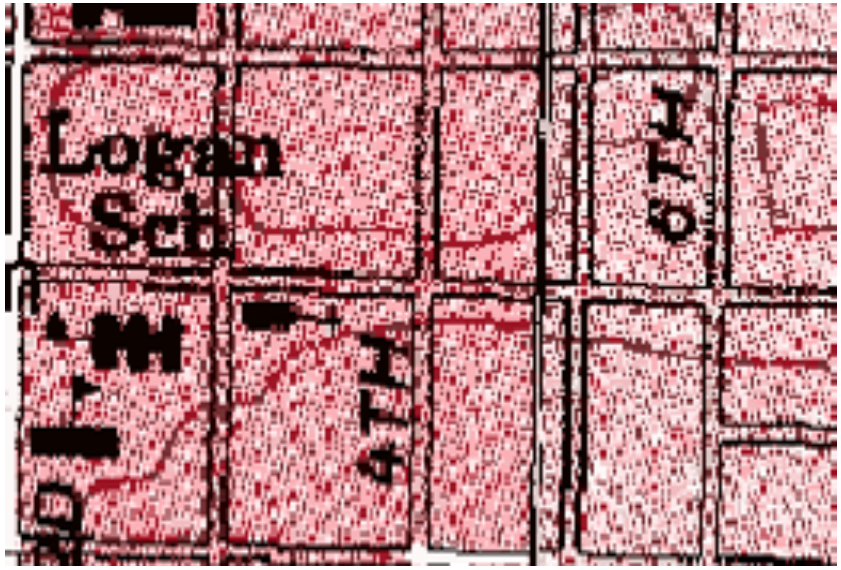
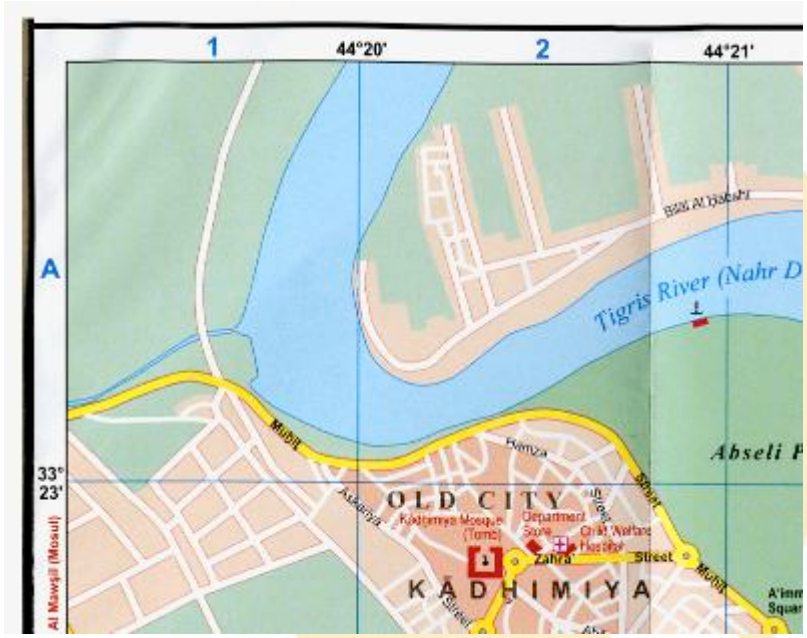
- **What if we cannot automatically remove the background from raster maps?**
  - Raster maps usually contain noise from scanning and compression process





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Difficulties

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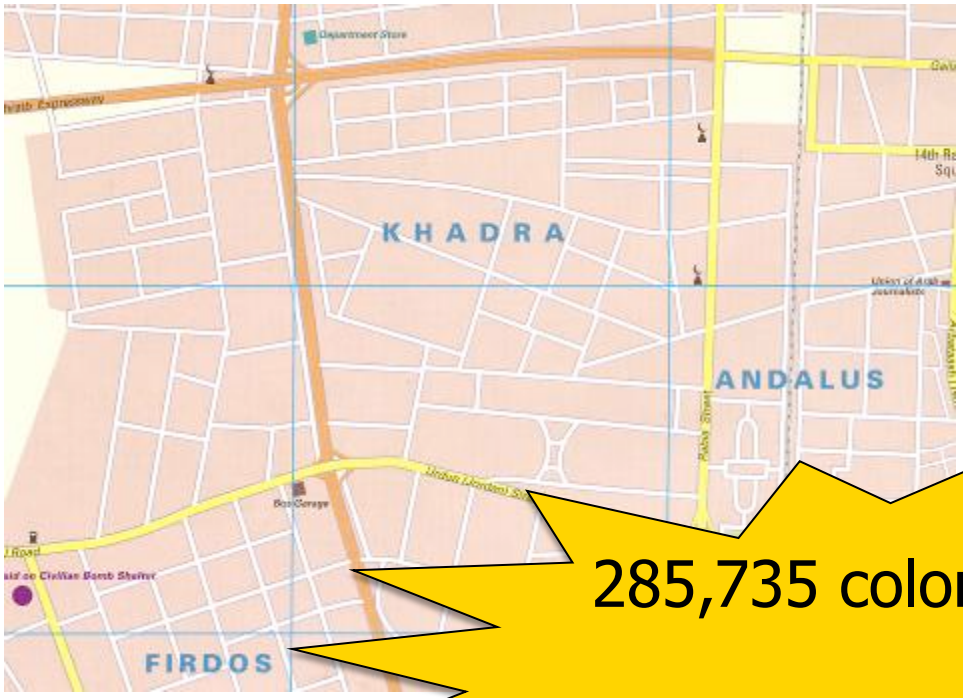
- **Raster maps contain numerous colors**
  - Manually examining each color for extracting features is laborious



285,735 colors

Grayscale histogram

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Color Segmentations

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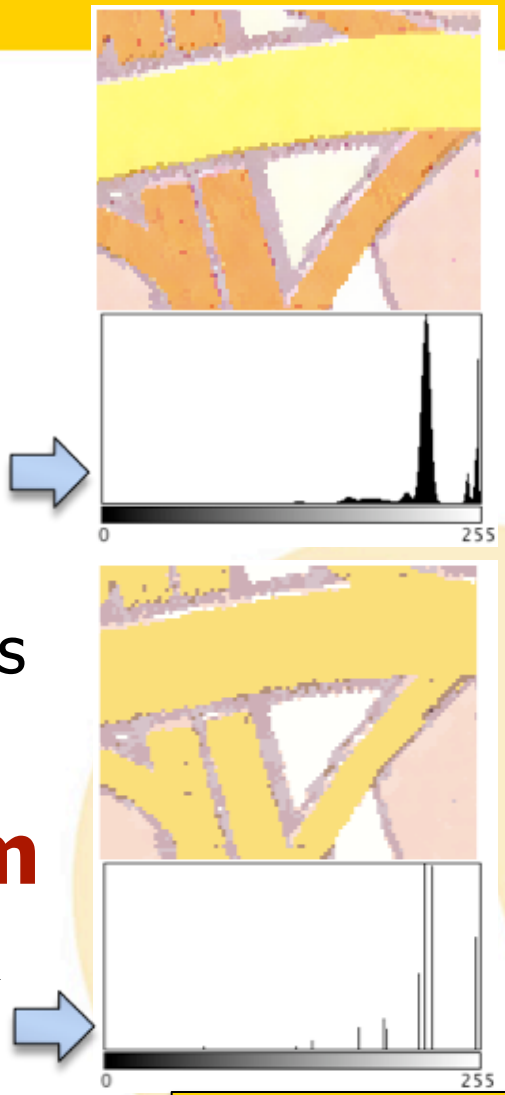
- **The Mean-shift algorithm**
  - —Consider distance in the RGB color space and in the image space
  - —Preserve object edges
  - —From 285,735 to 155,299 colors
- **The K-means algorithm**
  - —Limit the number of colors to K
  - —From 155,299 to 10 colors (K=10)



Grayscale histogram

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User Labeling

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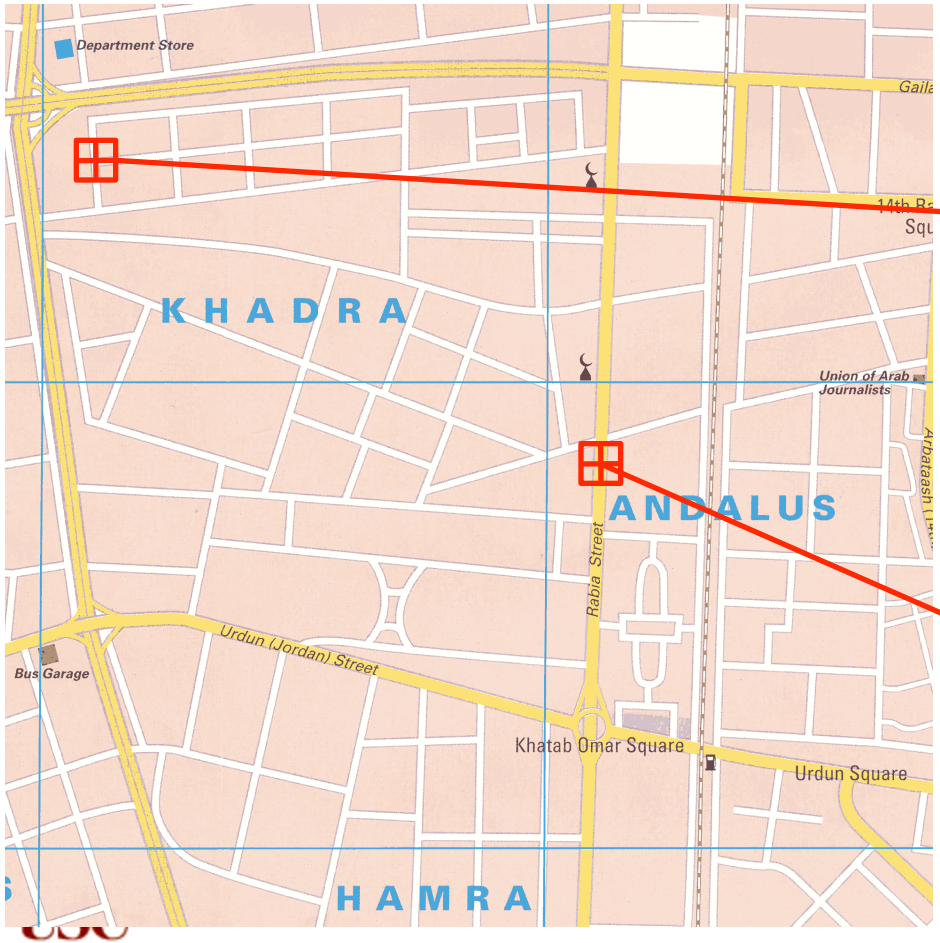
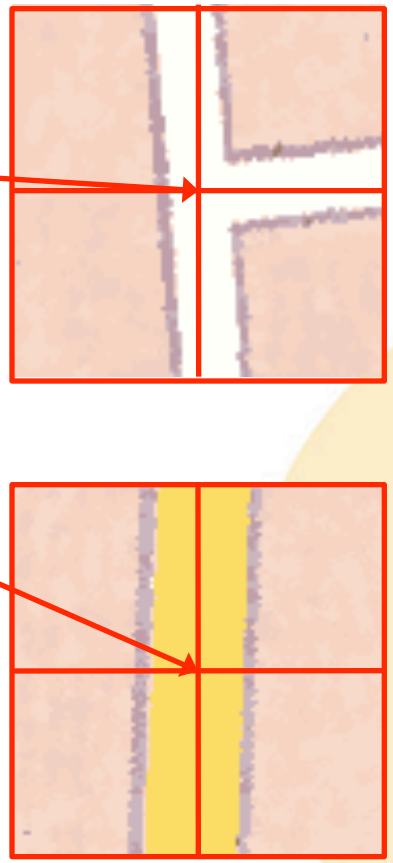
- **To extract the road layer, the user needs to provide a user label for each road color (at most K colors)**





User label should be (approximately) centered at a road intersection or at the center of a road line

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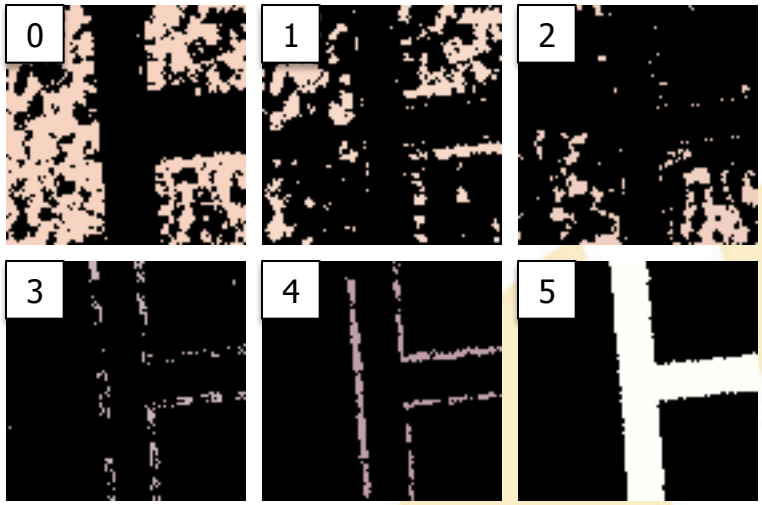
Label Decomposition

ISI Information Sciences Institute

- **Decompose each user label into color images so that every color image contains only one color**



(background is shown in black)

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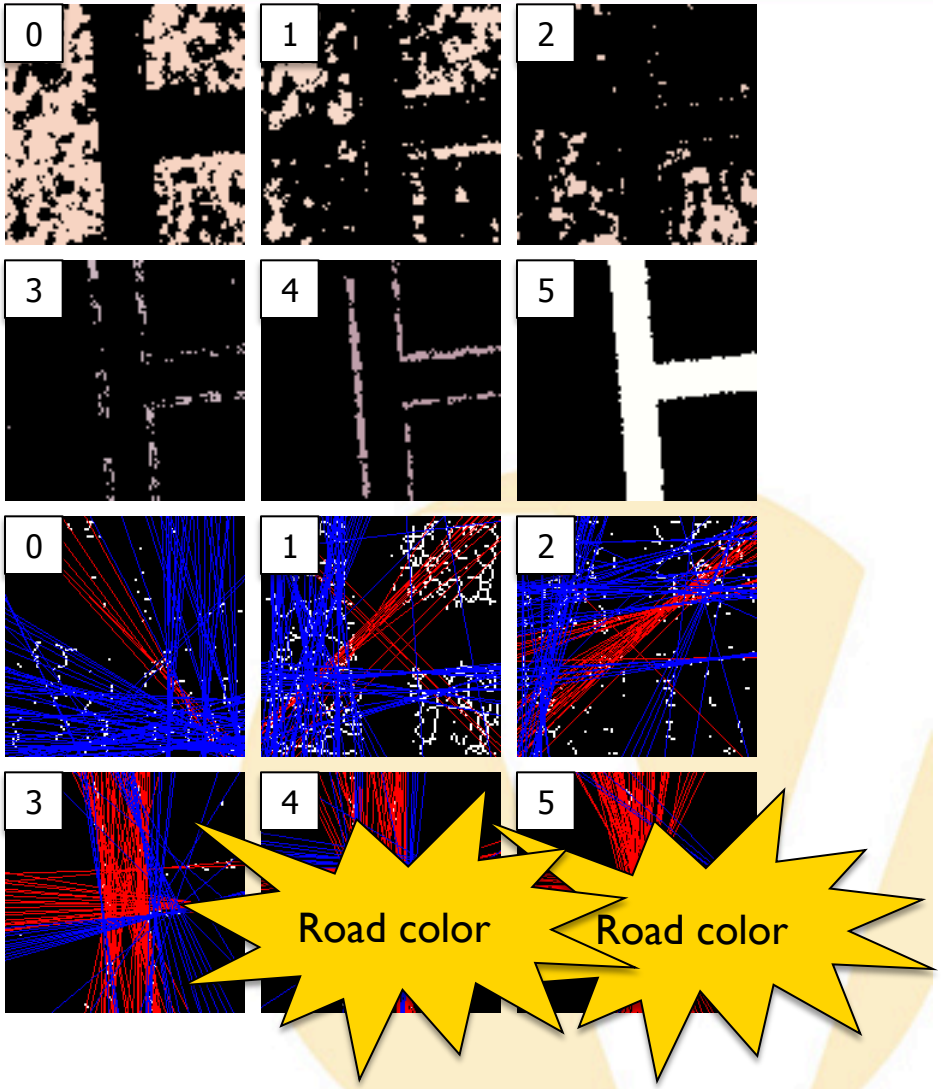
Hough-Line Approach to Identify Road Color

- **Detect Hough lines**
- **The center of the user label is the center of a road line**
  - The Hough lines that are far away from the image center are NOT constructed by road pixels
- **Identify road colors using**
  - The average distance between the Hough lines to the image center

Red Hough lines are within 5 pixels to the image center



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Initial Road Template

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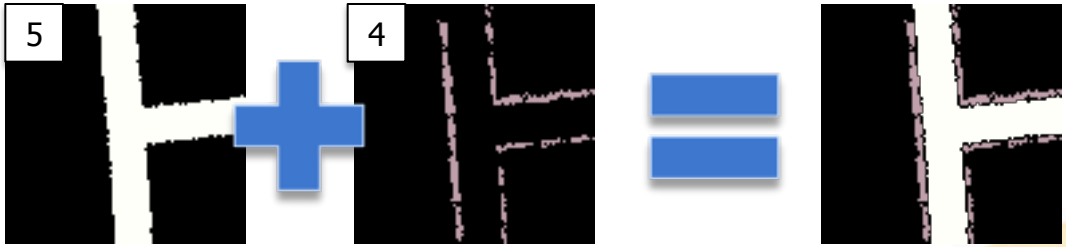
- **Generate an initial road template using the images of identified road colors from the Hough line approach**



(background is shown in black)

(road pixels are shown in red, background is shown in black)

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Road Topology Extraction using Identified Road Colors

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- Identify a set of road colors from each user label
- Use the identified road colors to extract road pixels
- Apply morphological operations to remove solid areas and reconnect lines

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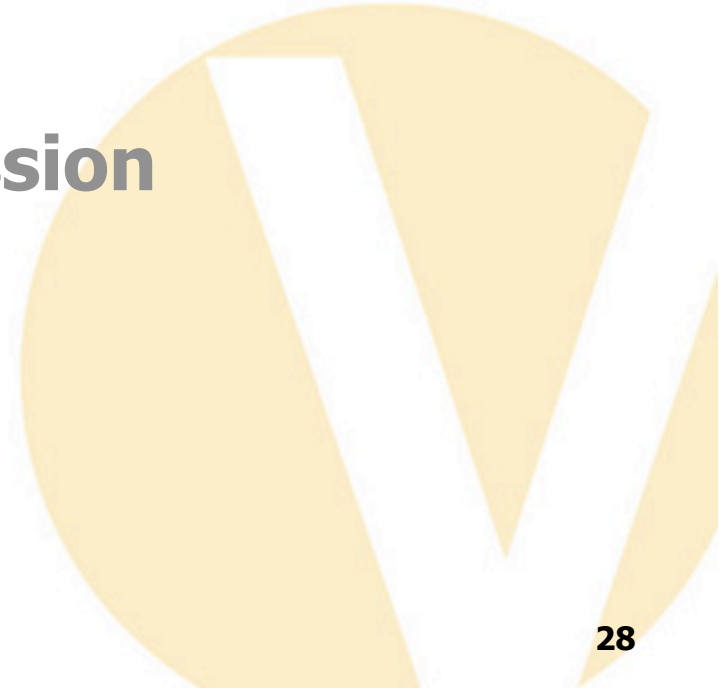

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Automatic Map Registration

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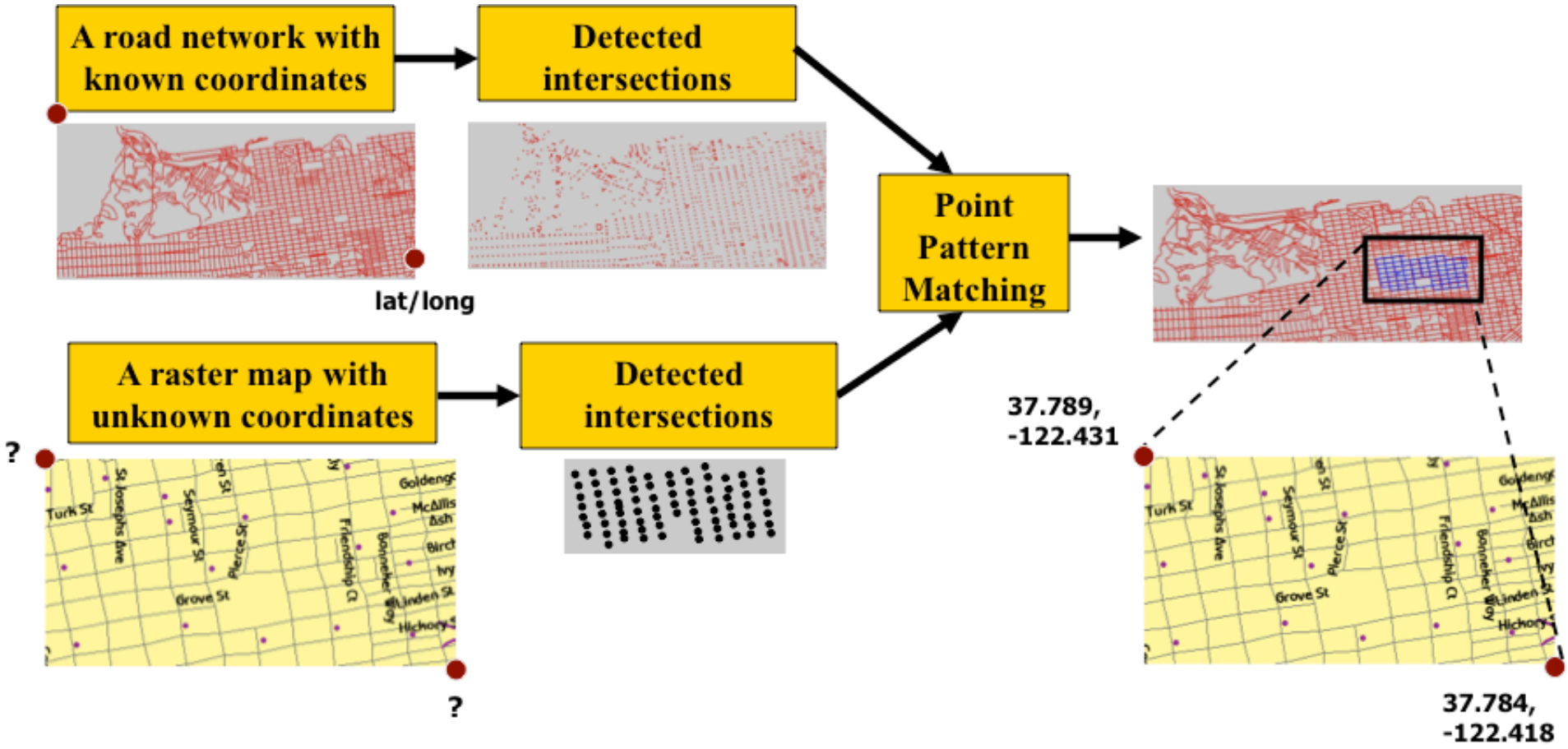
- **Exploit the pattern of intersections found on a map and compare to a road vector dataset**



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Road-Intersection Template Extraction

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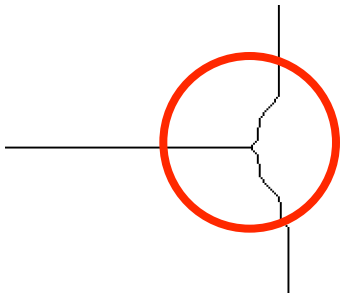
- **Road-intersection template**
  - road intersection position
  - road connectivity
  - road orientation

- **Road lines are distorted by the thinning operator**
- **The extracted road-intersection templates will not be accurate**



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Road-Intersection Position Detection

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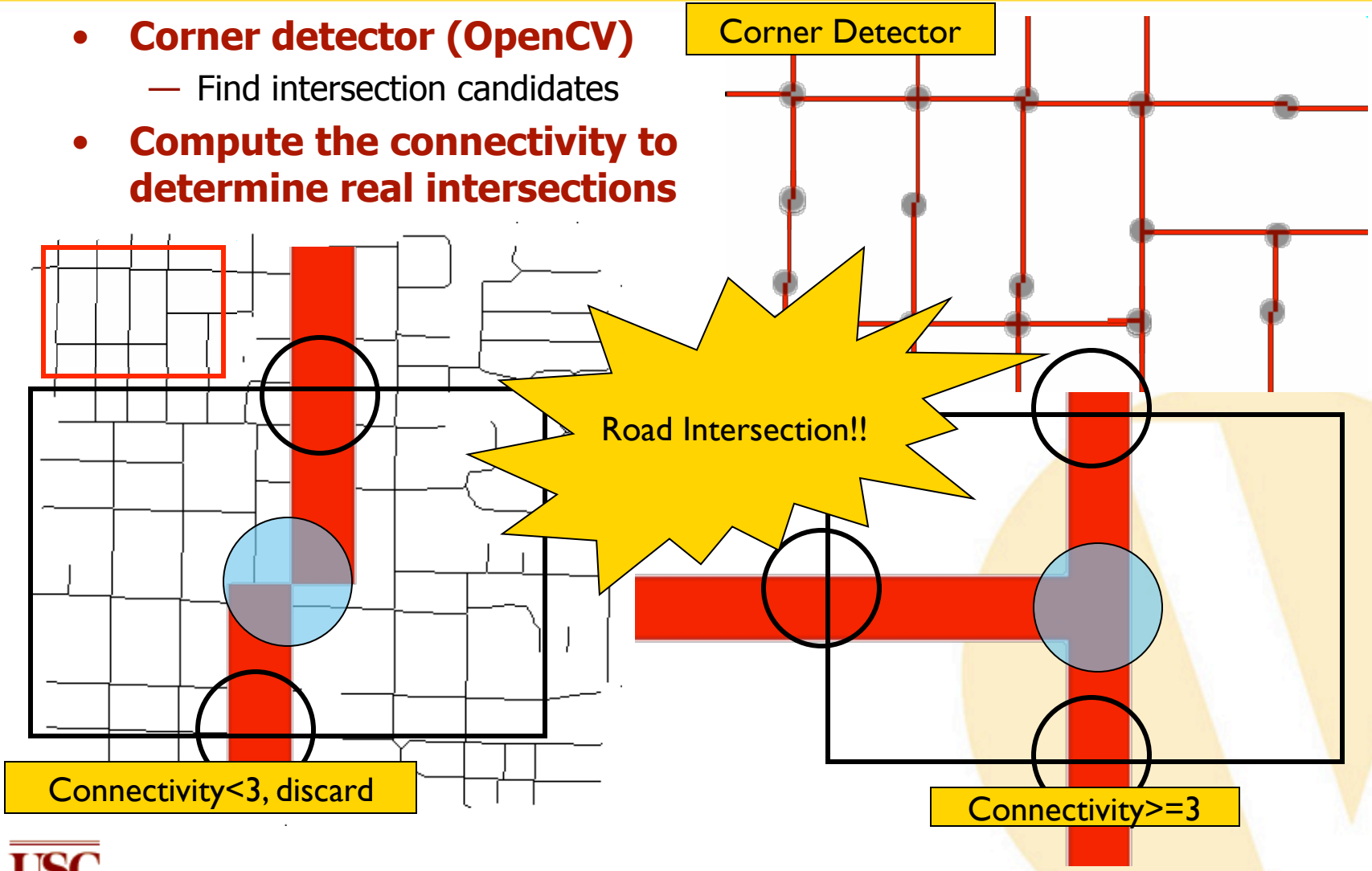
- **Corner detector (OpenCV)**
  - Find intersection candidates
- **Compute the connectivity to determine real intersections**



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Distortion Correction

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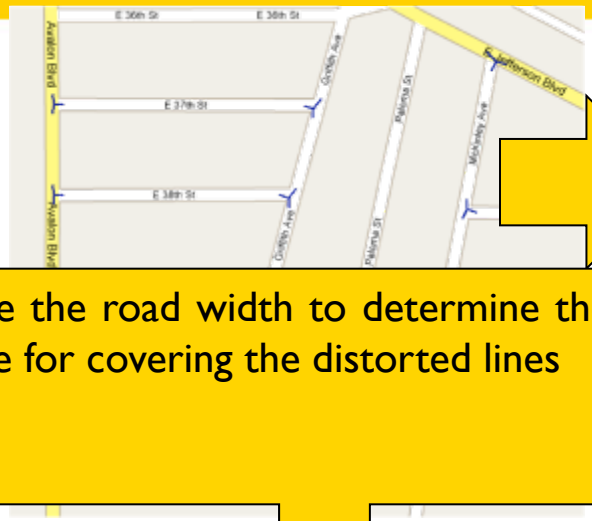
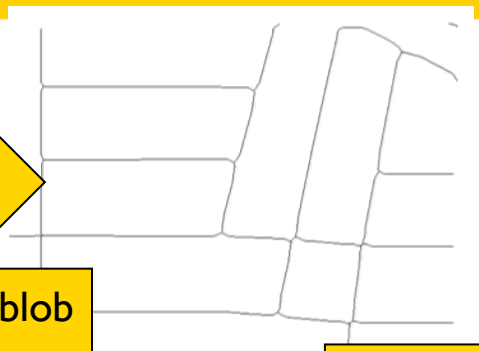
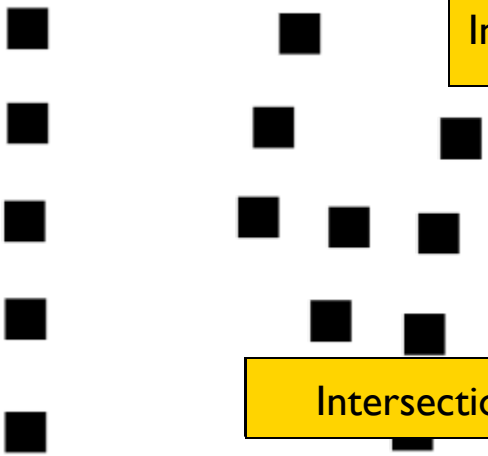


Use the road width to determine the blob size for covering the distorted lines

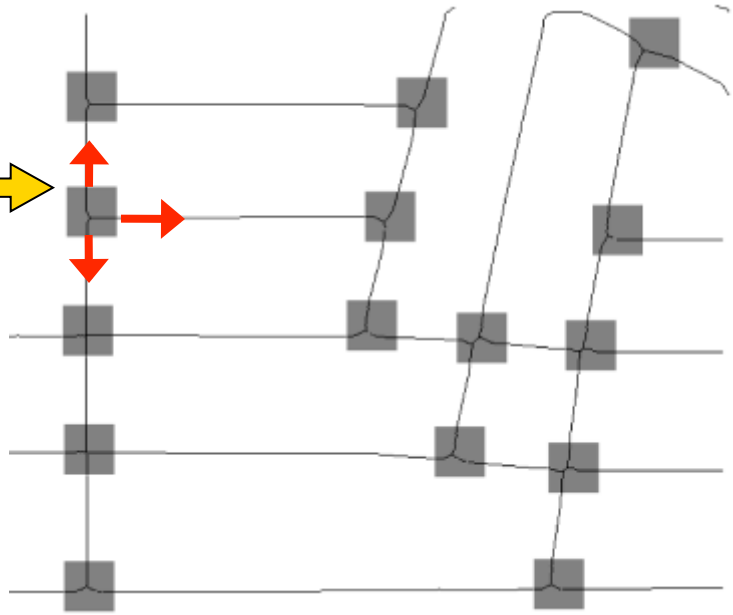


The thinned lines



Intersection Positions

Intersect the images



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Accurate Road-Intersection Templates

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With distortion

Avoid distortion

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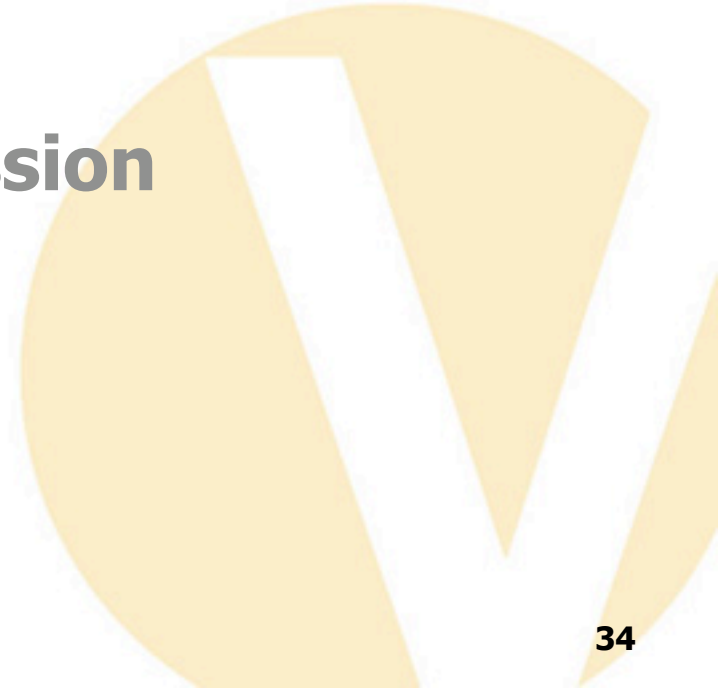

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Next Steps: Road Vectorization

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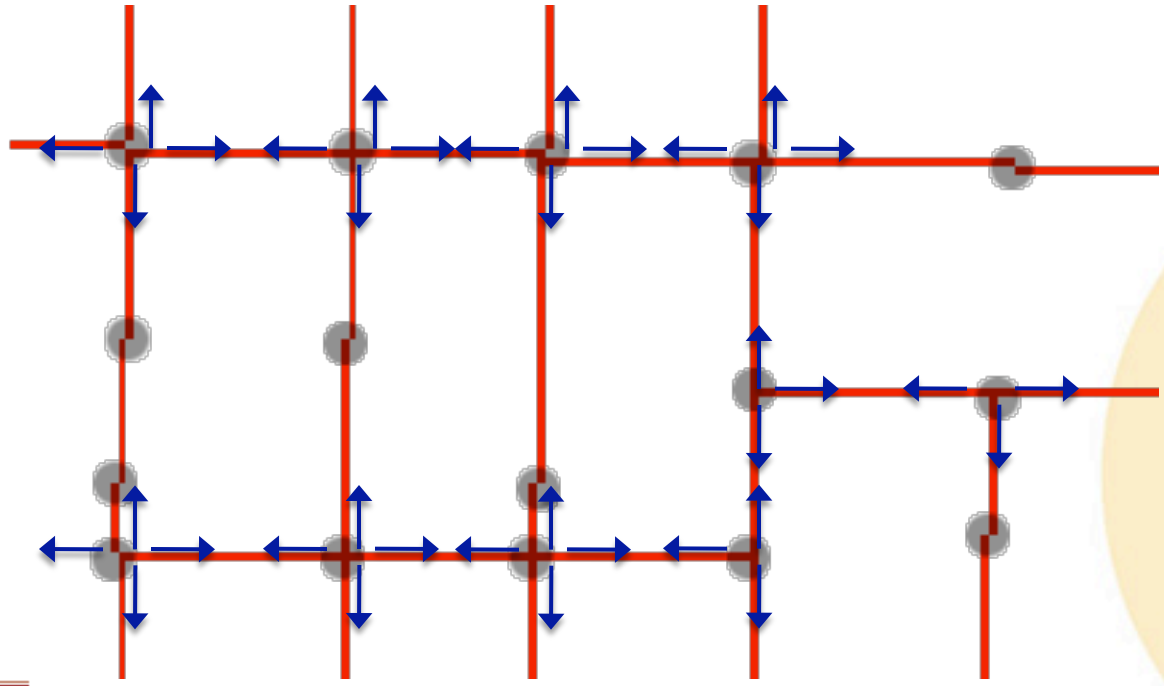
- **Start from the extracted road intersections to connect the salient points and produce the road vector**



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Next Steps: Text Recognition

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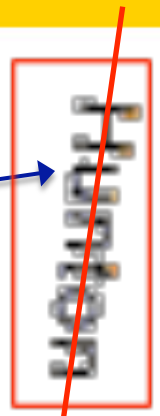
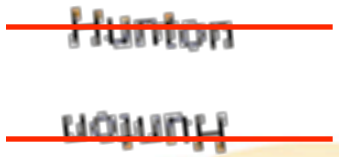


Rotate each string image according to its central axle



Optical character recognition

- **Generalize OCR techniques to apply to maps**
  - Identify individual characters regardless of orientation
  - Exploit background knowledge to improve accuracy

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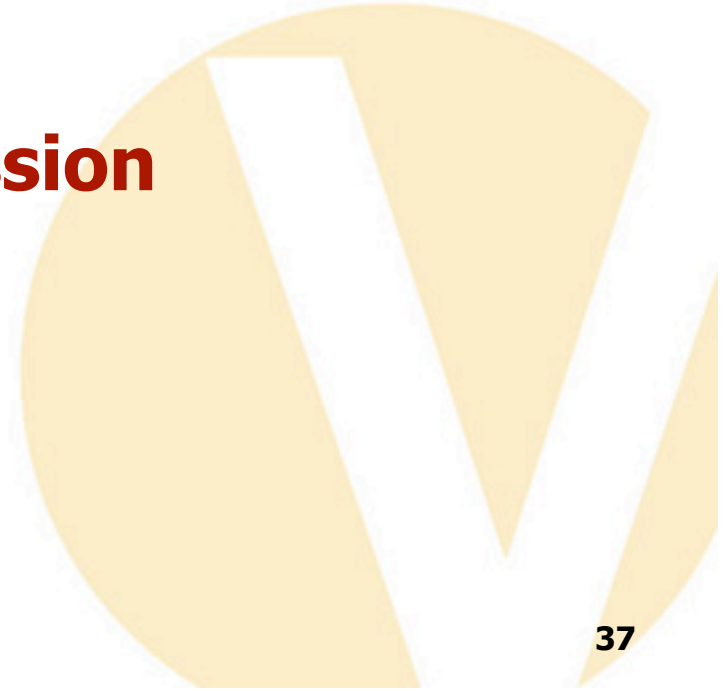

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Related Work

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- **Map Feature Extraction Using Map Specification (Samet and Soffer, 94, 96; Myers et al., 96)**
  - — Require huge amount of prior information and training
- **Text/Graphics Separation and Text Recognition (Bixler, 00; Li et al.,00; Cao and Tan 02; Vela, 03; Pouderoux, 07)**
  - — Require fixed pre-processing steps, e.g., binarization with fixed threshold
- **Supervised Graphics Extraction (Khotanzad and Zink, 03; Salvatore and Guitton, 04; Chen et al. 06)**
  - — Laborious training tasks, e.g., labeling all combination of line and background pixels
- **Road Extraction and Vectorization (Bin, 98; Habib et al., 99;Itonaga et al., 03)**
  - — Require lots of parameter tunings, e.g., road width
- **Map, Vectors, and Imagery Conflation (Chen et al., 06; Chen et al., 08;Wu et al., 07)**
  - — Exploit for determining feature locations

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Discussion

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- **Presented a general approach to discovering, registering, extracting features from maps**
- **Contributions**
  - —Ability to identify maps
  - —Ability to extract road and text layers
  - —Automatic recognition of road intersection
  - —Algorithms to automatically determine the geocoordinates
- **Applications**
  - —Annotating imagery
  - —Creating and updating maps
  - —Constructing gazetteers

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